Ambient Intelligence and Smart Environments **23**

Intelligent Environments 2018

Workshop Proceedings of the 14th International Conference on Intelligent Environments

Edited by
Ioannis Chatzigiannakis **Paulo Novais**
Yoshito Tobe **Oliver Amft**

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INTELLIGENT ENVIRONMENTS 2018

Ambient Intelligence and Smart Environments

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Preface

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Intelligent Environments (IEs) refer to physical spaces into which IT and other pervasive computing technology are woven and used to achieve specific goals for the user, the environment or both. IEs have the ultimate objective of enriching user experience, better manage, and increase user awareness of, that environment. The accelerating pace of today's technological developments urges the materialization of IEs with such innovative ideas and the whole community, from scientists and researchers to the general public, yearns for this.

The 14th International Conference on Intelligent Environments focuses on the development of advanced intelligent environments, as well as newly emerging and rapidly evolving topics. In the present edition, we are pleased to include in this volume the proceedings of the following workshops, which emphasize multi-disciplinary and transversal aspects of IEs, as well as cutting-edge topics:

- 2nd Workshop on Citizen Centric Smart Cities Solutions (CCSCS'18)
- 2nd International Workshop on Intelligent Systems for Agriculture Production and Environment Protection (ISAPEP'18)
- 3rd International Workshop on Smart Sensing Systems (IWSSS'18)
- 2nd International Workshop on Legal Issues in Intelligent Environments (LIIE'18)
- 1st International Workshop on Personalized Health \& Intelligent Workplaces Transforming Ergonomics (pHIWTE'18)
- 4th Symposium on Future Intelligent Educational Environments and Learning (SOFIEEe'18)
- 6th International Workshop on Smart Offices and Other Workplaces (SOOW'18)
- 9th Workshop on Intelligent Environments Supporting Healthcare and Well-being (WISHWell'18)
- 7th International Workshop on the Reliability of Intelligent Environments (WoRIE'18)

In an attempt to support the technical foundations, design approaches and immerging methodologies for the above cutting-edge topics, a number of advanced tutorials were given by well-known experts in the field. The aims of these tutorials are to introduce these topics of interest to PhD students and other "early career researchers", plus other people who are beginning to develop interests in those areas.

As it can be understood from this list, these workshops and tutorials, organized in conjunction with IE'18 main conference, provide a forum for researchers, scientists, engineers and developers to engage in many interesting, imaginative and active discussions that will engage further research in these key areas of Intelligent Environments:

- Building Interactive Environments by means of Capacitive Sensor Surfaces
- Semantic web techniques meet sensor data
- Choosing your ontologies for sensor data applications
- Intelligent Systems for Smart Building Management
- Computing in the Fog: Recent Technological Advances and Development Techniques
- Digital Object Memories in Instrumented Spaces
- Social Interaction with Cloud Network Robots
- Business Process Management approaches and techniques applied to smart environments
- From Awareness To Foundation: Human Behavior in Computing

The proceedings contain a series of contributions reflecting the latest research developments in IEs and related areas, focusing on stretching the borders of the current state of the art and contributing to an ever increasing establishment of IEs in the real world.

We would like to thank all the contributing authors, as well as the members of the Organizing Committees and Program Committees of the workshops for their highly valuable work, which contributed to the success of the Intelligent Environments 2018 event.

The Workshops and Tutorial Chairs would like to take the opportunity to thank Professor Massimo Mecella and Professor Juan Augusto, the general chairs of IE'18, and Professor Daniele Riboni and Professor Paul Lukowicz, the program chairs of IE'18, for their trust in our work, and all the other members of the IE'18 organization for the confidence they placed on us.

We are also grateful to the local staff that worked thoroughly for the success of this event. Thank you for your esteemed help, without which this event would not have been possible.

June 2018

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Contents

Tutorials

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Intelligent Environments 2018
I. Chatzigiannakis et al. (Eds.)

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Building Interactive Environments by Means of Capacitive Sensor Surfaces

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Abstract. Any conductive surface can be turned into a sensor plane by measuring the increase in its capacitance brought about by conductive objects approaching the layer. Depending on the size, material and distance of the objects to detect, this capacitance measurement can become quite difficult as electrical perturbations in the sensor's vicinity may overshadow the usable signal. In our tutorial we present an efficient measurement hardware and appropriate filter algorithms to account for this challenge. The result is a self-calibrating sensor board, which can measure up to eight different sensor surfaces independently in real time. This offers a unique platform for creating interactive environments.

Keywords. Sensor Surface, Capacitance Measurement

1. Introduction

Making environments interactive requires equipping them with some sensor modality. These sensors are particularly interesting, when they do not change the looks and haptics of the environments or when they are even invisible. An example, which falls into this category, is a capacitive proximity sensor that can turn a surface into an interactive plane. If the material of the surface is already conductive, it can be used as sensor plate right away.

Figure 1.

Figure 1 shows the example of glass, which is equipped with a transparent conductive coating. Electrically connected to our capacitive sensor module (lower right corner), the sensor surface can detect a human hand from a distance of about 15cm. This signal can be used to control other appliances such as the LED lamp (in the foreground) in this example. Any conductive material can be used this way, from metallic furniture surfaces to conductive liquids. In cases where a non-conductive surface should become a sensor, it is often possible to place a conductive layer underneath the visible surface.

This is the case, for instance, with our sensitive underlay SensFloor® [1] that is placed underneath the floor covering.

Figure 2.

Figure 2 shows this system. It consists of triangular sensor plates made of conductive polyester textile (grey material) eight of which are connected to an electronics module in the middle (brown squares). These modules constantly measure the capacitance and send out a radio signal when a change is detected, e.g. by people walking across the parquet the underlay is covered with. The wireless signals are analyzed by a receiver which controls building automation functions depending on the location and status of the inhabitants.

As different as the applications are the materials and the environment of the sensor surfaces. Therefore, a robust adaptive capacitance measurement principle is required.

2. Measurement principle

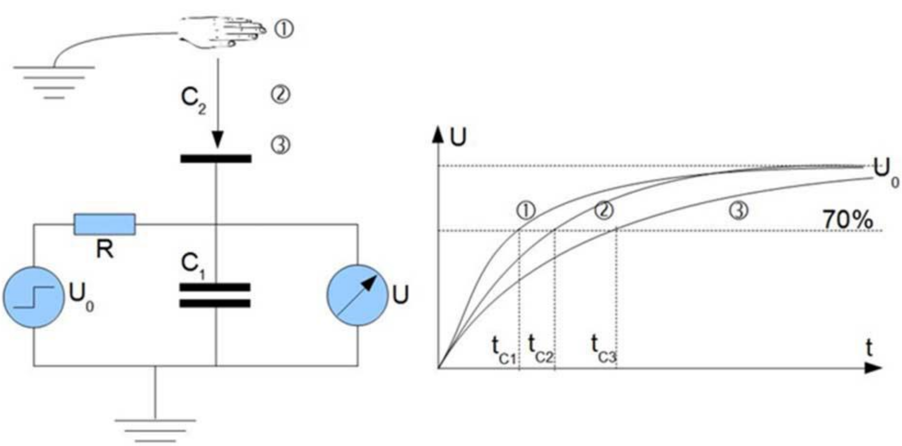

Figure 3.

Figure 3 shows the measurement principle schematically. While there are many different possibilities for measuring capacitances (see e.g. [2]), we have decided for the charging time method. In this setup consisting of two capacitors C1 and C2 in serial connection, the capacitance C1 is influenced by the material, size and distance of the upper plate of C2. In our example, this plate is a human hand approaching the conductive surface. The capacitance of C1 is determined by measuring the time it takes to charge it by means of a fixed voltage source U0 up to a certain level (here: 70%). We use the switch of a microcontroller's IO port from logical zero to logical one to determine the point in time when this level is reached. As can be seen in the diagram on the right of figure 3, the time depends on the distance between the hand and the surface.

In practice, however, the situation is more complicated as the charging time also depends on many other factors such as the stability of the voltage source or electromagnetic fields in the environment. Furthermore, the capacitance change induced by the hand in C2 is very small compared to the base capacitance of C1. Most of these difficulties can be overcome by averaging over multiple measurements and by applying special filters that account for known drifts or oscillations in the base capacitance. These algorithms reside within the firmware of our sensor module.

3. The sensor module

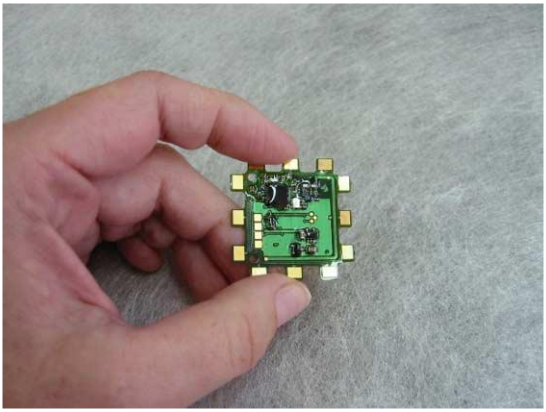

Figure 4.

Figure 4 shows our sensor module. Of the twelve golden connection pads at the borders, eight are used to contact up to eight sensor plates each of which is measured independently 10 times per second. The other four pads are used for a redundant DC power supply of 5 to 12 volts. The main component on the flexible board is an 8 bit microcontroller with built-in radio transceiver module. An indicator LED, a Quartz, a voltage regulator and a printed antenna for 868/920MHz transmission frequency, completes the setup. With an overall height of 1.4mm, the module can be directly integrated together with the sensor plates in a flat arrangement such as the SensFloor® underlay.

As soon as the board is powered, it starts out with a recalibration measurement that determines the base capacitance of the connected sensor fields. This base capacitance is considered as the empty state. From this moment on, the detection of any capacitance value which exceeds a predefined level is indicated by the activation of the LED and initiates the transmission of a radio message containing the ID of the module and the normalized capacitance values of all eight connected sensor plates.

A compensation algorithm guarantees that fast decreases or slow increases of the base capacitance lead to an adaptation of the base capacitance. This way the measurement accounts for objects which are taken away after the recalibration cycle and drifts caused by changes in the humidity or temperature of the environment are respected.

In commercial SensFloor® installations, the radio messages are analysed by a receiver based on the widely known Raspberry Pi® platform. To this end, this embedded computer is equipped with an expansion board carrying a compatible radio receiver and eight potential-free relays. By means of a web-interface, the receiver can be configured such that the relays indicate events such as the activity of single or groups of sensor fields or activity patterns that are typical for people lying on the floor after a fall. By means of higher level data analysis it is possible to count the number of people, their trajectories, their speed or their gait pattern on a floor equipped with the sensor underlay.

4. Summary

We have briefly described the principle of capacitance measurement based on the charging time method and the hard- and software that utilizes this principle for realizing interactive sensor surfaces. By means of filters and drift compensation algorithms, a robust detection of approaching dielectric objects such as human body parts is possible. This setup allows for countless applications in the domain of healthcare, retail and security. As any conductive surface can become a sensor plane, objects of daily life are equipped with responsive functions contributing to an intelligent environment.

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Intelligent Environments 2018
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Semantic Web Techniques Meet Sensor Data

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Abstract. Semantic Web technologies have been gaining traction in the last decade as an important tool to enable data interoperability. They allow to represent, interlink, publish, query, and reason with heterogeneous data. The data is described using ontologies, formal definitions of the types of the entities that exist in the domain, and of relations that link them. Ontologies give formal semantics to the data, which allows for data exchange with shared and unambiguous meaning, logical reasoning, and data discovery. In addition, the Linked Data principles portray guidelines to publish semantic data on the Web, based on semantic web technologies, to ease the discoverability and reuse of data. Semantic Web technologies are used in a variety of fields, including intelligent environments, healthcare, life sciences, linguistics, and cultural heritage, among other. Ontologies are also present in industry whenever interoperability or heterogeneous data integration is required. Examples include knowledge graphs in large corporations, such as Google, Facebook, IBM, Adobe, or Yahoo. The goal of this tutorial is to present the basics on Semantic Web technologies, and Linked Data principles and best practices. The tutorial assumes no prior knowledge on the topics, and can serve as an introduction for people interested in attending the tutorial "Choosing your ontologies for sensor data applications."

Keywords. Semantic Web, Ontology

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Choosing Your Ontologies for Sensor Data Applications

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Abstract. Semantics is increasingly seen as key enabler for integration of sensor data and the broader Web ecosystem. Analytical and reasoning capabilities afforded by Semantic Web standards and technologies are considered important for developing advanced applications that go from capturing observations to recognition of events, deeper insights and actions. The goal of this tutorial is to cover the fundamentals and best practices of Semantic Web technologies in a concise way, and show how can they are to model ontologies for Intelligent Environments, including notions of ontology modelling and presenting two of the most relevant ontologies for Intelligent Environments:

Keywords. Semantic Web, Ontology

1. Outline

- The new W3C Semantic Sensor Network (SSN) ontology [1] jointly standardized by the W3C and the Open Geospatial Consortium enables to describe observations, samplings, and actuations activities, their result, the system that made it, the features of interest and its property that is observed or acted upon.

- The ETSI Smart Appliances Reference (SAREF) ontology [2] focuses on the concept of device, which is defined in the context of the Smart Appliances study as "a tangible object designed to accomplish a particular task in households, common public buildings or offices. In order to accomplish this task, the device performs one or more functions". Extensions for different verticals are under development for the Energy-, Building-, Environment-, and Industry- domains.

- The SEAS ontology [3] is a modular and versioned ontology with all the terms it define having the same namespace. It is built on top of SSN, and contains as a core four simple ontology patterns to describe physical systems and their connections, value association for their properties, and the activities by which such value association is done. These ontology patterns are then instantiated for different engineering-related verticals.

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Intelligent Environments 2018
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Intelligent Systems for Smart Building Management

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Abstract. Managing smart buildings is a challenging task, particularly in presence of contrasting goals, such as satisfying users' needs and reducing the energy consumption. Artificial Intelligence allows to design smart buildings really capable of proactively support the users to reach their goals. Intelligent systems should be capable of exploiting the information gathered by sensors pervading the building, understanding the context, selecting the best actions to perform, and actively modifying the environment. The design of such systems is a complex task, because of the possibly wide set of functional and non-functional requirements, and the dependences among intelligent functionalities and their embodiment in the building's cyber physical space.

Keywords. Artificial intelligence, Ambient intelligence, Smart buildings, AAL, Sensors, Wireless sensor networks

1. Motivation

The design of smart buildings poses many challenges, due to the need of dealing with opposite goals, such as minimizing the energy consumption and maximizing the users' wellness, and to the necessity of guaranteeing a low level of intrusiveness. Ambient Intelligence (AmI) faces such issue by envisioning smart environments which surround users with pervasive sensors and actuators, and which apply intelligent methods to understand the environmental conditions and take the proper actions to reach system's goals [1]. In such a vision, Artificial Intelligence has a crucial role since it provides the enabling methodologies and tools for understanding the context from multiple and inaccurate data, learning users' habits and preferences, and adapting the system behavior in order to satisfy and anticipate users' needs.

2. System Architectures for Supporting Intelligent Functionalities

The design of the system architecture and its physical infrastructure, composed of sensors and actuators, strictly depends on the definition of the desired intelligent functionalities.

In [2] a reference architecture is proposed to design advanced Building Management Systems, with a particular focus on energy saving. Such architecture is composed by the following four components:

- *Sensory and Actuation Infrastructure*: represents the physical embodiment of the intelligent system in the external world and directly affects the realizable intelligent functionalities;
- *Middleware*: is responsible of dealing with the heterogeneity of physical devices, and provides the intelligent system with a unique point of access to sensory data and actuating controls, as proposed in [3];
- *Processing Engine*: implements the advanced functionalities of the AmI system; it is worth noticing that such component may be deployed according to a fully centralized approach or to a decentralized approach, depending on the specific requirements of the system;
- *User Interaction Interface*: is responsible for the interaction between the system and the end user, in order to provide him with relevant information, and to obtain implicit and explicit feedback about the user's satisfaction, as proposed in [4];

Through such components, it is possible to implement a sensing-reasoning-actuating-interacting loop, which allows the intelligent system to continuously perceive the environment and the context, reason in order to select the actions to be performed, actively modify the environment, interact with the users, and again perceive the environment to verify the effect of its own actions. The emphasis on the interaction with the user, with respect to the classical sensing-reasoning-actuating loop [5], aims to highlight its importance, not only to provide the user with relevant information, but mainly to obtain from him some feedback about the adequateness of the performed actions, in order to enable an adaptive behavior.

3. Environment and Context Sensing

The sensory infrastructure exploited by the intelligent system should include devices capable of perceiving the environmental state and the current context. It can include sensors to perceive environmental physical quantities, such as temperature, humidity, and light intensity, besides to devices devoted to measure the energy consumption, as proposed in [6]. The environmental monitoring enabled by such devices is not enough to focus system goals on users' satisfaction. On the contrary, devices capable of perceiving data related to the context (e.g. user presence or activities) are required. The presence of users or their activities may be detected by different technologies, characterized by different costs and which produce data with different accuracy levels. The designer is required to identify the best trade-off between costs and data accuracy, by considering also that dealing with noisy data involves a greater effort by intelligent modules. The sensing infrastructure can be enriched also with mobile and personal devices, especially to gather data related to the users' behavior, as in [7,8].

4. Intelligent Functionalities for Smart Buildings

The focus on energy-awareness and users' wellness introduces several functional requirements for the design of the intelligent system. Some intelligent functionalities proposed by works presented in the literature are the following:

- understanding the context (e.g., user presence, actions performed by the user);

- learning user habits;
- learning user preferences;
- planning the optimal sequence of actions which allows to reach system's goals.

4.1. Context Understanding and Learning User Habits

A smart building reacts to environmental changes by properly controlling the actuators. It is not desirable that such reactions are statically coded, but, on the contrary, they should depend on the current context conditions, that may change over time. For this reason, it is fundamental that the intelligent system is capable to extract contextual information from raw sensory data. The most relevant context information is the presence of users in the monitored premises and their activities. Such knowledge may be exploited to switch the appliances to a low consumption mode when users are absent, or to adapt the environmental conditions to their activities. One of the most popular approach is to adopt methods capable of dealing with the intrinsic uncertainty of sensory readings and with the partial correlation of such data with the considered environmental features, such as Bayesian (or Belief) Networks, as proposed in [9,10,11].

Detecting the activities performed by users allows to build predictive models of their habits. Such models represent user behavior patterns and are built by exploiting past sensory data and information explicitly provided by users.

4.2. Learning User Preferences

In order to satisfy users' needs, it is necessary to know their preferences about the environmental conditions. An ideal intelligent system should be capable to learn the mapping between users activities, current environmental conditions and the conditions preferred by users. To perform such learning process, the intelligent system can exploit both explicit and implicit feedback obtained from users [4]. The former is obtained when users voluntarily provide an evaluation of the current environmental conditions, by using an opportune system interface. The latter requires that the sensory infrastructure supports a non-intrusive user monitoring, and it is obtained by interpreting the observed interactions between users and actuators. Such feedback can be exploited to tune the system behavior; for instance, if the user interacts with actuators, his preferences are expressed by the selected settings, while if he does not perform any action, we can assume that he agrees with the system policy.

4.3. Intelligent Planning

Finally, an intelligent system should have the capability of performing intelligent planning to completely automate the building management. Such functionality requires ability to predict users' activities and the environmental changes, besides to know the effect of system actions. By exploiting such knowledge, it is possible to design intelligent mechanisms which identify the best sequence of actions to carry on in order to reach system's goals (e.g., maximize user's wellness while respecting energy constraints).

Traditional intelligent techniques adopted for planning are characterized by high computational costs; such characteristic hinders the necessity of performing prompt actions in response to environmental and context changes. Thus, the designer should find a good trade-off between long-term deliberative intelligence, capable of exploiting future predictions of the environmental state, and reactive intelligence, capable of providing fast responses to world changes.

5. Main Challenges

Most of the intelligent approaches proposed in the literature to implement intelligent systems for managing smart buildings require a training phase to learn system parameters. For example, to define a Bayesian network it is necessary to learn the conditional probability tables, or to design a fuzzy controller it is necessary to learn the set of fuzzy rules. Such knowledge, implicitly coded into the adopted model, could be known before the real deployment of the AmI system, or it could be learned after a training phase performed at runtime. In the former case, the system designer relies on the hypothesis that re-using the same knowledge in different deployments does not relevantly affect the system accuracy. In the latter case, it is necessary to adopt some semi-automated mechanisms for supporting the gathering of new data required to adapt the intelligent system to new scenarios, without excessively bothering the user. In a real scenario, facing such problem represents a great challenge because the first hypothesis is not realistic and there is a lack of robust methods that enable the self-learning at runtime.

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Computing in the Fog: Recent Technological Advances and Development Techniques

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Abstract. The concept of combining the resource-bound last-mile sensors of any Internet-of-Things-related application with computational capabilities is receiving increasing attention from researchers and practitioners. Recent technological advances in embedded devices has led to the production of small-sized heterogeneous multi-core processors that incorporate pattern machine engines on-the-chip and support the execution of power-efficient algorithms. We are now capable of analyzing the data collected from the sensors on the spot, classify the data, detect abnormal events and produce advanced alerts. The capability to locally process the data allows to transmit to the cloud infrastructure and store only the segments that correspond to an abnormal behavior. In this way the embedded device would conserve battery power and minimize memory requirements. Therefore, the so-called Fog computing approach extends the cloud computing paradigm by migrating data processing closer to production site, accelerates system responsiveness to events along with its overall awareness, by eliminating the data round-trip to the cloud. Offloading large datasets to the core network is no longer a necessity, consequently leading to improved resource utilization, protection of private and confidential information and quality of experience (QoE). Fog Computing can address the ever-increasing amount of data that is inherent in an IoT world by effective communication among all elements of the architecture.

Keywords. Ambient intelligence, Internet of Things, Wireless sensor networks, Stream Processing

1. Motivation

We are gradually moving from vertical single purpose Internet of Things (IoT) solutions to multi-purpose and collaborative applications interacting across industry verticals, organizations, and people [1]. With the ever-increasing amount of data that is inherent in an IoT world, the key to gaining real business value is effective communication among all elements of the architecture.

In the past several approaches have been proposed in order to address the potentially huge number of sensor data arriving from the IoT domain, each one of them applied in different parts of the network architecture [2,3,4]. Starting from the low-end devices, the approach of in-network aggregation and data management has been proposed where sensor devices follow local coordination schemes in order to combine data coming from different sources and/or within the same time period based on similarities identified using data analysis. Usually these techniques operate in combination with network-level routing protocols and/or lower-level medium access control protocols [5]. For an overview of different techniques and existing protocols see [6]. Since this approach relies on spatial and temporal correlation without taking into consideration semantic correlation of the data, very few theoretical algorithms are used in real-world deployment since they significantly limit the concurent support of different high-level applications.

Currently the dominant approach followed by large industries focused SMEs and startups is the development of cloud-based IoT platforms that simplify the interconnection of smart devices, the collection of data generated to the cloud, and the central processing of the information utilizing other cloud-based services [7]. New tools have been developed that allow the analysis of the time-series in a streaming way, hence the name Stream Processing Frameworks (among the most well known are Apache Storm and Flink). Commercial platforms (e.g., such as AWS IoT) provide a cloud-based back-end that helps developers focus on how to accelerate the creation of compelling solutions that integrate with existing business processes and IT enterprise infrastructures.

It is evident that the cloud-based approach needs to address multiple performance issues appearing at all levels of the network architecture while transferring massive datasets collected from the sensors and delivered to distant machine clouds: (a) network bandwidth issues at the network edge, (b) network energy consumption as traffic flows through the network core, (c) continuous I/O operations on the data centers where datasets are stored, (d) increased exposure of data across third-party cloud-based services. As stated in [8] minimal possible latency, network bandwidth preservation, increased security and enhanced reliability are elements of paramount importance for any IoT-related application. The necessity for data collection, storage and availability across large areas, the demand for uninterrupted services even with intermittent cloud connectivity and resource constrained devices [9], along with the necessity of sometimes near-real-time data processing in an optimal manner, create an amalgam of challenges where only radical and holistic solutions apply. Interestingly offloading large datasets to the core network is no longer a necessity [10].

2. Fog Computing & Dominant Characteristics

Fog computing was conceived as a distributed computing paradigm delivering computational resources, storage and control to consumers, through an intermediate operations layer strategically placed between the secluded cloud data centers and end-user equipment. This approach greatly alleviates bandwidth consumption, increases the data processing capacity of isolated nodes, reduces latency and provides additional security and reliability while accelerating system responsiveness.

Fog computing layer nodes have dedicated interfaces for communicating with the network core layer, the actual gateway of any cloud data center to the outside world. In modern networking deployments, the network core layer consists of software defined networking (SDN) nodes which facilitate extensive governance and precise supervision [11]. This approach, renders the architecture significantly more robust, due to the fact that packets originating from end devices are not directly accessing the entry point of the cloud per se, instead they undergo a second inspection process that discards all malicious, potentially harmful, or problematic content. End devices are rather easy to be compromised since they often remain unattended, giving physical access to attackers. In addition, their limited computational capacity and strict energy efficiency requirements prevent the deployment of sophisticated cyber-security or encryption mechanisms. Fog also resolves a series of IoT-related constraints as follows.

2.1. Extensive bandwidth requirements

The phenomenal growth of the IoT ecosystem towards supporting billions of devices, generates a data-oriented issue. Lots of barren datasets are collected to by the end nodes and are submitted to the cloud to be processed. Such an approach appears to be rather ineffective, since it consumes hefty amounts of bandwidth before possibly categorizing the processed data as null and meaningless. The collection rate of such datasets constantly rises, therefore a certain level of pre-processing at the edge of the network is rather compulsory. Data trimming on the edge will effectively reduce bandwidth requirements and consequently traffic costs and necessary cloud storage [12]. Dedicated fog computing nodes could alleviate computational resource provisioning in the cloud, where only valid data will be processed and categorized for a fraction of the networking expense.

2.2. Necessity for decreased latency and autonomous operation

As the total number of interconnected nodes increases, cloud services will encounter severe challenges towards providing uninterrupted services in cases of irregular connectivity. The advent of 5G [13] will most probably solve the majority of connectivity issues currently compromising service continuity in the cloud, but since redundancy and robustness are required in existing deployments, one could consider fog computing as an intermediate or supplementary method of addressing these issues. Many industrial or safety-critical systems such as patient monitoring platforms, automated production lines and traffic optimization applications, often require end-to-end latency of just milliseconds. This demand will be tackled by 5G, however current deployments are not yet capable to support it, rendering such systems bound to obsolete functional archetypes. Additionally, a certain level of autonomous operation is important for providing the aforementioned service continuity. Regardless of interruptions in connectivity, any safety critical system must remain operational and secure. Data accumulation should proceed and once connectivity is re-established, uploaded to the corresponding cloud repository. This is a perfect use case of how a dedicated fog node could help such situations. Obtained sensor data could be temporarily stored, potentially pre-processed in the intermediate layer, from which operators may get notifications regarding ill operation or imminent danger.

2.3. Enhanced Reliability and Security prerequisites

As more data traverse through the network the possibility of errors also increases, since bit error rate, data transmission latency and packet droppings are proportional to the actual size of transmitted data. Such an increased error margin cannot be tolerated when emergency or safety critical applications rely their proper functionality on similar techniques. Uninterrupted service is of paramount importance for IoT applications, together with protecting resource constrained devices, update the security level of large distributed systems in a trustworthy manner and response to compromises without causing intolerable disruptions [9]. Fog enables service cohesion and stability by acting as complementary layer to the cloud and the necessary endpoints. Its nodes could possibly act as proxies for security updates delivery and management of sensors, perform additional security functions such as encryption or deep packet inspection and take advantage of local information and context to detect threads in near real-time. This embellished degree of functionality where resources and services of computation, communication or control, are now located closer to the users fortifies applications, boosts system awareness of end customer needs and upgrades efficiency and performance to a whole new level.

Fog computing unveils a novel architectural concept that will most likely also enable fascinating business models for computing and networking. The major advantage of fog is no other than supporting networking in the edge, together with all the delay-critical services that can be deployed in this layer.

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Object Memories in Instrumented Spaces

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Abstract. In instrumented environments physical objects augmented with functionality and digital services play an important role. In this tutorial I plan to give an overview on existing infrastructures, that support the design and operation of such environments. We will discuss how object memories can be represented and how events related to those objects can be routed and handled. In particular, we will discuss an infrastructure that has been used for more than 5 years in the Innovative Retail Laboratory a joined research lab of a large German retailer (Globus) and the German Research Center for Artificial Intelligence. Here every item in the supermarket is considered to be augmented with information in a semantic product memory. The tutorial aims at researchers that plan to experiment and build complex intelligent environments and discusses the tools needed for those.

Keywords. Instrumented Space, Object Memories

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Social Interaction with Cloud Network Robots

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Abstract. "*Making Robots More Acceptable*" -- the words of Professor Gordon Chen who leads ICS (Institute for Cognitive System) at TUM. What exactly is a robot that does not give discomfort to us and we can easily accept its existence as a part of everyday life? Now we obtain capabilities to access ubiquitous information spaces and our human ability and cognitive performance will be gradually enhanced. Robots will also be integrated well into the human life and helping us naturally. They will have rich sensory perception and expressive facial signals, and are going to be social partners for us. In this tutorial, we are discussing what kind of "sociality" robots should have in human robot interactions (HRI).

Keywords. Cloud Network Robotics, Sociable Robots, Human Robot Interaction

1. Introduction

Being human, the behaviors with "sociality" will have an important meaning. Like communication skill to understand or sympathize with others, skill to recognize multiple contexts at the same time correctly and skill to create moderate intervals with interaction partners, ability to ensure social performance is various. Robots, and even everyday things, are also similar. An information system or a robot which has advanced interpersonal communication skill, can show correct judgement in all circumstances and be able to cooperate with people, robots, everyday things and various information services, such existence is probably an "acceptable" information system or robot.
Robots are interactive interfaces in real-world between users and ubiquitous information services. If the robot technology advances and many of objects in our everyday life are robotized, the cooperative world with such novel things "next generation IoT" will be opened. We call robots and IoT devices which provide a certain kind of sociality "Sociable Robots" and "Sociable Things".

Robots that work as an edge terminals of cloud services are called a "Cloud Network Robots". The architecture of the Cloud Network Robots which realizes cooperative operations among heterogeneous robots can be the base of Sociable Robots and Sociable Things. A wide variety of robots aim at achieving their goals while sharing information on services that each can provide, autonomously and adaptively forming communities corresponding to tasks they are faced with, and working together with various cloud services. Some of them will coexist with us as actors of ubiquitous and cloud information services and some will argument our human ability by making full use of M2M (Machine to Machine) communication and M2S (Machine to Service) communication.

2. Cloud Network Robotics and Sociable Robots

The Cloud Network Robots are beginning to be implemented in various forms such as agent software on information devices like smart phones, communication robots, and personal mobility robots such as wheelchairs and EV vehicles. The technical issues of Cloud Network Robot are as follows.

- Cooperation and collaboration technologies among heterogeneous robots
- Data linkage technologies between robot and cloud information service
- Many-to-many human robot interaction technologies

In addition to these issues, we will discuss the following two more issues for Sociable Robots.

- Highly accurate perceptual processing and context recognition technologies
- Social and affective interaction technologies

From the viewpoint of the sociality, the perception and context capturing function possessed by robots themselves is an important factor in determining behaviors of robots in human interactions. We are focusing attention on the emotional recognition of the communication partner, that is, the acquisition mechanism of human's emotional changes, which is indispensable for realizing "social and emotional interaction", and have been exemplifying its principles, implementation methods, and application examples. We have exemplified many-to-many human robot interactions in various usage scenes by implementing "sympathizing robot", "remote ice breaking robot system", etc. (Fig. 1). Topics covered in this tutorial range over "pseudo-emotional behaviors of robot in HRI", "the personality of robot naturally being built by HRI", "creating moderate interval and proximity in HRI" and so on. These are examples of next generation social and emotional human robot interactions.

Figure 1. Affective Interactions: sympathizing robot, remote ice breaking robot, and expression amplification robot

3. Topics and Projects to Introduce

Our projects to be introduced in this tutorial for discussing the topics, "Cloud Network Robotics" and "Sociable Robots", are as follows.

Conversation Handling in Many-to-Many HR Interaction Considering Emotional Behaviors and Human Relationships

In the future, communication robots are expected to join many-to-many human-robot interactions. Thus robots need to handle interruptions requesting a new task from the outside of the current conversation. We have proposed a novel scheduler which decides switching timing of conversation tasks when a robot is interrupted [1]. The model grasps a structure of current conversation based on adjacency pairs to find breakpoints of the conversation. In order to decide whether to switch conversation tasks on each breakpoint or not, the model prioritizes conversation tasks considering an importance of its topic and a length as contexts of each conversation task. The model also uses human relationships and emotional behaviors to decide priority of conversation tasks. The result of an evaluation experiment (Fig. 2) shows that our proposed scheduler could impress subjects more favorably than that which always prioritizes an interrupter.

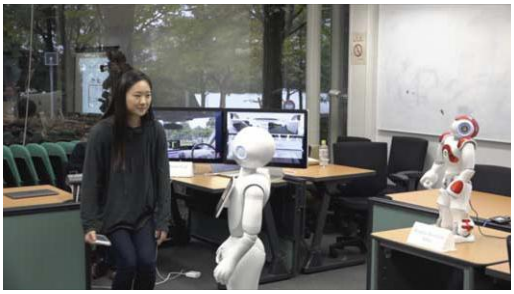

Figure 2. An experiment scene of many-to-many HR interactions

Creating Comfortable Spatial and Timing Interval for Smooth H2R Interaction

In human-to-human communication, it is important to grasp the sense of distance to the other party and respond at an appropriate distance, that is, communication that is conscious of 'intersection', which is considered to be the same for robots. Also, being able to act autonomously and work in a wide range of robots is an important element in coexistence with people. We have proposed a human robot communication method in which the robot judges the reaction of the opponent in stages, decides the appropriate intervals according to the spot, and the robot shrinks or separates the distance himself. The robot himself measured the intersection from the expression and behavior of the opponent and designed and evaluated a service that allows the user to take a distance that allows the user to feel confident and comfortable communication.

Long-term Characterization of Robots based on Human Child's Personality Development

Inadequate variety of personalities for communication robots may cause unnatural interaction with them and reduction in attachment. We have proposed C^2AT^2 HUB, where communication robots are characterized by changing tendency of affect transition based on long-term interaction with users [2]. In C^2AT^2 HUB, robots' affect is defined as two types; “interpersonal affect” and “emotions”, and transition of each type of affect is adjusted by history of users’ actions to robots in order to characterize robots gradually. Evaluation experiment revealed our approach characterizes robots naturally and improves impression of robots.

Expressive Robotic Avatar with Multimodal Emotion Detection to Enhance Communication of Users with Motor Disabilities

In current society, there are numerous robots made for various purposes, including manufacturing, cleaning, therapy, and customer service. Other robots are used for enhancing H2H communication. We have proposed a robotic system which detects the user's emotions and enacts them on a humanoid robot (Fig. 3) [3]. By using this robotic avatar, users with motor disabilities are able to extend their methods of communication, as a physical form of expression will be added to the conversation.

Figure 3. Ex-amp robot: concept and experiments

4. Summary

This brief summary discussed what kind of “sociality” robots should have from the viewpoint of Human Robot Interactions (HRI). The contents of the tutorial cross the fields of Cloud Network Robotics, Cognitive Robotics and Affective Robotics, and can be expected to be applied to a wide variety of domains without being limited to a specific area such as RO-MAN (RObot and huMAN Interactive Communication). We hope that this tutorial will be a breakthrough when designing new generation robot systems and IoT systems.

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Business Process Management: Approaches and Techniques Applied to Smart Environments

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Abstract. Business Process Management is an established discipline that deals with the identification, discovery, analysis, (re-)design, implementation, monitoring, and controlling of business processes. In turn, the Internet of things (IoT) is the inter-networking of physical devices, vehicles, buildings, and other items embedded with electronics, software, sensors, actuators, and network connectivity enabling these objects to collect and exchange data. Up to know Business Process Management (BPM) and IoT have developed as two different fields with relatively few touch points. However, there is an increasing amount of work demonstrating the benefits of a closer link of business process management and IoT in the context of smart environments. In this tutorial I will give an overview of existing business process management approaches applied to smart environments and illustrate examples of successful combinations of BPM and IoT to enhance smart environments. Moreover, the tutorial will cover challenges that need to be addressed to better unveil this potential and outline research opportunities.

Keywords. IoT, Business Process Management

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From Awareness to Foundation: Human Behavior in Computing

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Abstract. In the advancing ubiquitous computing, relationship between human users and computer systems has been rapidly evolving and getting more complicated. Through various types of users' devices, such as notebooks, smartphones, watches and wearables, and also those that embedded inside our surrounding environment, we let the computer systems "sense" information about ourselves and the physical space, and let the systems "inform" (and provide) various types of value-added and services. In this talk, I present some of our latest work on understanding human activities and even some internal status (such as mood) through various types of sensing technologies spanning from device sensors, mobile sensors, and participatory sensing. Furthermore, I will also focus on the problem of "interruption overload" that occurs when human users' are overwhelmed by an increasing amount of proactive information provisions from the computer systems, and present the latest research on "human attention management", a research challenge actively researched by the Ubicomp community in the recent years.

Keywords. Human behavior, Interruption

2nd Workshop on Citizen Centric Smart Cities Solutions (CCSCS'18)

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I. Chatzigiannakis et al. (Eds.)

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Introduction to CCSCS'2018

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Smart Cities can be considered as a new paradigm or a concept that is emerging all over the world as a necessary and unavoidable response to the constant urban population growth and associated technical, material, social, and organizational problems, in order to improve the quality of life of their citizens, and to provide a more economic competitive, sustainable and livable city. The recent development of important technologies, such as low power miniature sensing devices, high-speed wireless and wired communication networks, and high-performance computing systems, enables the creation of new possibilities and capabilities, fostering the opportunities for smart city realizations.

Intelligent solutions to the referred problems, intended to control pervasive computing systems, such as citizen-aware intelligent environments, will help and contribute to the construction of a sustainable smart city, providing value-added, intelligent, adaptive, context-aware, user-centric and sustainability services, with realizations such as smart home/smart building, smart energy, smart mobility, smart parking, smart health or citizens well-being, that is, providing smart services intended to be more efficient, with reduced resource consumptions and promoting the well-being and good quality of life of their citizens, without neglecting the benefits of a citizen sensor. With the citizen as an active and proactive actor of the Internet of Things, reliable and definitive solutions for problematics such as Road Safety and Vulnerable Road Users, among others, could finally emerge. However, the smart city realization means everything should be considered in large scale, in real-time, dynamically, with uncertainty with restrictions, and adapt to different objectives. Furthermore, the standard computational intelligence algorithms may be insufficient or not robust enough to deal with smart city big data analytics.

The purpose of this workshop is to gather and present new and original research towards citizen-centric solutions within the scope of intelligent environments and smart cities, capable of active context awareness, automatically changing their functioning in response to discovered context, enabling that way the improvement not only of city efficiencies, but also citizens quality of life.

This second edition of the Workshop on Citizen Centric Smart Cities Solutions (CCSCS'18) presents four articles centered around citizen centric services, reinforcement learning in intelligent environments, social networks to enhance product development and a systematic review on engineering intelligent environments.

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Digital Citizen Engagement Framework: An Approach to Citizen Centric Smart Cities of the Future

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Abstract. Smart city capabilities are currently realized in a staggered fashion or they exist in silos. However continuous improvement and personalization is expected by citizen for sustained engagements. This is possible only if the service enabling platform is able to continuously learn about the citizen persona and her need. This enables a platform to transform the way the services are delivered to an individual citizen. The current study provides insights to develop Digital Citizen Engagement Framework (DCEF) to build a platform for citizen to personalize the engagements with smart city services. The framework is arrived at through Content Analysis, a qualitative research methodology identifying various categories and themes to manage technical components and features that need to be part of DCEF that can be deployed in a Smart City to make it future ready. Our initial experiments on an Ambient Assisted Living (AAL) use-case for geriatric care proves the effectiveness of our proposed framework.

Keywords. Human-centric system, service orchestration, framework for citizen engagement, ambient assisted living, Personalization, Contextual Enrichment, Localization, Smart Cities.

1. Introduction

In this section, we try to capture the motivation behind our work, the objectives of the current study, and a brief survey of related works and enumerate the key scientific contributions of our current work.

Digital citizen is a person who continuously engage using the power of digital technologies with the required services offered by the City based on her needs. The

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"smartness" or "Intelligence" is not a measure of how advanced or complex the technology being adopted is, but how well a service uses technology to improve the QoL (Quality of Life) of citizen. DCEF is designed to make the citizen smart by continuous, sustainable personalized engagement with the smart services offered by the city/service providers.

Figure 1 captures how typically a smart citizen can get engaged in with the DCEF a personalized way. Beyond smartness provided in the services, the framework has to ensure the way the services are rendered and how the citizen is enabled to have sustainable interaction with the smart services. This requires sensing of the environment, sensing the behavior, her engagements, physiological parameters, her need and feedback. Sensing through citizen by onboarding her own assets and sensing the citizen by various other means like wearables, video images, activities are required to personalized the services to her. The below diagram depicts the sensing, information abstraction, contextualization and business enrichment of data, and intelligent orchestration of services to render personalized services to citizen. The data needs to be enriched with contextual information for businesses to provide highly personalized services to the citizen.

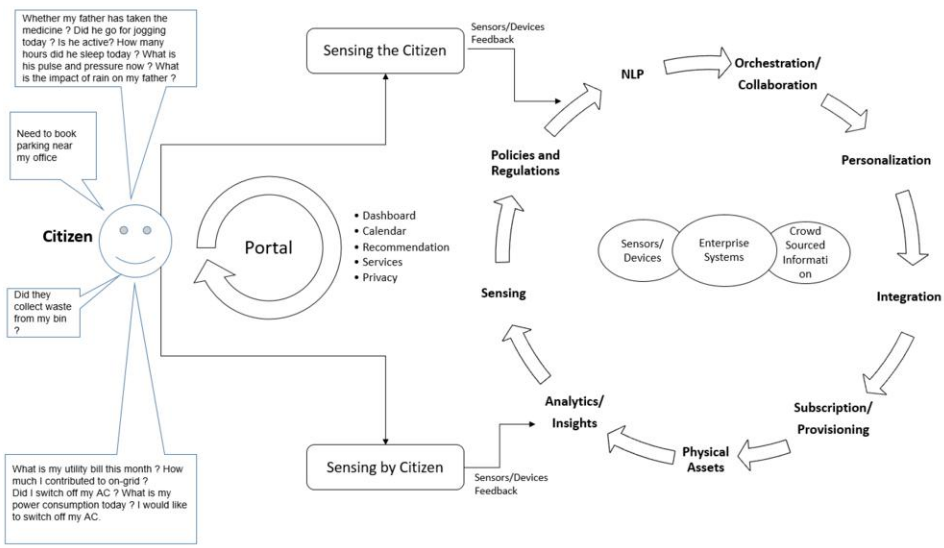

Figure 1. Smart Citizen Personalized Services

1.1. Motivation

Current smart city deployments are infrastructure centric and managed in silos. Citizens get confused in the journey due to multitude technologies and challenges in citizen experience. Although it is well known that the major stakeholder in the smart city context is the citizen. Hence, instead of approaching the smart city paradigm from technological angle or e-governance perspective, we approach the smart city paradigm from a human information interaction (HII) [Albers, 1] perspective. This enables us to understand the key value metrics that is appreciated by a citizen when she is either contributing to a service like in the case of participatory sensing; or engaging with a smart service as in the case ambient assisted living.

1.2. Objectives

The central objectives of the study are:

- To arrive at the key factors influencing the design of a Digital Citizen Engagement framework that is future ready;
- Ideal digital framework for citizen to engage with smart services offered by a smart city/provider?
- Personalize the engagement there by the quality of life is maximized?

1.3. Related Works

[P. Vlacheas et al,2] proposes a cognitive management framework for Internet of Things (IoT), in which dynamically changing real-world objects are represented in a virtualized environment, and where cognition and proximity are used to select the most relevant objects for the purpose of an application in an intelligent and autonomic way. This practical need impels us to develop a new paradigm, named cognitive Internet of Things (CIoT), to empower the current IoT with a "brain" for high-level intelligence [Wu, Qihui et al, 3]. [Cretu, Liviu-Gabriel, 4] provides an event driven architecture for smart city solutions that enables a kind of city where digital artifacts enable the interoperability between Internet of Services, Internet of Things and Internet of Humans. [Hoseini-Tabatabaei et al, 5] provides insights into how todays smartphones have become increasingly multipurpose platforms, it is still a challenging task to add opportunistic sensing and context processing capabilities without jeopardizing the users overall mobile phone experience. [Uckelmann, Dieter et al, 6] proposes a design framework for service-oriented interactive systems integrating the concept of persona. This enables to extract relevant elements towards deriving the design of main functionality of a user interface. [Eloff, J. H. P et al, 7] discusses important aspects of dealing with human data in the context of smart cities; like security and privacy etc. [Robson, Karen et al, 14] extends the idea to wearable devices, grid for wearable provides information on contextual self-awareness and other situation awareness using wearable devices. [Spector, Yishay, 8, berg, Christina et al, 9] provide viable business models for user centric smart cities of the future.

We find that there is gap related to defining digital citizen engagement framework focusing on human personas and the factors that are needed to make it operational. [Marco Conti, 17] defines Internet of People as all networking functions take into consideration that Internet devices can be users' personal devices, and therefore exploit models of the human behavior to determine the way these devices should operate in the network.

We next delve into the particular application of Ambient Assisted Living (AAL) which is an important aspect for human information interaction (in fact Internet of People (IoP)) with IoT. [Augusto, J, 10] shows that there are different types of caregivers that are needed to be considered to provide assisted life-cycles for Night Optimized Care technology. This means that the framework for assisted living also needs to adapt itself for providing night care for subjects suffering from insomnia and nocturia. [Schultz, Joseph S et al,11] conducted studies to list the Distinguishing Elderly Needs across factors like: a) Health b) Safety c) Independence d) Mobility & e) Participation. The findings of [Fowler, Jie G, 12] show that Chinese Older People, at-least those who are part of Internet chat groups, exhibit higher levels of happiness through consumption, though consumption is not the key to happiness. In the front of IoT based healthcare, Najafi hopes he and his group will be able to build devices that could be safely implanted in children with severe heart problems and last 30 to 50 years [Najafi, Nader et al, 13].

[Diego Reforgiato Recupero et al, 16], worked on the paper that introduces an open, interoperable and cloud based citizen engagement framework for the management of administrative process of public administrations, which also increases the engagement of citizens. However the mentioned framework does not address how it would manage personalization and human centric aspects which would be possible through citizen persona and human intelligence that are required for cognitive and sustained engagements.

1.4. Key Contributions

The key contributions of this paper are as follows:

An indication at the reference architecture for a future ready framework for digital citizen which is not addressed in earlier studies and literature:

- An interoperable data model which enriches and stores IoT data with business context is needed. Mere IoT data is insufficient;
- Identification of components needed in a DCEF to make it citizen centric.

The rest of the paper is organized as follows: Section 2 provides an overview of the proposed system. We elucidate the effectiveness of our design through real-life case studies based on field deployments, in Section 3. Section 4 provides insights into Implementation of the framework along with performance and scalability analysis through instances of Ambient Assisted living and Activity tracking sensor (Actrack) applications. Finally, In Section 5 we draw the conclusions of our study and also provide a road-map for future work.

2. System Overview

In this section we illustrate our system architecture and the rationale behind our design principles.

2.1. Theory of Design

We begin our study with the study of existing literature as illustrated in section 1.3. A summary of key findings in provided in table 1. Based on the key attributes mined, we proceed to detail our philosophy of design.

The research methodologies that were used by us include content analysis as research methodology using coding the variables and case study analysis.

Table 1. Analysis of State-of-the-Art

Literature Reference	**Variables**	
Citations	**Themes or Category**	**Attributes Learned**
[2,3,4,6]	Management Framework	Cognitive IoT and IoP
[5,14]	Technology Framework	Contextual data Modeling, Service orchestration
[7,8,9,10,11,12,13]	Technology Features	Device configuration, semantic web, security & privacy

Our Content analysis pointed to the frameworks and the features that can be part of the Digital Citizen Engagement framework where AAL is a primary use case. These facts were corroborated through the case study analysis on AAL platform. Our findings are provided in section 4.

2.2. Architecture Overview

The architecture of DCEP is illustrated in Figure 2. DCEP employs a micro services architecture providing engagement as a service to citizen. The service is profiled, personalized and provisioned by learning citizen personas by contextualization and correlating of data from variety of sensors. The sensed information includes but not limited to activity, behavior, feedback and physiology measurement helping multi-dimensional analytics to personalize the services to citizen.

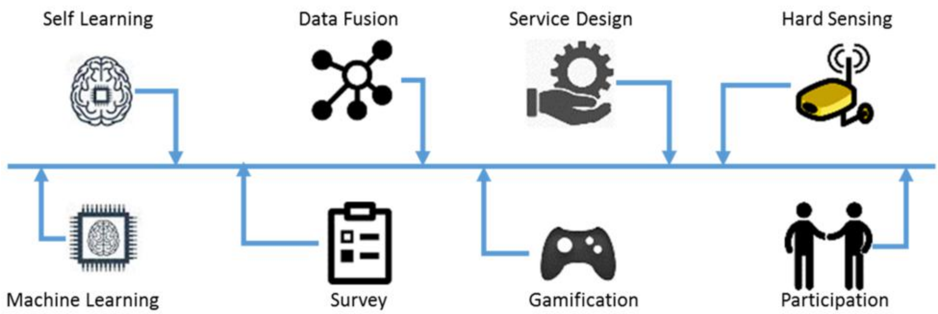

Figure 2. Features of DCEF

The architecture would also aspire to take care of the attributes arrived through literature review in table 1. Human sensing provides low and high level inferences based on multitude of sensor data which enables understanding of both persistent and transient context. Personalized services are those services which are rendered to citizen knowing her persona, her engagements and the context. This is illustrated in figure 3.

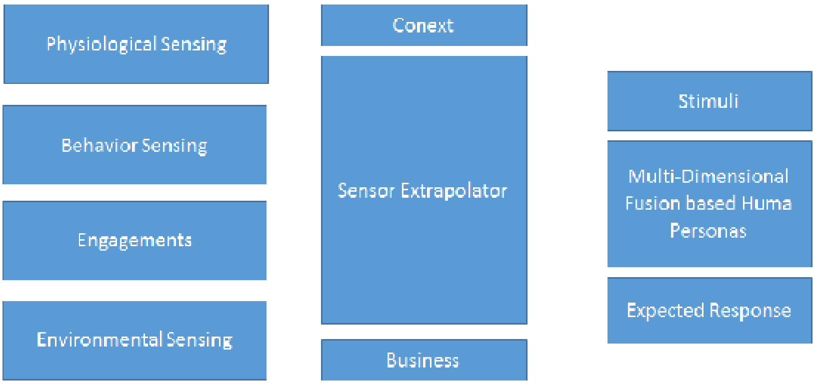

Figure 3. Human Sensing Architecture for Personalization

3. Snapshots of Implementation

In this section, we provide an example of Ambient Assisted Living Framework highlighting some of the concepts presented so far. This framework is primarily targeted at a specific group of citizens namely Elderly citizens interact with AAL platform hosted in DCEF. The AAL platform not only enables sensing of the elderly citizen and alerts that caregiver but also learns about the citizen and her various personalization parameters which will also be fed into DCEP. The services provided by AAL platform is not only through traditional services like authorization, profiling and subscription but also learning about the individual through physiological sensing, behavioral sensing, sensing the various engagement opportunities of the elderly citizen with the system. This helps us to learn about the person across various service paradigms, creates various opportunities for engaging with him and, alerts the rights and services recommended for them.

Another means of personalizing the service is by monitoring the activities of the citizen by using the Actrack application which can be used in AAL platform. We use the above notion to show how an activity recognition application Actrak [Chandel, Vivek et al, 15] can be implemented using the same. In case of Actrak, the sensor being used is the three axis accelerometer on user’s mobile or wearable device and is able to provide data on her physiological movements for her personal factors. Citizen decides to on onboard her own device and the device provides meta data like age, height, weight and gender for accurate estimation of Body Metabolic Index (BMI). Based on this, day-long activity, calorie burnt using various steps and calorie charts can be generated.

4. Case Study

4.1. Ambient Assisted Living for elderly

The AAL scenario for elderly citizen is monitoring enabled by sensor enabled home for motion, activity sensing, utility sensing and physiological sensing with the help of wearables.

Some of the sensors and their features that are used in the rooms for the AAL platform are:
- Passive infrared (PIR) for detecting motion;
- Door Contact (two piece magnetic sensor) for detecting door open/close activity;
- Smart Plug to meter electricity consumption;
- Medibox sensor to monitor medicine intake;
- Bed contact (accelerator sensor) for detecting sleep activity on bed.

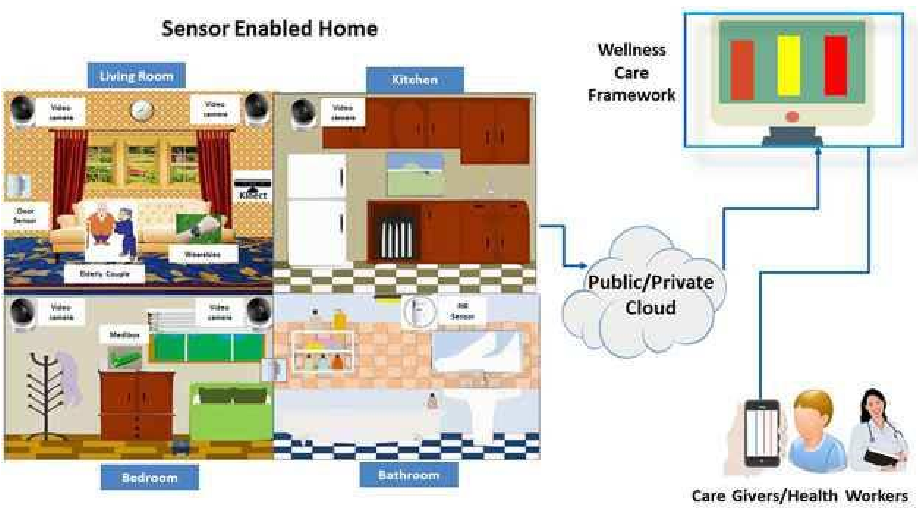

Figure 4. AAL Overview

Figure 4 depicts the layout and type of sensing and services for tracking activities of Daily Living (ADL) and creating quantified life charts of individual subjects. Figure 5 shows how personalized services are enabled using an assisted living framework on the DCEP. It also provides details of how sensor data is analyzed to understand both behavior and wellness parameters of the elderly citizen.

Recommendation and personalization of citizen engagements would require defining citizen personas. Continuous learning of attributes which influence/impact the definition of citizen personas can be categorized into following:

- Profile
- Behavior
- Physiological
- Location
- Engagement
- Feedback
- Culture/Community
- Environment
- Activity

Many of these inputs are dynamic and state dependent. Contextual enrichment of the personas will help the take decision on what, when, where and how part of the services. For example, recommendation to citizen to adhere to special medication, when he is diagnosed with an ailment like dementia which would need different method of reminding the citizen, when there are chances of citizen missing medication.

Following is the brief description on some of the key components for the Citizen persona in figure 5:

- Citizen persona listener: It is a listener component looking at the data which has dependency to attribute of the citizen, which is being learnt as part of defining citizen personas.

- Citizen persona manager: This component implements a factory type of pattern matching, which in turn will call attribute specific citizen persona processors to learn and define the persona attributes.

- Citizen persona [attribute] processor: This component manages attribute specific processors which in turn calls algorithms/process for learning, in order to categorize the persona attributes.

- Citizen persona APIs: Once the citizen personas are defined, the orchestrator (business processes) and the recommender will leverage the citizen persona services to personalize and recommend the services to citizen.

To illustrate how citizen persona can help in providing personalized service, we can look at an example – The AAL personalized service can help in sending reminder to medication box and also to the care giver to alert and ensure elderly medicine intake after 1 PM and before 1:30 PM, if the elderly citizen has not taken the medicine. The system also knows that she has sleeping pattern between 1:30 PM and 3:30 PM. In the event of elderly citizen hasn't taken the medication in spite of the alerts from the service and if we are able to monitor and notice that there is down trend in her pulse, then immediate alert to caregiver and reporting to hospital and paramedical care can help the patient, a great deal.

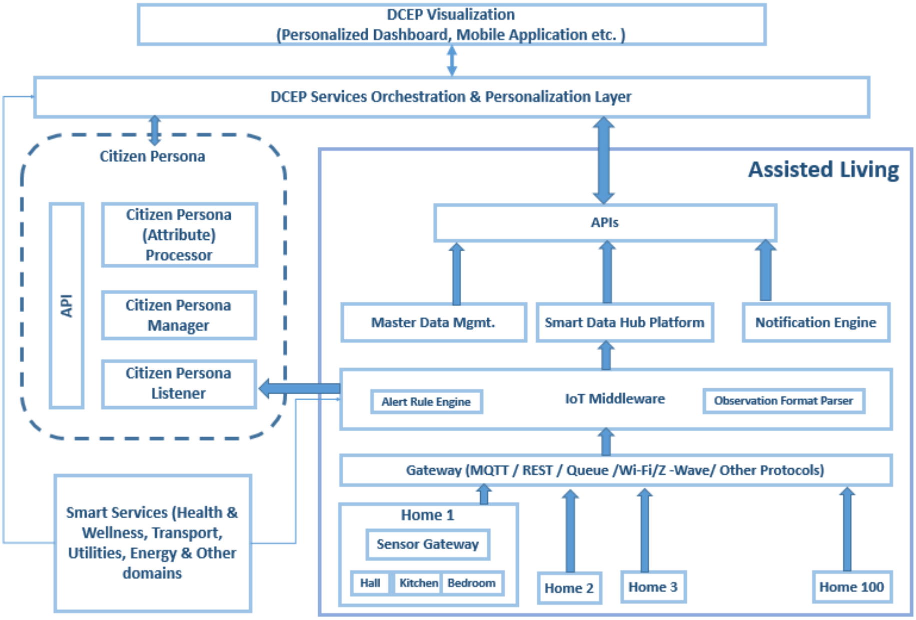

Figure 5. AAL Framework

5. Conclusion and Future Work

In this paper, we have shown how sensor driven context can lead to rendering of personalized services to citizens. We further show that sensor driven applications and associated algorithms can be uniformly implemented on a conceptual DCEF and we also showed how this works for an AAL scenario. As a future work, we plan to implement novel algorithms to build citizen personas through the data and enhance its features to achieve further personalization. We show in our current paper that understanding of human individuality and community uniqueness is key to effective assimilation of information, orchestration of services as well as effective citizen participation and becoming mascots for government initiatives. The future work can also cover privacy and security aspects of the personalized services through DCEP.

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Reinforcement Learning Based Approach for Smart Homes

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Abstract. Smart Homes are environments that automate action and adapt themselves to user behaviours. In this sense, it is necessary to employ learning strategies to allow Smart Homes to truly become intelligent, in a sense that they anticipate needs and actions. This requires constant monitoring of environments, users and their actions, as well as, non-supervised dynamic learning strategies.

The purpose of this work is to develop a system capable of taking the best action possible based on its environment. In this document, we present a reinforcement learning approach to automate lights and appliances in a Smart Home environment. An intelligent agent perceives the ambient and the past interactions of the user with the home in order to learn what is the best action to perform, which action has a certain reward associated in order to inform the agent his behavior. A reinforcement learning algorithm learns a policy for picking actions by adjusting its weights through gradient descent using feedback from the environment.

Keywords. Reinforcement Learning, Smart Home, Machine Learning, Intelligent Agent

1. Introduction

Smart Homes are being more coveted nowadays, a recent research of [1] has shown a gain interest on Smart Homes but a decrease in home automation over time, this is simply because Smart Home technologies can do more than automate a house. This lead to more and more companies diving in this area of business, for instance, tech giants like Google LLC, Samsung, Apple and more [2]. The need of extending capabilities is essential to make a difference in the market.

Smart Home is defined as a living or working space that interacts in a natural way and adapts to the occupant. Adaptation refers to the fact that it learns to recognize and change itself depending on the identity and activity undertaken by the occupant with minimal intervention [3]. Hence, a Smart Home agent must be able to predict the mobility patterns and device usages of the inhabitants. The Smart Home behaves as a rational agent, perceiving the state of the home through sensors and acting on the environment through actuators. The goal of the Smart Homes is to maximize comfort and safety, optimize energy usage and eliminate strenuous repetitive activities.

A single day in the life of a person consists in a numerous set of actions. These actions, over a period of time, can be learned by an intelligent system and prove useful to predict future actions. For instance, the blind case. A person waking up at 8 am opens the shutter in the bedroom, an intelligent system could learn this pattern and switch shutter on the room at a particular time predicting the waking time of the user. Another possible scenario would be the opposite, the system predicts when the shutters are closed. A system could learn to do this by analyzing the users patterns.

In this article, a deep learning system is proposed to learn user habits within a Smart Home and predict the best interval to activate actions. The system uses a reinforcement learning technique to predict the reward for each 15-minute interval in a day for a given action. The input to this system is a simulated historical data, which contains user past interactions with the system. The system makes use of a deep learning technique and a policy technique to give rewards to the learning system as it tries to learn user habits with each action that takes place along the day.

The multi-agent system and algorithms proposed and methodology along with the results obtained are discussed in the next sections of this article document.

2. Related Work

Existing projects towards Smart Homes use mostly a multi-agent system (MAS) methodology. In multi-agent systems, agents can additionally communicate and coordinate with each other as well as with their environment. An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors [4] . MAS provides a valuable framework for intelligent control systems to learn building and occupancy trends. [5] . However existing systems use mostly a pattern mining technique [6] to determine what can be the next action. An example of this is the MavHome project by Cook et al. [7], an home that acts as a rational agent which aims to maximize comfort and productivity of its inhabitants and minimize operation cost. In order to achieve this goals, the house must be able to predict, reason about, and adapt to its inhabitants.

Therefore, some systems use a reinforcement learning approach, Che et al. (2010) use an event processing tool to handle the events from the home automation devices, prediction algorithms to predict the next action and reinforcement learning to decide which actions are suitable to be automated [8].

In recent past, with the advance of deep learning, a new level of reinforcement learning has surged Deep reinforcement learning. Although there are challenges, impressive applications has appeared. Mnih et al. (2013) from the University of Toronto show how a computer can beat a human in an old Atari video game using deep reinforcement learning in Tensorflow. Tensorflow is an open-source machine learning framework. It used a Q-Learning model combined with a Convolutional Neural Network to predict the next action, given the image of a game at that instant [9].

More recently, Gokul et al. (2016) present the first deep reinforcement learning model for home automation system. The system makes use only of images to learn the users needs using Deep Q-Learning to make the system understand and learn the user patterns and actions without the need for intervention of a user [10]. The results are similar to ours, it also delineates rewards for each action for different time intervals in a day based on a robust reward function based on Q-Function. However, the lack of user intervention leads to system without user feedback, in this way, the feeling of control is not maintain. According to Balta-Ozkan et al. (2013) there are some impasses regarding the social embrace of this technology, being loss of control and apathy one of the main concerns [11]. Our approach aims to avoid these social barriers.

In this paper, Tensorflow deep reinforcement learning is used in the context of Smart Homes, using a gradient policy to make the system understand and learn the user patterns and actions. The data collected by the system is controlled by the user, providing a feeling of control. In addition, the user has the power to decide which action he wants to be automatized of all available in the system.

3. Reinforcement Learning

Reinforcement learning is learning what to do, how to map situations to actions, so as to maximize a numerical reward signal. The primary aim is to cast learning as a problem involving agents that interact with an environment, sense their state and the state of the environment, and choose actions based on these interactions. In reinforcement learning the agent comes pre-equipped with goals that it seeks to satisfy. These goals are embodied in the influence of a numerical reward signal on the way that the agent chooses actions, categorizes its sensations and changes its internal model of the environment. Despite the obvious connection of these terms to behavioral psychology, some of the more impressive applications of reinforcement learning have been in computer science and engineering applications [12].

Reinforcement learning lies between supervised and unsupervised learning. It makes use of sparse and time-delayed labels - rewards. The system at each stage tries to maximize the reward.

This approach will not consider states, this means that rewards for an action is not conditional on the state of the environment. All we need to focus on is learning which rewards we get for each of the possible actions, and ensuring we choose the optimal ones, this is called learning a policy and we will discuss our policy in section 3.1.

3.1. Policy Gradient

The simplest way to think of a Policy gradient network is one which produces explicit outputs. In the case of our case study, we dont need to condition these outputs on any state. As such, the network will consist of just a set of weights, with each corresponding to each of the possible time of the day to do an action, being turn the lights on, shutter, and so on, and will represent how good our agent thinks it is to do the respective action in that interval. Weights are all initialized at the same value, being all intervals equal to the agent at the initial state.

To update our network, we will simply use an e-greedy policy. This represents that our agent will choose the action that corresponds to the largest expected value, but occasionally, with e probability, it will choose one interval randomly. This randomness is crucial, it allows the agent to try out each of the different intervals of the day to continue to learn more about them, without it, the agent would ignore potential better intervals than the one chosen. Once our agent has taken an action, it then receives a reward of either 1 or -1. With this reward, we can then make an update to our network using the policy loss equation 1.

$$loss = -log(\pi) * A \tag{1}$$

In equation 1, A is advantage, and is an essential aspect of all reinforcement learning algorithms. It corresponds to how much better the agent action was than the baseline, being 0. Intuitively, a positive reward indicates a increase weight to that specific interval, and a negative reward, a decrease weight.

The parameter π is our policy. In this case, it corresponds to the chosen interval weight.

This loss function allows us to converge to the best interval to do the respective action. The agent will be more or less likely to pick that action in the future. By taking actions, getting rewards, and updating our network in this circular manner, we will quickly converge to an agent that can solve our problem.

In order to predict the best interval of the day to execute possible actions. We developed multiple agents, each with their respective weights and rewards. These agents run simultaneous, being possible by our chosen machine learning framework, Tensorflow.

3.2. Learning Agents

Agents are responsible for perceiving the past interactions of the user and, based on that information, choose the best time of the day to perform the action. Each agent, one for each possible action, take his decision according to what he thinks it has the most reward.

To accomplish that, we establish the agent updating procedure. With the policy defined, we use the Tenserflow library. It provides a set of classes and functions that help train models. In this work, we use the *GradientDescentOptimize* to train the reinforcement learning algorithm.

The parameter *Chosen interval* represents the interval chosen by the agent. Training with a gradient descent method. The agent is updated by moving the value for the selected action toward the received reward.

The agent will be trained by the actions taken in the environment, and receiving positive or negative rewards. Using rewards and actions, it allows us to know how to properly update our network in order to more often choose actions that will yield the highest rewards over time.

3.3. Reward Function

Reward functions describe how the agent ought to behave. In other words, they have normative content, stipulating what we want the agent to accomplish. In our work, we have multiple distinct actions that we want to accomplish, therefore, we created different agents. Different reward functions were needed, one for each possible action in our environment.

When the agent does the right action in the right interval, we reward it with a positive reward, otherwise, in other all actions possible, we reward it with a negative reward. There are only two possible rewards, this is called a binary reward function, where we specify a single action to be rewarded in a specific time of the day:

$$R(a1, interval) = 1$$

$$R(a2..n, interval) = -1$$

For example, when the agent predicts the best hour to turn on the lights, if it chooses to light them when the user usually turn them on ($a1$) it receives a positive reward, otherwise ($a2..n$), receives a -1.

4. Experiments

In this section, we present our approach. The architecture proposed, along with algorithm are discussed in this section.

4.1. Architecture

The figure shown in figure 1, represents our system architecture. A user interacts with an environment daily, these daily interactions are perceived and stored in a data set.

In order to answer the problem defined, which focuses in the importance of the user in an automation environment, it is needed to establish a solid connection between the automation system and the user. With this in mind, we developed a multi-agent system, with distinct agents. This multi-agent system is defined as Logical Unit in this paper.

The Logical Unit is responsible for the decision making in our system. It contains two types of agents, intelligent agents, and the interface agents. Interface agents are responsible for communicating with the user and the system. The system is capable of suggesting the user of the action chosen by our intelligent agents, and the user can express his opinion about the decision of the agents. This results in our system converging to the user personal preference actions. Interface agents are vital to accomplishing this, as they serve as intermediates between the system and the user.

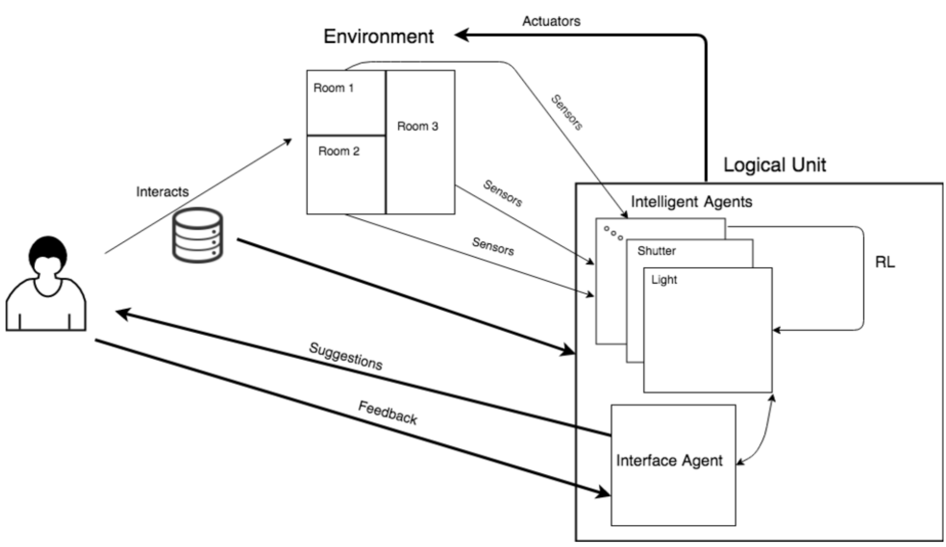


Figure 1. System Architecture

Intelligent agents can view and perceive the environment through sensors and act upon that environment through effectors. The environment is composed by different rooms, these rooms have multiple sensors regarding the appliance. The logical unit has multiple intelligent agents, one for each appliance in the environment, lights, shutters, temperature and others. These agents perceive their respective sensor in the different rooms and after the deep reinforcement learning process, they actuate through actuators in the ambient. For instance, the shutter agent, is responsible for the automation of the shutters in the different rooms.

Reward functions are dependent of the user pattern, present in historical data sets, in account which action the user took in that instant, if it correspond to the agent decision, a positive reward is granted. The reward function associated with each action can drastically change after receiving the user feedback, indicating the possibility of adapting to the user preference.

With the architecture presented, it is possible to answer the problems raised in this paper. It is capable of converging to different usage patterns and discern between different contexts in the form of user preferences. The possibility of communication between the user and the system is the principal distinct factor between this work and the previous one studied in the related work.

4.2. Algorithm

The reinforcement learning algorithm present in the logical unit is responsible for making the intelligent agents intelligent, it allows them to learn about the environment and acting on them, these actions are rewarded in order to converge to an optimal automation. Our ultimate goal is to know when to do a respective action, for example, in which time of the day we should open or close the shutters. First, we need to define the global variables and initialize them, define the number of intervals in the day, initialize the weight and define the loss function, initialize total number of episodes to train agents on, initialize total reward for intervals for each agent and define the chance of taking a random interval e. Then we proceed to define the multiple reward functions, one for each intelligent agent procedure. Lastly, agents will train by taking actions in our environment through the following procedure in algorithm 1.

Algorithm 1 Deep Reinforcement Learning

procedure TENSERFLOW SESSION TO OPEN SHUTTERS
    $tf.Sessions()$ *as sess*:
    $dataSet \leftarrow Historical\ Data$
    Initialize loop counter i=0
    while Number of Days **do**
        Initialize loop counter $j = 0$
        while Number of Episodes **do**
            if $random\ number < e$ **then**
                $interval \leftarrow Random\ interval$
            else
                $interval \leftarrow chosen\ interval$
            $reward\ Open \leftarrow Reward\ Function\ for\ interval$
            Update the network and the Reward
procedure TENSERFLOW SESSION TO X ACTION
    Same procedure as open shutters Session, Reward Function differs.

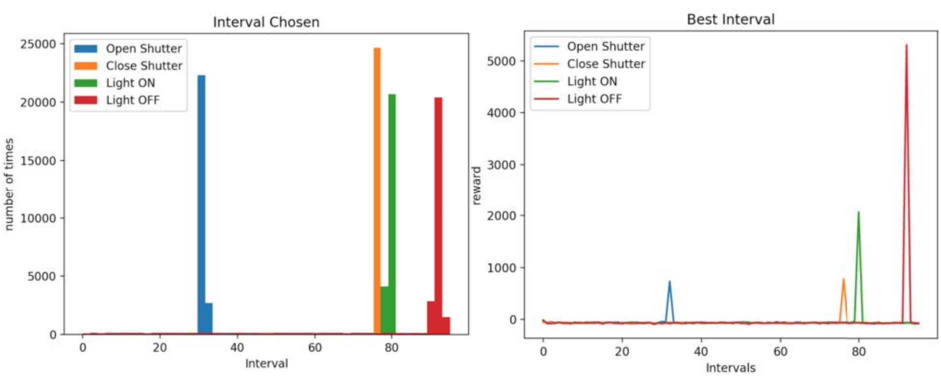
These procedures are replicated to the different intelligent agents present in the system, with an exception for reward functions. Each intelligent agent has is own reward function as is own reward variable. This is absolutely needed since each action is independent of other actions present in the system, the user has the power to decide each action wants to be automatized, thus the need of independence on these intelligent agents.

5. Results

In this section, the results obtained are discussed for the case study presented. For experimental purposes, we simulate a user interaction with a system, based on real events of daily activities. It is considered the light and shutter appliances. The environment is a home environment with 2 different rooms.

We have created two distinct users, each one residing in a different room. In order to replicate a real situation, the data were simulated based in a Gaussian deviation, in other words, the data-set contains some noise, adding some challenge to the algorithm to find a pattern. In the results presented in this section, we consider 96 intervals, each one of 15 minutes, representing a day.

Agents are trained using 30 days of data. The training procedure consists of 1000 repetitions of daily data. In order to explore all intervals defined, the probability to choose a random interval was delineated to 20 percent. The following figures, figure 2 and 3 represents the decision making on both rooms, respectively in 1 and 2.

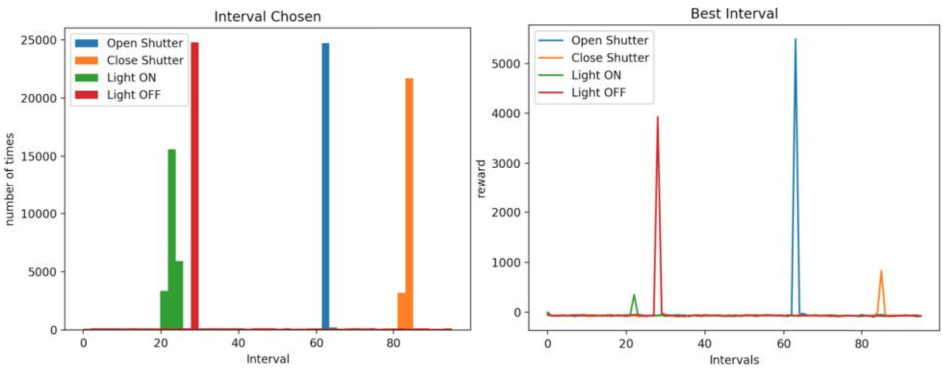


(a) Agent chosen action (b) Rewards for the different intervals and actions

Figure 2. Room 1

Room 1 is inhabited by a day laborer. It can be clearly seen in figure 2a, that the agent inclines significant more to a determinate interval than others, when considering the action. This is caused by the neural network prediction. For example, the agent predicts that the interval 32 is best to open the blinds in room 1, representing 8:00 am, which makes sense for the day laborer who wakes up around this hour.

For each action chosen, the agent will confiscate his reward. On figure 2b, we can see the reward associated to each action at a certain interval. In this case, our algorithm prediction is according to the system reward. Seeing the shutter example once more, interval 32 is the interval with most reward for opening the shutters, solidifying our agent prediction.



(a) Agent chosen action (b) Rewards for the different intervals and actions

Figure 3. Room 2

Room 2 is inhabited by a nocturne laborer. Figure 3a represents the interval predicted by the agent. It differs significantly when compared to room 1, with this, it can be affirmed that the system is capable of adaptation to different behaviors in the environment.

Figure 3b represents once more, the reward associated with each action at a certain interval. Some actions have a bigger rewards than others, for example, our system is more confident at the hour of turning the lights off comparing to turning them on. This is simply because of the variation of the light sensor in the user past activities. The more unpredictable the user is, the less confidence the system has.

In order to show the impact of the user on the system, lets remind the day laborer example in room 1. Figure 4 represents the updated rewards after the user disagrees with the system decision on turning the light off in 2b. As expected, the user has a great impact in the system decision, giving more weight to the user feedback than to the historical data in the reward function.

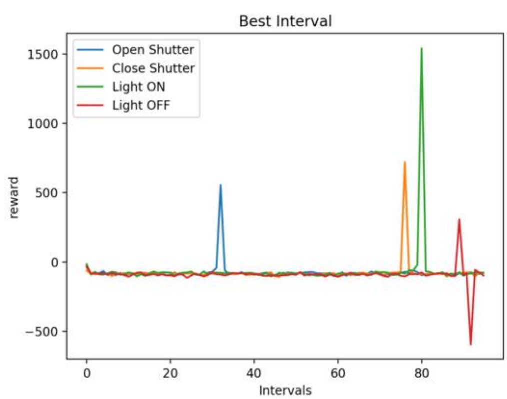


Figure 4. Rewards for the different intervals and actions after feedback in Room1

In this section, we simulate a user interaction with a system based on a Gaussian distribution, to provide some variance in the intervals chosen by a user for a determined action, however, using real data, we expect more unpredictability. This result in more variation in our reward by interval graph, as the highest reward value is not so inclined to one specific interval, difficulting the identification of time intervals where these actions are more appropriate. To avoid such variance, pre-processing data is expected to be needed, alongside with a more robust and complex reward function, tweaked to minimize the confusion.

For now on, we aim to develop a capable system to be used in a real world environment.

6. Conclusion

In this paper, a reinforcement learning model approach for Smart Home is introduced. Unlike the previous reinforcement learning approaches, this paper highlights the role of the inhabitant to combat the social impasses of Smart Homes. With the help of deep learning and neural networks, the ability of the system to predict the subsequent action given the state of the environment and the user pattern is successfully demonstrated based on non-supervised techniques.

The system was tested based on its ability to predict the best 15 minute interval present in day for lights and blinds in different rooms present in a home. User Feedback was also been tested and it demonstrates how influential it is upon the system. More research work has to be performed to generalize this system to all appliances. It was demonstrated that this model for home appliances, but it can be extended to others environments, either public or private.

It is intended to increase the complexity of the reward functions, being more dependent of the user feedback and environment sensing instead of being totally dependent of their user pattern. In this way, the aim is to help the user to avoid wrong habits, directing them to a routine they desire. Also, external data from public Application programming interfaces (API's) are planned, allowing this system to not be restricted to sensors to perceive the environment.

Acknowledgement

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The Usage of Social Network Feedback to Enhance the Development of a Product in an Industrial Smart Environment

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AbstractWith a new industrial revolution, Industry 4.0, changing the organisational and manufacturing processes of an organisation, the increase of importance of consumers interests and preferences is more evident. Organisations face a need to understand their consumers opinion, while being able to address their index satisfaction variables. The explosion of data that we face, results in an increase of information that is present on external sources (such online social platforms), that contain valuable insights about consumers opinion regarding an organisation or, more specifically, products. This information is correlated with the smart manufacturing process, and can also affect the decision-making processes. This work presents a vision for an intelligent component that is able to construct knowledge about the feedback gathered from external sources, in order to aid or take control of decision-making processes, by determining which supplier should supply a specific material, based on consumer opinion.

Keywords. Decision-Making, Industry 4.0, Smart Manufacturing, Supply Chain

1. Introduction

In a world marked by eras and revolutions, industry is facing one of the biggest changes to date, an industrial revolution entitled Industry 4.0 (I4.0) [1] that is focused on the restructure of the value chain process, by integrating computation, networking and physical processes. This revolution aims to impact the overall performance, quality, and controllability of the manufacturing process [2]. This revolution is parallel to the increase of focus towards consumers and their preferences. Organisations are facing new challenges, which include the necessity of understanding the interests and preferences of their consumers, while successfully address their satisfaction index. Organisations should be able to make strategical and tactical decisions, in real time, allowing for a bigger involvement from the consumers on their smart manufacturing processes [3], by understanding their opinions, preferences, and demands.

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Information about their consumers might be represented in data that, usually, is not directly available to organisations (trough their traditional feedback process). Therefore, is imperative that organisations are able to gather data from external sources of information (such online social platforms), in order to enhance the intelligence associated with their smart manufacturing processes, and creating a strong relationship with their consumers by understanding and fulfilling their needs. The perceived quality of a product is strongly related with the manufacturing process, but also contains a relation with the quality of the materials used to manufacture that product. This results in a decision-making process that organisations need to perform regarding the suppliers of their needed materials, which can be an hard task to manage.

We believe that online social platforms contain data that truly expresses the opinion of consumers towards a specific product, or an organisation in full. The nature of these platforms, allows users to speak on a freely way, which often results on expressing opinions that truly correlates to their feelings. Those expressions can express, for example, the perceived quality value of a product, that can differ from the organisation perception. In this work we present a vision for an intelligent component that generates knowledge from external gathered information, to aid or control decision-making processes. This vision is detailed on a theoretical case scenario of application, that helps to understand how the expressed opinions of consumers can affect the manufacturing process of a product.

This work is divided into the following sections: Section 2 contains a brief concept overview of I4.0, and focus on the consumer; Section 3 introduces the concept of industry as a smart environment, and the decision-making processes that industry faces; Section 4 contains an explanation of our vision, which includes a theoretical case scenario; This work ends in Section 5, with a conclusion.

2. Industry 4.0

The industrial world has seen three revolutions trough the time [4], and is currently facing a new revolution, entitled Industry 4.0 (I4.0), that is focused on the restructure of the value chain process involved in manufacturing industry [3]. This revolution, with origin on the German manufacturing sector circa 2010 [5], was driven by the advances of technology such wireless sensor networks, Internet of Things, big data, cloud computing, embedded systems, and mobile Internet [6]. These technologies started to be adopted and brought into the manufacturing environment, leading the transformation of digital era [4].

The key idea of I4.0 is the formulation of new values for the industry, trough the creation of new business models, and the resolution of various social problems [2]. Smart factories are formed by the advanced manufacturing capabilities associated with a digital infrastructure that must be able to capture, generate and spread intelligence [7]. In I4.0, the future of all manufacturing process is based on the concept of a smart factory [8], which demands a shift from independent to interactive, from close to open and from stable to dynamic, in order to take advantage of the value chain of manufacturing and decentralised resources [8].

2.1. The Consumer as a Manufacturing Input

Under the I4.0 concept, the increasing usage of social networks and adoption of new technologies has influenced consumers opinions on product manufacturing, personalisation and delivery, requiring industrial organisations to become self-aware, self-maintenance, capable of making market predictions, and able to respond to market demands [9].

With consumers taking an important role in industrial production models, organisations aim to be able to construct their products around their preferences. In order to achieve this goal, is imperative for organisations to understand their consumers, an objective that can be fulfilled by analysing external sources of data, that often are not directly available to the organisation. Enhanced process of production, also known as smart manufacturing, are referenced as a merger of operation and information technology which work together within an integrated process, and largely benefits from consumer knowledge inputs.

The focus on the consumer by organisations is justified by the desire to increase their satisfaction, while seeking their opinion and feedback. The index of satisfaction of consumers can be represented in three categories [10]:

- Perceived value;
- Consumer satisfaction;
- Consumer loyalty.

The following four variables are related to the previous described categories:

- Image;
- Expectations;
- Perceived quality of 'hard-ware';
- Perceived quality of 'human-ware'.

Additionally, the consumers opinion is a very important measurement, and can be directly responsible of numerous products and/or services changes. As result, organisations can use the opinion produced by their consumers, to perform a deep analysis about the strengths and weaknesses of their products and/or the services, allowing to improve them with a high certainty value that the changes will be accept by a large majority of their target audience. Another possibility is the analysis of opinion related to new products and services that the consumers would like to see in the future, leading to a challenging task called prediction [11], that allows the organisation to be active on the market (instead of reacting to its changes) and, in the best possible scenario, define it.

3. Industrial Smart Environment

With the advancements and implementations of I4.0, is interesting to look at the Industry as a Smart Environment (SmE). By definition, a SmE is an ecosystem of interacting objects that has been enriched with technology (sensors, processors, actuators, information terminals, and other devices interconnected through a network) that have the capability to: self-organise; provide services and manipulate complex data; enhancing the global behaviour of a system by providing high level functionality; which results on an added value to the typical services expected in a specific environment. This physical space is smart in nature, and that smartness results from a interaction of different devices and computing systems, aiming to enhance the services that can provide to humans.

Manufacturers, belonging to different kind of industries, have established between them a business process collaboration, that typically operates on a supply chain, to introduce major benefits into their business activities, as well to be able to respond to a ever more demanding consumer. With the introduction of I4.0, industries need to be able to provide a faster response to tailor made, and highly personalised consumer needs. This necessity will create a bigger demand in the supply chain and will constitute the need for better communications to integrate suppliers and consumers [3].

Smart Manufacturing envisions the enterprise that integrates the knowledge gathered from their consumers, partners, and the general public. Responding with a coordinated, performance-oriented enterprise, minimising energy and material usage while maximizing economic competitiveness, and environmental sustainability [12]. Manufacturing process transformations are facilitated by the application of manufacturing intelligence in a cycle that is sufficiently accelerated to: produce a new demand-dynamic performance orientation using advanced data analytic; modelling and simulation to produce a fundamental transformation to transition/new product-based economics; flexible factories; and demand-driven supply chain service enterprises.

3.1. The Decision-Making Process in Industry

The decision-making process is omnipresent on every aspect of a daily life routine [13]. Decisions are based on the will to fulfil previous setted goals, mainly displayed because of their attachment to an individual or a group, and is a process that can be divided into sub-decisions and tasks [14, 15]. The evaluation process is a hard task to carry out, and the effectiveness of a decision is an uncertainty since the decision-making process can be influenced by the variables used [13]. Overall, this process is an arduous and complex task due to the need of taking into account every single factor, with different importance to the final decision. This can be established by assuming a set o variables, like category of decision, previous acquainted knowledge, expectations of specific situations and personal preferences [15].

Similarly to the daily situations where we face the need to perform some decision making processes, manufacturers also face this necessity. The concept of I4.0 creates an approximation between the digital and physical environments present on an industry context, creating a synchronisation between them, and defining the conditions that can enable the increase in their quality, which can be directly correlated with the product quality [16].

In industry, the process of decision making and their consequences will be different, due to the inclusion of data from multiple sources, like the production equipment and consumer-management systems, and will allow to make better decisions with access to more quantity and quality of information [17]. The decisions could be made in diverse contexts like strategic, tactical, operational and real-time, that will be related to multiple phases of the production process and even business decisions [16], improving the quality of them. The industrial processes will be better, their flexibility and efficacy will increase, the products made will be customised, a reduction of costs in the products will happen, and the processes will be optimised [18, 19]. In a similar way, manufacturers face constant decisions regarding the materials that are used on the manufacturing process of their products and, by association, the suppliers and/or partners that supply those materials.

4. Using Feedback to Enhance Product Development

Under I4.0, there has been an astounding growth in the advancement and adoption of information technology that has increasingly influenced consumers perception on product innovation, quality, variety and speed of delivery. With an increase focus on consumer opinion and feedback, organisations look to increase the index satisfaction of their consumers (perceived value, consumer satisfaction, and consumer loyalty), while analysing the strengths and weaknesses of their products.

With indexes variables like image, expectations, and perceived quality of the product they are receiving, consumers have their expected quality values that organisations try to correspond to. More specifically, is possible to assert that the overall quality of a product can be directly related to the materials that were used to produce it. Therefore, there is a strong correlation with the suppliers which can lead to a difficult decision-making process, especially when considering other factors beside quality (like material price, warranty period, on time delivery, reliability, transportation cost, or others).

How can organisations improve their decision-making regarding the manufacturing process? How can organisations gather information about the quality of their products after they are delivered to their consumers? And in which way that information can influence the supplier of a specific material? In our vision, the strong presence of online social platforms on the daily activities of most people, generates data that can help the resolution of those questions. Even more, we believe that those platforms can act as a constant source of feedback that relies upon the freedom of speech, and approximation to the true opinion of consumers.

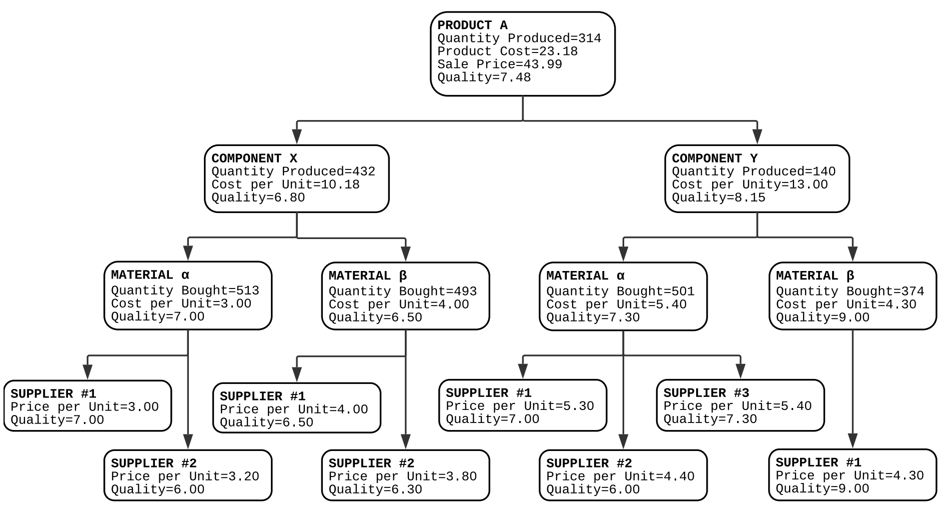

Figure 1. Product manufacturing components, with representation of data that can be used as criteria in decision-making processes (Important note: the data is not real, and is only used for demonstration purposes)

This vision is better comprehended when contextualised into a scenario. Therefore, let us consider the following: An organisation that develops a Product A, and has a social presence among their consumers (either by being active on a online social network platform, or by their own forms of direct interaction, like online support services). In this scenario, for simplification, we are only considering the manufacturing process of a single product, trough the combination of two different components (X and Y). The visual description of this scenario is present on Figure 1, which in addiction to the definition of the components of Product A, also contains de definition of their materials (illustrated by α and β) and respective suppliers. It is important to notice that all the data represented on this figure is not real, and was only defined for demonstration purposes.

With an online social presence from organisations, the scenarios where they advertise their products are common. These online platforms are also heavily used by consumers (not restrictedly for interacting with a specific organisation, but for general personal usage), and are full of data that often contains information or opinions regarding them, products, or even organisations. With this flow of data is perceptible for us humans to understand the information that it represents, however, it can be hard to manage when talking about large volumes. Therefore, the usage of machine learning techniques and natural language processing, permits the assignment of this task to a computational entity, or even the adoption of a virtual intelligent sensor [20].

Even when talking about the manufacturing process of only one product, this represents a multiple-criteria decision-making problem for the organisation. One common scenario is the choice of supplier for each material, taking into account different criteria like Quality or Price per Unit. Supposing that the criteria Quality has a higher preference value over Price per Unit, Figure 1 represents a possible definition of suppliers based on those preferences. Either types of criteria values are known for the organisation, by their knowledge regarding the suppliers (which defines the value for Price per Unit), or by a perceived criteria value (as seen in Quality).

Based on this scenario, the definition of an intelligent component that contains knowledge about the internal aspects of the manufacturing process (like perceived quality of materials, components composition, or suppliers list), and is able to collect and understand feedback trough external sources, can be vital for the quality improvement of a product, acting at the same time as a constant feedback source after introducing their product to the market. This feedback gathering aspect, is an addiction to the traditional internal means, and can work to every aspect of an organisation (which includes public image, product delivery process, customer service, among others).

Following the scenario of the manufacturing process of Product A. Organisations can control the quality of their processes while the product is being manufactured, however, is difficult for them to evaluate the perceived quality of their products after being used by their consumers, or even to get a feedback on their quality perception. With a tendency for people to express their opinions on a freely and open way on online social platforms, with the help of machine learning techniques and natural language process, is possible to collect and classify their opinion (sentiment/opinion analysis). More specifically, the intelligent component should be able to identify what are the reasons behind negative opinions, and even consider global opinion towards a specific organisation.

If, theoretically, there is a high amount of negative opinions correlated to Product A, natural language processing techniques can help identify if the negative opinion is towards the whole product or just for a defective component. For example, a vast quantity of negative opinions that identify Component Y as being defective or to not show the desired quality, this information generated from the intelligent component, can aid organisations with their decision making process. In this scenario, correlating the internal information regarding the manufacturing process of Product A, with the help of the external sources of feedback that identified Component Y as being defective or with low quality, organisations can identify which material is causing this situations. If Material α is identified as the source for consumers dissatisfaction, the organisation can adjust their perceived Quality value for that material, based on the feedback obtained from their consumers. Therefore, taking into account the criteria preference in the multiple-criteria decision-making process, the decrease value in perceived Quality of Material α can result in a change of supplier from Supplier #3 to Supplier #1, since the latter has a lower Price per Unit value. On a similar way, the positive opinions related to a product, or a specific component, should positively improve the perceived quality value and reinforce the relationship between the organisation and that supplier/partner.

The intelligent component can act as a advisor that provides suggestions, or should be able to take control and manage the decision-making process, by combining the internal factors of the organisation with external gathered ones. It is important to note that this change of suppliers should not be immediate. The intelligent component should be able to determine a sample number of information that can actively influence the decision-making process. By allowing organisations to be proactive in the market and addressing these situations on a shorter time, their consumers are established as a central and important factor on their manufacturing process, while being able to continuously gather information about their products after they are delivered to their consumers.

The vertical integration of I4.0 means implementing a smart factory that is highly flexible and reconfigurable. By including the opinion of their consumers, the intelligent component is directly correlated with Analytics and Data Management, by fulfilling the necessity of process the stored data (internal or gathered externally) in a way that could be part of the decision-making processes of the organization. Finally, the intelligent component could improve the operational efficiency of the company, with a direct impact on the manufacturing process, and contribute to an increase of the quality of their products while directly answering the index satisfaction of their consumers.

5. Conclusion

With developments on the implementation of Industry 4.0 (I4.0), organisations are shifting their focus towards their consumers, by seeking to know their preferences and interests, while determining their index of satisfaction. The focus on the consumer demands that new types of data need to be gathered, and that data could not be directly available to organisations. With the strong impact of online social platforms on the daily routine of most people, even organisations adopted those platforms as a mean of communication and relationship with their consumers. This social presence often contains data that can help organisations to address the needs of their consumers, or even improve the quality of their products, which results on a image reinforcement on the market. These platforms can act as a constant source of feedback that contains external data that is not available to organisations otherwise.

By looking to organisations as a smart environment, is possible to enhance the global behaviour of a system in order to provide a high level functionality. The association with smart manufacturing means that, even more than the past, consumers take a decisive role on the manufacturing processes. Therefore, the data present on online platforms can influence the those processes, and act as a 'window' to the external world that can help organisations to understand the demands of their consumers.

In our vision, organisations can address their consumers needs, while improving the quality of their products, by using these external sources of data, as a complement to the internal knowledge that regarding their manufacturing processes. The implementation of an intelligent component that can generate knowledge from the data present on online platforms (by the usage of machine learning and natural language processing techniques), can act as a bridge that connects two different of knowledge. The theoretical scenario of application present on this work, allowed to understand the impact of consumer opinion on the definition of a new material supplier, by adjusting the perceived quality value of a component, that directly impacted the decision-making process. In addiction to the improvement of their products, the inclusion of this intelligent component allows organisations to have a source of feedback from their consumers, after a product is delivered to them. This can lead to future improvements (or new versions based on desires), reinforcement of relationships with suppliers (when consumers positively influence the perceived quality values), and being proactive on the market, at same time as they improve the relationship with their consumers.

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Engineering Intelligent Environments: Preliminary Findings of a Systematic Review

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Abstract. Intelligent environments are complex systems that may require a diverse set of hardware devices, software libraries, networking and human computer interactions. New tools and techniques that can facilitate the engineering of such systems are thus critical. However, given the size and heterogeneity of the literature and in the light of, to our knowledge, there being only informal surveys restricted to specific issues have been conducted, we have seen the need to organise and synthesise the existent research corpus to obtain a clear idea on the main approaches that have been utilised for the development of IEs. To address this research gap, this systematic literature review was carried out. This paper presents the review's preliminary findings that are expected to provide avenues for further research in this area. We find that there are different approaches for developing IEs and the development cycle consists of several phases. However, not all phases have received equal consideration. An evaluation framework which could offer guidance on the choice of the most suitable techniques per phase should also be the target of research efforts.

Keywords. Intelligent Environments, engineering, systems development lifecycle

1. Introduction

An Intelligent Environment (IE) consists of a range of embedded devices, sensors, network architectures and middleware, intelligent algorithms, and diverse human computer interactions amongst others [4]. The underlying theories for IEs are from pervasive/ubiquitous computing, smart environments and ambient intelligence. An IE builds on concepts from these key areas by integrating smart environments with ambient intelligence and is based on the pervasive/ubiquitous availability of services. In simpler terms, this is how an intelligent environment is able to acquire and apply knowledge about its occupants and their surroundings in order to improve their experience by providing better comfort, security, efficiency and productivity. The engineering of IEs is therefore a complex undertaking since it involves a wide range of multidisciplinary areas. This, in tum, is driving the need for new tools and techniques that can facilitate the design, implementation and management of such advanced systems.

However, research in this field has been technology driven to a large extent [13]. A lot of focus has also been placed on the development of applications for IEs rather than

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on the engineering of such complex systems [35]. In the context of IEs, where quality, reliability, and safety of users are some of the key requirements, use of suitable techniques is thus essential [4]. Therefore, it is imperative to study the various processes and techniques involved in effectively conceptualising, designing and implementing Intelligent Environments. There is the need to organise and synthesise the existent research corpus to obtain a clear idea on the main approaches that have been utilized for the development of IEs, what issues they addressed and what open issues still need to be tackled. To address the research gap, this systematic literature review seeks to identify, synthesize, and present the findings reported about engineering of Intelligent Environments to date.

This paper consists of the following sections. In section 2, we explain the systematic review process. Section 3 discusses the results of the review with a brief discussion of the researchable issues on this topic. Section 4 concludes the paper.

2. Systematic review process

According to [25], "*A systematic review is a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest*." The review process consists of several activities such as the development of review protocol, the identification and selection of primary studies, the data extraction and synthesis, and reporting the results. We followed all these steps for the reported study as described in the following sections of this paper.

2.1. Definition of research questions

With the objective of developing an understanding of the state of research regarding engineering of IEs, this study has been driven by the following research questions:

RQ1: How are IEs engineered from a systems development perspective?
RQ2: What are the stages of IE development process that have been mainly considered?
RQ3: What are the techniques which are mainly adopted during each stage of the development lifecycle for IEs?
RQ4: What are the open issues to be further investigated with respect to development of IEs?

2.2. Data sources and search strategies

The search process was performed using automatic and manual search of specific conference proceedings and journal papers since 2000. We only selected papers that are written in English and available online. The search strategy included electronic databases and manual searches of conference proceedings. The following electronic databases were used.

- IEEEXplore (www.ieeexplore.ieee.org/Xplore/)
- Scopus, Elsevier Science Direct (https://www.elsevier.com/solutions/scopus /)
- ACM Digital library (https://dl.acm.org/)
- Google Scholar (http://scholar.google.com/)

- SpringerLink (www.springerlink.com)
- Web of Science (https://webofknowledge.com/)

We also searched the following conference proceedings:

- International Conference on Intelligent Environments
- International Conference on Ambient Assisted Living Technologies
- International Conference on Pervasive Computing and Communications
- International Conference on Cyber-Physical Systems

Different kinds of papers were considered for this study: industry experience reports, theoretical, empirical and experimental academic papers. The review process proceeded in four stages. In stage 1, the electronic databases were searched using every possible combination of search items listed in Table 1. The Boolean "AND" operator was used to combine the search items from Category 1 and 2. This resulted in a total of 4210 publications.

Table 1. Search terms used in the review process

Type	Category	Keywords
1	Primary term	Intelligent Environment, ambient assisted living, smart environment, pervasive system, cyber- physical system
2	Secondary term	Engineering, development, development methodologies, development lifecycle

2.3. Screening papers

The titles of the articles were carefully examined in the second stage. Any title which was clearly outside the scope of the review was removed from any further consideration. Articles that address editorials, prefaces, discussion comments, news, summary of tutorials, workshops, panels and poster sessions were also excluded. During the third stage, each abstract of the remaining 608 articles from the previous stage was investigated by the researcher. At the end of stage 3, 217 papers were left for stage 4 of the selection process.

Finally during the last screening, the whole paper was read to determine its relevancy. The following inclusion (I) and exclusion (E) criteria were applied:

I1: The paper should have some focus on the engineering of IEs; individual phase or lifecycle.
I2: Does the paper discuss application of a systems development methodology or approach for IEs?
E1: Posters, panels, abstracts, presentations and article summaries
E2: Publishing source not relevant

70 papers out of the 217 articles were selected by carrying out the quality assessment based on these four screening criteria. In order to extract significant data from the list of articles obtained, a data extraction form was created using Microsoft

Excel, as shown in Table 2. The design of this form was motivated by [25]. The items bibliographic references, approach identifier and approach aims allowed us to answer RQ1. Items phase in development cycle informed us about RQ2. Items phase in development cycle, technique identifier and technique aims were aimed towards answering RQ3. Finally, to answer RQ4, each paper was carefully scrutinised to gather about limitations and future work as highlighted by its author(s).

Table 2. Data extraction form

General Concern	Specific data
Study	Paper identifier Date of data extraction Bibliographic reference: Author, year, title, source Type of article
Approach	Approach identifier Approach aims Phase in development cycle Technique identifier Technique aims Limitations Future work

3. Results and discussion

3.1. Overview of studies

In the following section, we present the main findings of our study. To begin with, we synthesized the data by identifying themes emanating from the findings reported in each of the reports reviewed in this study. Figure 1 shows the publication frequency of the selected papers from 2000 until 2017. The majority of the studies are from conference proceedings (54%) from 31 different conferences. Journals had 45% of the studies from 18 different journals. Whilst the last couple of years may have seen a statistical decrease in papers, over the decade there has been an 'increasing trend.' This could indicate an interest among researchers to consider applying some methodology for development of IEs.

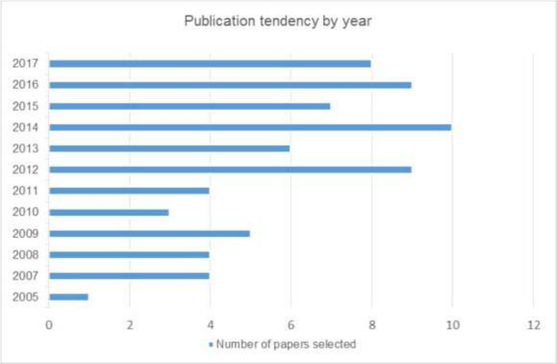

Figure 1: Publication tendency by year

3.2. How are IEs engineered from a systems development perspective (RQ1)?

As shown in Figure 2, a total of 15 distinct approaches were identified for engineering IEs. However, we also noted adoption of mixed approaches in certain projects. Overall, the user driven approach [1; 6; 9; 10; 14; 15; 17; 19; 23; 32; 34; 41] appeared more frequently than the rest.

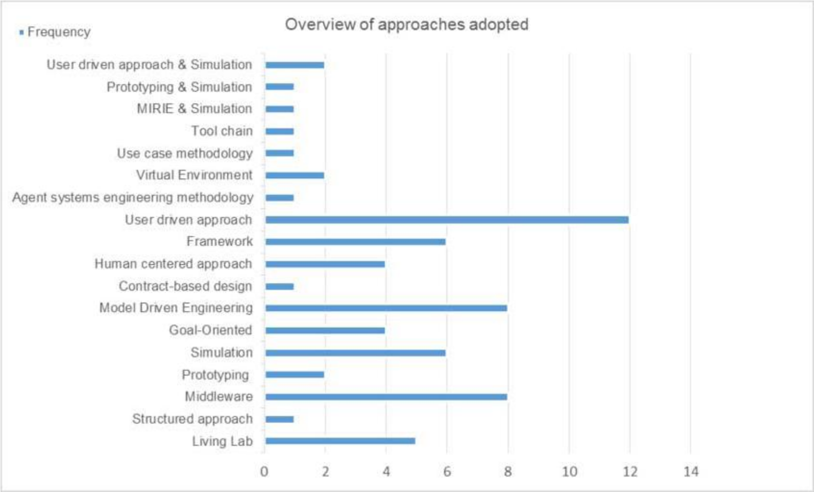

Figure 2: Approaches for development of IEs

3.3. What are the stages of IE development process that have been mainly considered (RQ2)?

According to the study findings in Figure 3, requirements engineering as well as analysis and design phases occupy the major share of attention compared to the other three phases. However, the maintenance stage seems to have been largely overlooked. Only one project [37] briefly mentioned about maintenance phase without offering any mechanism or guidelines on change management for IEs.

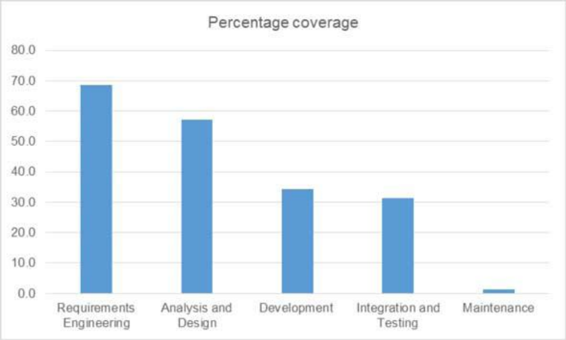

Figure 3: Systems development phase discussed in the papers

3.4. What are the techniques which are mainly adopted during each stage of the development lifecycle for IEs (RQ3)?

Requirements engineering is a key process in systems development methodologies as it defines what a customer or user expects from a new or modified product [40]. A closer scrutiny of the selected papers has uncovered a multitude of techniques for gathering requirements, as shown in Figure 4. However, two of the most prominent approaches are the use of focus groups [6; 10; 15; 16; 18; 19; 21; 22; 31; 34] and scenarios [1; 2; 5; 30; 33; 36; 37; 38; 42; 43].

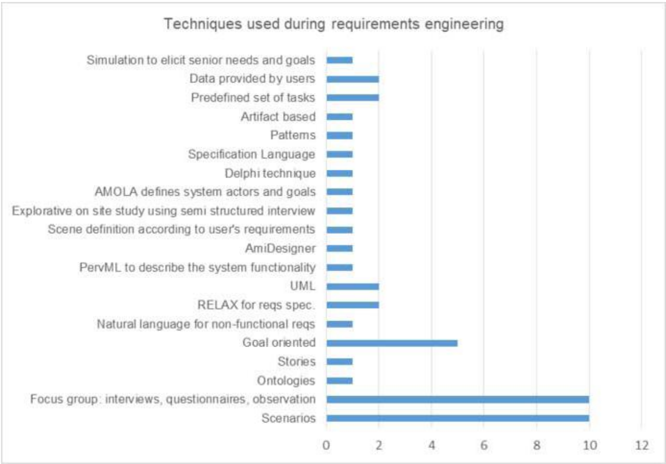

Figure 4: Techniques used during requirements phase

The list of Systems Analysis and Design (SAD) techniques identified in the reports is presented in Figure 5. We gathered that model based techniques were more often utilized during this phase. Some examples are [2; 5; 11; 12; 26; 27; 32; 37; 38; 44].

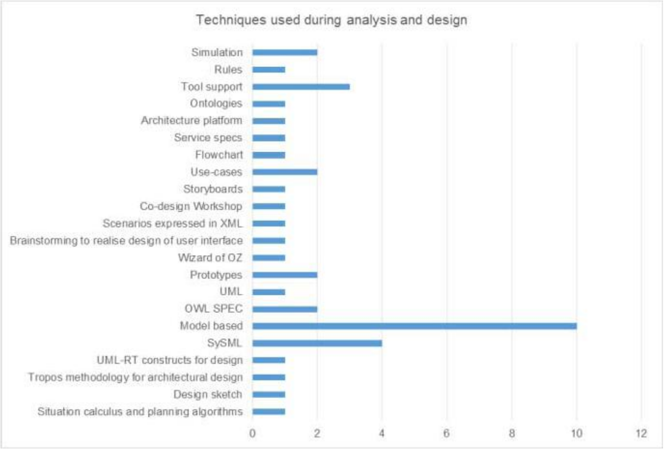

Figure 5: Techniques used during analysis and design phase

As far as the development of IEs is concerned, we found a number of techniques as shown in Figure 6. Although tool support [3; 8; 28; 29; 30; 43] appeared more frequently, it is closely followed by techniques such as prototyping, simulations and middleware.

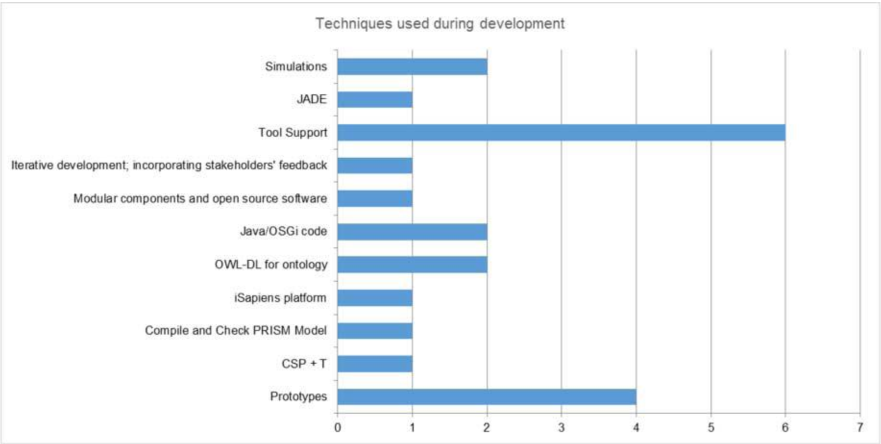

Figure 6: Techniques used during development phase

Figure 7 represents the list of techniques during integration and testing phase. Conventional techniques such as unit and integration testing [6; 12; 34] were quite popular. However, simulations [28; 37; 38] are also gaining in popularity. They enable regulation of the environment, which appears to be relatively difficult in real situations. They also offer the possibility of evaluating user interactions and algorithmic behavior in a safer test environment before actual deployment to the real world [37].

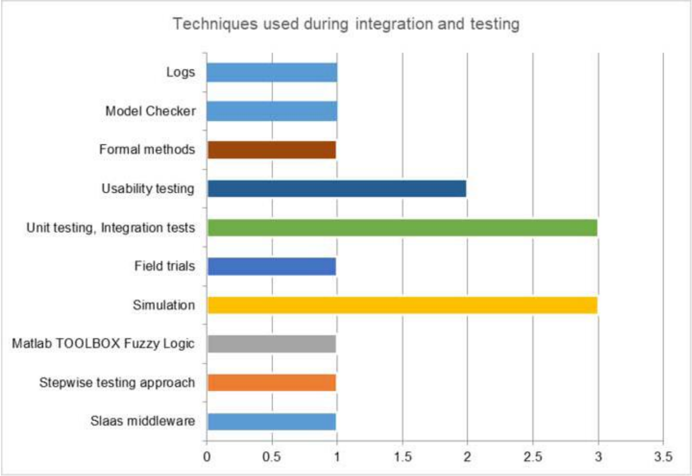

Figure 7: Techniques used during integration and testing phase

3.5. What are the open issues to be further investigated with respect to development of IEs (RQ4)?

For sake of brevity, we are only presenting the main themes which we have uncovered from the study findings. The following papers [1; 10; 11; 24; 26; 27; 31] have emphasized on the need for more real-world applications of IEs for more realistic evaluation of IEs. Some authors have identified addressing usability issues and improving tools which would allow end-users to develop their own IEs [18; 37; 43] as priority. Consolidated efforts aiming to bridge the communication gaps between end-users and designers of IEs were highlighted in the following papers [28; 33; 36; 43].

3.6. Discussion

The review has provided further insights into the techniques which are used by researchers during each phase of the development cycle. However, the limitations of the approaches are still open for further investigation. We note that, for the most part, the IEs were developed in an ad hoc manner. Maintenance appears to be one of the least considered phase. There are no perfect systems and bug fixes or upgrades will always form part of a system life cycle [39; 40]. The review also raises the questions why there is no consensus upon techniques used during a project's phase and there is not yet a standard systems development methodology for IEs. Current research effort is looking towards developing an evaluation framework [20] which could offer guidance on the choice of the most suitable techniques for engineering of IEs.

4. Conclusion

The main motivation for this study was to carry out a systematic literature review on how Intelligent Environments are engineered. We largely followed the guidelines by [26]. The initial search resulted in 4210 papers, out of which 70 were selected for extraction. This report provides preliminary findings of our study.

In terms of an overall methodology, a user driven approach was found to be quite prominent. However, not all phases in the development cycle have received equal consideration. Focus groups seem to be the most accepted method for gathering requirements followed by scenarios. For analysis and design, model based approaches are quite popular. Tool support and prototyping are mostly used during development. Unit and integration tests along with simulations are more frequent during integration and testing. However, the results show that maintenance phase has been largely overlooked.

It is also quite evident from these initial findings that there is no consensus upon techniques used during a project's life-cycle and there is not yet a standard systems development methodology for IEs. Development of an evaluation framework which could offer guidance on the choice of the most suitable techniques for engineering of IEs is in the pipeline.

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A Low-Cost Multi-Modal Sensor Network for the Monitoring of Honeybee Colonies/Hives

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Abstract. Honeybees, which play an essential role as pollinators, have suffered a significant decline in recent years. Different types of sensors, including acoustic, chemical, vision, mass and temperature, can provide important information to assess their well-being. However, a multi-modal sensor system would need to be economical and affordable in order to be used on a large scale, including by less wealthy farmers or beekeepers. We present details of a low-cost sensor network system to allow the continuous monitoring of honeybee hives in a non-invasive manner, discussing its advantages relative to other existing systems for the same purpose, and initial results from the deployment of such a system in four hives.

Keywords. honeybees; beehives; monitoring; multi-modal sensor network; signal processing

1. Introduction

The honeybee (Apis mellifera) is of very great importance both to the human race and ecology in general, primarily due to its major role as a pollinator of crops and many other flowering plants. However, over recent years, honeybees have been suffering a near catastrophic decline in numbers, including the complete collapse of many colonies. This is due to a variety of factors, including parasites and diseases (e.g. the varroa mite and European and American foulbrood), the use of pesticides such as neonicotinoids, and large scale single crop "monoculture" agriculture, which can restrict bees' sources of food and pollen. Moreover, conventional beekeeping, which has optimising honey yields for sale and human consumption as its principal aim, includes many practices which may not actually be in the best interests of the honeybees. Various aspects of bees' natural behaviour, including breeding and swarming, tend to be suppressed or rigidly controlled, and these factors probably contribute to decline in genetic diversity amongst honeybee populations, making them less resistant to diseases, pesticides and the negative effects of parasites [1]. Furthermore, whilst occasional inspection of hives by beekeepers is essential to check for parasites and diseases, over-frequent inspection is disruptive to the bees, tends to weaken the bees' natural protective materials (notably propolis, used to seal the hive to protect it from outside threats), diverts colony resources to their repair, and can actually increase the transmission of diseases and parasites between colonies via the beekeepers' clothing, etc.

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Although several systems have been developed for the non-invasive monitoring of beehives, most of these are relatively expensive and likely to be beyond the means of most farmers and beekeepers. In this paper, we present details of a low-cost sensor network system, using inexpensive sensors and Raspberry Pi microcomputers, to enable the continuous monitoring of hives whilst allowing the bees to lead their lives with as little disruption as possible.

2. Related Previous Work

2.1. Honeybee Ecology

Much work has been carried out on the biology and ecology of honeybees. Notable amongst this is the work of Seeley (e.g. [2, 3]) who studied the habits and preferences of honeybees over many years. Seeley proposed some principles, backed-up by empirical evidence, regarding what features would make a hive "bee friendly". In a previous paper [4], we described the design and construction of such hives, following Seeley's guidelines, although at that point we had not been able to equip our hives with bespoke sensor networks.

2.2. Monitoring of Honeybee Colonies

There have been several previous attempts to monitor honeybee colonies automatically. However, the majority of such studies have used a single modality to perform this monitoring. Ferrari et al [5], Bencsik et al [6], Howard et al [7] and Qandour et al [8] used acoustic analysis of the sounds made by the bees to infer what was happening within the hive. In [5], the aim was to predict swarming events, whereas in [7] it was to discern whether or not the hive contained a healthy queen, whilst in [8] it was to detect infestations of parasites. Other authors made use of other modalities. Veeraraghavan et al [9], Campbell et al [10] and Salas & Vera [11] used computer vision approaches to monitor bees. Kridi et al [12] and Zacepins et al [13] monitored the temperature within hives, again with the aim of predicting swarms. One of very few previous genuinely multimodal studies is that of Gil-Lebrero et al [14], which employed temperature and humidity sensors, and a weighing scale and monitored 20 hives in Cordoba, Spain over 32 days in the Summer of 2016.

3. Hive Design, Construction and Deployment

As described in our previous paper [4], we have adopted the same philosophy as Neumann & Blacquière [1] – namely allowing the bees to live as naturally as feasible – and the guidelines of Seeley [2, 3] for hive size, design, location and orientation, subject to a constraint of making the hives accessible for maintenance. (Seeley's recommendation for hives to be 5m off the ground is not practical from this perspective.)

Our hives [4] are all of capacity 40 dm^3 with an entrance hole South facing, of area 12.5 cm^2 at the bottom of the hive, and approximately 1.5 m off the ground. With the exception of the latter, all these attributes follow Seeley's recommendations. Details of the hive design and how its constituent parts can be cut and assembled from a template on plywood (or other material with suitable weather-resistant properties) can be found in [4]. Because our new design hives do not allow for honey extraction, we call them “pollenbee” hives, whilst we call the conventional hives “honeybee” hives, see Fig. 1 and Table 1. We had previously deployed 12 pollenbee hives, without sensors, around the South of England. In the current phase of the project, we have equipped two pollenbee hives and two conventional honeybee hives with sensors, all situated close together at an apiary at Kingston University in the South-West suburbs of London.

Figure 1. Left Hand Side image : the hives in the Kingston University apiary. Viewed from the west, the hive entrances face south. From front right to back left: PB01, power “hutch”, HB01, HB02 and PB02. The distance from the nearest hive to the furthest is of the order of 30 metres, with the first 3 being within about 15 metres. You can just make out the green camera module on PB01 on the far right of the LHS picture. This camera views the hive entrance, as shown in the Right Hand Side image.

Hive	Hive type	Hive name	Short name
1	Pollenbee	Pollenbee 1	PB01
2	Honeybee	Honeybee 1	HB01
3	Honeybee	Honeybee 2	HB02
4	Pollenbee	Pollenbee 2	PB02

Table 1. Details of the types of our hives and their labelling.

4. Sensor System Design and Implementation

All four of our hives are equipped with commercial sensor systems produced by Arnia Ltd [15]. They are also equipped with a bespoke sensor system of our own design, that specifically allows us to collect raw acoustic data from the hive and video recordings of the hive entrance which the Arnia system cannot provide, as well as weight data on all four hives, which would be prohibitively expensive in the Arnia solution. In this respect, our bespoke sensor system was also designed to provide comprehensive multi-modal monitoring of the bee colonies in the hives at a low cost. Our system’s network topology uses a single Raspberry Pi 3 [16] as a WiFi hotspot, to which the other nodes connect using the Raspberry Pi’s onboard WiFi (see Fig. 2). We are also shadowing some Arnia sensors, such as hive temperature and humidity, and have added a few more sensor types such as hive gas concentrations and light levels.

4.1 Sensors Used, Sampling Rates and Data Rates

The sensors used in our bespoke network are specified in Table 2 and their respective sampling frequencies given in Table 3. The volume of data produced each day is quite small, (about 200kB per hive day) with the exception of the sound level data and the hive entrance video, which respectively generate about 6GB and 850MB per hive per day.

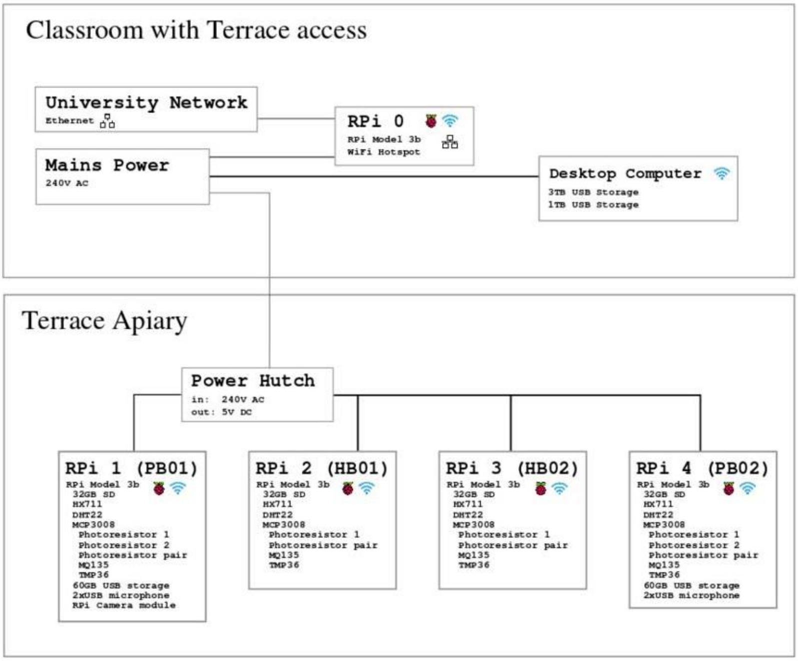

Figure 2. Schematic representation of our sensor network, power supply, etc. The code in parentheses after the number indexing each Raspberry Pi indicates which hive that Pi is deployed in, and the sensors in that hive are then listed below (see also Table 2). The various "slave" Pi computers are connected to the "master" Pi (RPi 0) via the Pi's onboard WiFi, and thence to the University network via the master Pi's Ethernet port. The power is provided from a 240V 50Hz AC mains, converted to 5V DC by a transformer/rectifier in the "Power Hutch".

Each Raspberry Pi is fitted with a 32GB SD card which hosts the Raspbian operating system (a version of Debian Linux) and works as a local hard drive. The low volume data is easily stored on these. The issue of the high volume data generated by the microphones (RPi1 and RPi 4) and camera module (RPi 1) was resolved by adding a 60GB USB hard disk to the Raspberry Pi (RPi). These still need to be backed-up every 3 to 4 days, and that backup cannot be done over the RPi WiFi network because its bandwidth is too small. Although having to back up the data manually, by removing the 60GB hard disks from the hives and manually moving the data to the 3TB drive on the desktop computer, is time consuming and inconvenient, a potentially beneficial side-effect is the fact that the hives then get regularly inspected the hives for a visual confirmation of their progress and well-being. Figure 3 shows one of the hives equipped with the monitoring equipment.

4.2 Power and Data Storage Requirements

The power requirements for each "smart hive" are non-negligible, and initial attempts to power each using a rechargeable battery and/or solar cell proved to be inadequate. A solution was eventually reached, powering the sensor systems and each Raspberry Pi from the AC mains, via a transformer and rectifier in the "Power Hutch". This required both mains power and weatherproof cabling and would not be suitable for deployment of the smart hives in remote locations. Alternative solutions for such situations and optimal sampling rates to reduce the data storage requirements (see Table 3) are being investigated.

Hive Name	**PB01**	**HB01**	**HB02**	**PB02**
Arnia Hive monitoring equipment (The Arnia Gateway measures global temperature in direct sunlight and rainfall)				
Hive internal temperature	yes	yes	yes	yes
Hive internal humidity	yes	yes	yes	yes
Sound level at hive entrance	yes	yes	yes	yes
Weight (mass) sensor	-	yes	-	-
KU bespoke sensor network with Raspberry Pi				
HX711, 4x50kg strain gauges, weight	yes	yes	yes	yes
DHT22, temperature and humidity	yes	yes	yes	yes
MCP3008 ADC	yes	yes	yes	yes
Photoresistor, exterior light level	yes	-	-	yes
Photoresistor, interior light level	yes	yes	yes	yes
Photoresistor pair, exterior light level	yes	yes	yes	yes
MQ135, interior gas sensor	yes	yes	yes	yes
TMP36, interior temperature	yes	yes	yes	yes
Hyundai 60GB USB drive	yes	-	-	yes
RPi camera, hive entrance video	yes	-	-	-
USB microphone, interior sound level	x2	-	-	x2

Table 2. Equipment and Sensors used with the two systems on the four hives.

Sensors used in bespoke KU network with RPi	**Sampling Frequency and size of daily generated data file.**
HX711 with 4x50kg gauges, Weight	Every minute (19 kBytes/day)
DHT22, temperature and humidity	Every minute (45 kBytes/day)
MCP3008 ADC	
- Photoresistor, exterior light level	Every minute (23 kBytes/day)
- Photoresistor, interior light level	Every minute (23 kBytes/day)
- Photoresistor pair, exterior light level	Every minute (23 kBytes/day)
- MQ135, gas sensor	Every minute (23 kBytes/day)
- TMP36, interior temperature	every minute (35 kBytes/day)
RPi camera, hive entrance video	12 seconds of 640x480 pixel MP4 video every minute, while exterior light level is above threshold (850 MBytes/day)
USB microphone, interior acoustics	12 minutes of 44100Hz recording every 20 minutes, recorded 24 hours per day (6 GBytes/day)

Table 3. The various sensors and their sampling rates and daily data volumes.

(a) (b) (c)

Figure 3. (a) Top view of the inside of a "pollenbee" hive with sensors (including an Arnia mass scale) fitted, (b) a side view of the same hive, showing one sensor on the outside of the wire grille which is almost encrusted with propolis and wax, (c) another side view, showing the wax combs and some bees.

5. Data Processing, Analysis and Visualisation

Although we have acquired data through our bespoke system from the hives for several months since March 2017, work on processing, visualising and analysing the data is still at a relatively early stage, and is the focus of the next phase of the project. We are exploring the use of time series, periodicity (e.g. auto- and cross-correlation) and frequency domain (e.g. FFT, Mel Cepstrum) analyses, plus more sophisticated pattern recognition techniques such as decision trees and artificial neural networks, to exploit and explore this data to the full. In contrast, the Arnia system is fully functional and provides a highly detailed web portal that reports the data with features for specifying time periodicity within and cross correlation between data channels.

Some examples of visualisations of our data, as time series, are presented in Figures 4, 5, 6 and 8 . It is clear from these that some signals (e.g., mass and temperature) exhibit fairly smooth variations over time, whereas others, such as relative humidity, are much noisier and may require smoothing before further processing.

6. Results and Discussion

Results obtained from a selection of the calibrated bespoke sensors in one hive over the period 10 – 15 June 2017 are shown in Figures 4-6. This hive is particularly noteworthy over this period since a swarm emerged from it around 9am on 13th June 2017, initially settling in a nearby apple tree before moving on that afternoon (See Figures 5 and 7).
The near periodic daily variation of hive temperature and humidity are not surprising since, during a Summer day, the external temperature will rise from sunrise (around 4:45am in London in mid-June) until late afternoon (perhaps around 17:00), then gradually fall through the evening and overnight. Furthermore, relative humidity will fall as the temperature rises if the absolute humidity is kept constant [17], and hence relative humidity will tend to be low when the temperature is high (and vice versa) even if the absolute humidity remains unchanged. Some authors (e.g. [5, 12, 13]) have reported that the hive temperature will tend to rise in the period immediately prior to a swarm. However, although there is some evidence of this in our data, it is difficult to identify it with certainty, since the daily temperature variation alone would suggest we should expect a substantial temperature rise over the morning subsequent to sunrise.

The hive mass, on the other hand, does show a clear indication of a sudden decrease in mass exactly coinciding with the time of the swarm (see Figure 6). During an ordinary day, the mass of the hive tends to drop a little, by around 500 to 600g, as bees leave the hive during the morning to forage. As they return later in the day, laden with pollen and nectar, the mass of the hive will tend to increase again, and by late evening the mass will tend to be around 300g greater than it was at dawn. However, between 08:40 and 09:30 on 13th June, the mass of HB01 dropped by 1900g, and although almost 700 g were recovered later that day, it was not until around 17:15 on 15 June that the mass returned to its pre-swarm level.

The contrast in the daily mass variation between ordinary (Figure 8), swarm (Figure 5) and hive inspection (Figure 6) days is clear. The regular pattern is for the hive mass to fall by around 0.5 kg as bees leave the hive in the morning, then to rise again in the late afternoon and evening as bees return to the hive laden with pollen and nectar. The mass tends to remain relatively stable overnight, before the pattern gets repeated the following day. For reference, in London sunrise is around 04:45 and sunset around 21:15 in mid June.

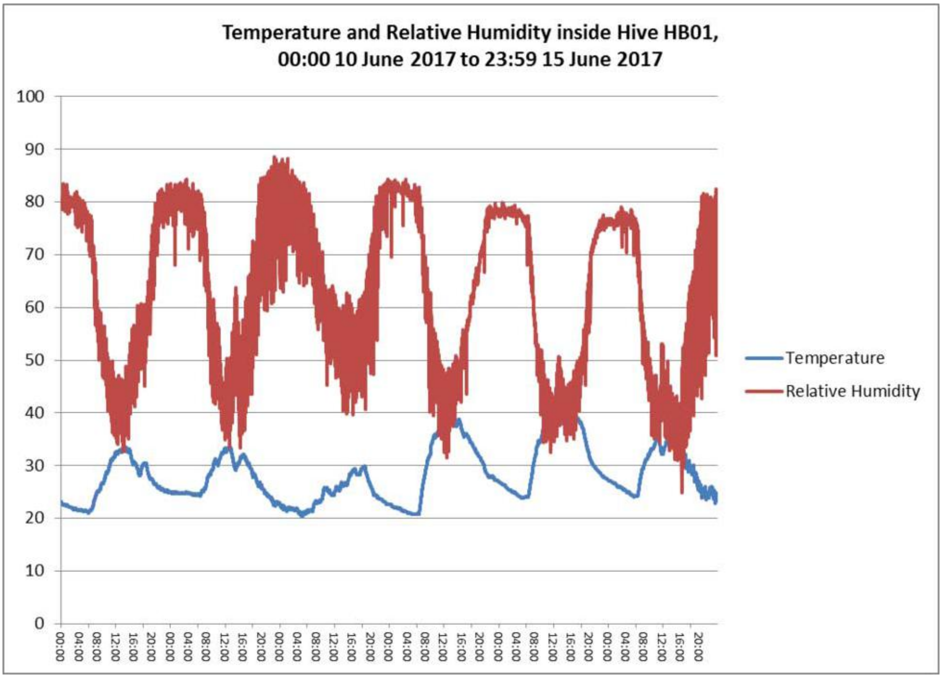

Figure 4. The variation of temperature (in ºC) and relative humidity (% of saturation) inside hive HB01 over the period 10 June to 15 June 2017, measured by our bespoke sensor system. A daily periodic component to both signals is clear.

It should be noted that the change in hive mass noted at the time of the swarm follows a very different temporal profile to the changes occurring over a time interval including a hive inspection. In the latter case (see Figure 6), there is a sudden drop in hive mass by about 15 kg as the roof of the hive is removed, but the mass returns to almost exactly the previous value when the roof is refitted a few minutes later.

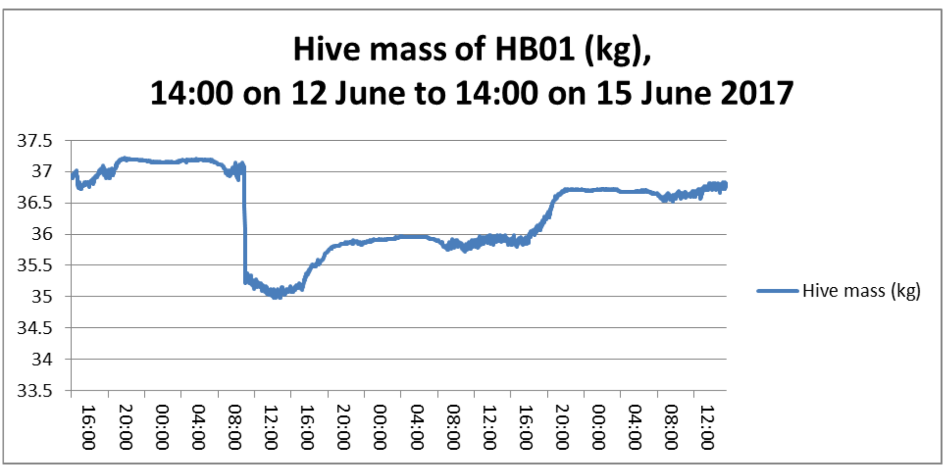

Figure 5. Mass of Hive HB01 over the period 14:00 on 12 June to 14:00 on 15 June 2017, measure by our bespoke sensor system. The swarm occurred around 09:00 on 13 June 2017, accompanied by a rapid drop in hive mass of around 1.8kg – much greater than the decline in mass during the morning of a typical day.

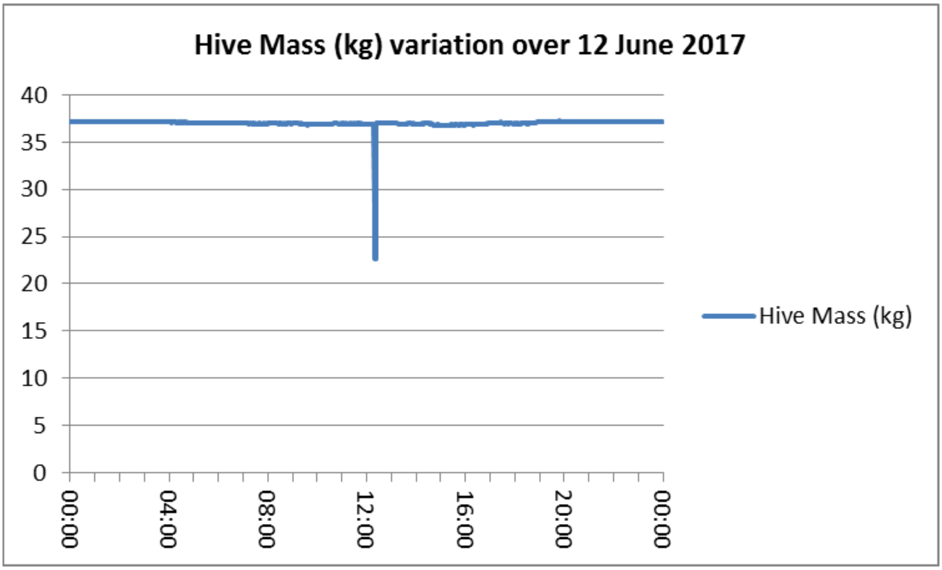

Figure 6. Variation of the mass of Hive HB01 over the course of 12 June 2017. An inspection of the hive (involving removing its roof, causing a temporary drop in mass of about 15 kg) took place between 12:18 and 12:22. Note that, over the course of this day, the mass variation due to bees leaving or entering the hive, consuming resources, and returning with pollen and nectar is negligible compared with the temporary change due to the hive inspection.

(a) (b) (c)

Figure 7. (a) a view of the swarm "beard" of bees around 2pm on 13 June 2017, after it had settled in an apple tree by a wall, around 50 metres from the hive it had come from, (b) and (c) close-ups of the beard, showing individual bees.

7. Conclusions and Future Work

We have successfully designed, implemented and deployed a low-cost network of sensors, controlled by a wireless network of Raspberry Pi microcomputers, to monitor honeybee colonies using a variety of modalities with a view to developing an environment to promote their well-being. Data is being acquired and analysed, using our bespoke sensor systems and Arnia commercial sensor systems, from four hives located in South-West London. Preliminary results of our analyses, including the variations in temperature, humidity and hive mass around the time of a swarm, are presented here.

We hope to identify salient features in the signals monitored which are indicative of important issues for bee colonies, such as swarming, loss of a queen, attacks by predators, infestations by parasites and other factors which may require human intervention. However, in line with the philosophy of Neumann and Blacquière [1] and Seeley [2, 3], we aim to interfere with the bees as little as possible, encouraging them to live in as natural way as feasible, in order to promote their well-being and genetic diversity through the process of natural selection.

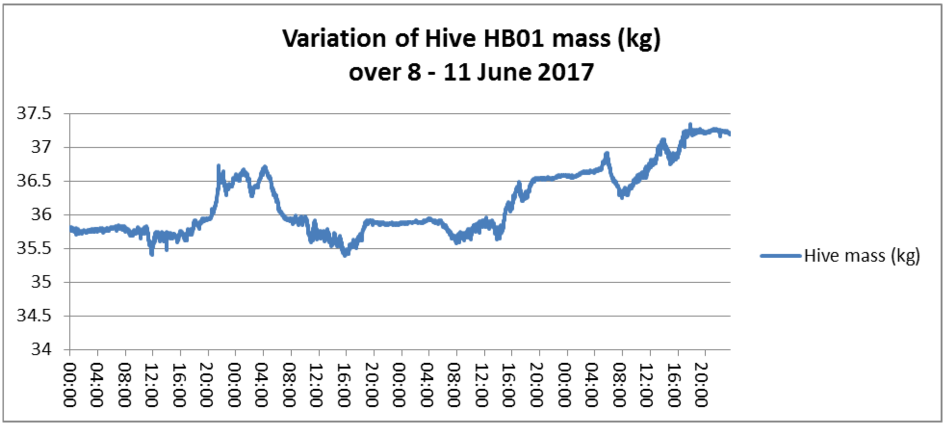

Figure 8. Variation of mass of hive HB01 over the period 9-11 June 2017 inclusive. During this time interval, there were no inspection of the hive, and it was before the swarm. We can see the mass rapidly declines by about 0.3 to 0.5 kg each morning. On 9 June there was also a further decline in mass by approximately 0.5 kg in the early afternoon. However, as the bees return laden with pollen and nectar in the late afternoon and evening, the hive mass rises again. The hive mass tends to be relatively stable overnight. Smaller short term rises and falls in mass could be due to rainfall and evaporation of rainwater respectively.

Regarding the affordability of our sensor system, the most expensive individual component is the USB 2 TByte hard drive, used to back up the data retailing at (GBP) £ 60 in Spring 2017. This might not be essential if (a) a PC with sufficient storage capacity were used as the "master" and/or (b) no storage of audio or video data was required. The Raspberry Pi microcomputers (Model 3 B Quad Core CPU 1.2 GHz 1 GB RAM), which retailed at £ 32 each, were the next most expensive items, followed by the camera module for a RPi which retailed at £ 22 (again, not necessary if video is not required). The HX711 strain gauges for mass (weight) measurement were £ 7 each, as were the DHT22 temperature and humidity sensors. The USB mini microphones each cost £ 3, and each ADC £ 5.50. Each of the 16 GByte SD memory cards for the individual RPi computers cost £ 10.50. Thus, a basic sensor system (with RPi, ADC, power supply, 4 strain gauges, temperature and humidity sensors, 16 GByte SD memory, but no video, audio or mass storage) should be realizable for about £ 100 for a single hive. If audio (via microphones), video (camera) and mass storage were also required, the cost would rise to about £ 190, but the marginal cost per additional hive on the same site (sharing power supply and mass storage) would be lower. For comparison, a commercial system produced by Arnia [15] would cost £ 300 for a central "Gateway" unit, plus £ 150 per hive for a sensor system (including audio, but not including video or mass/weight monitoring). Arnia's hive scales for mass monitoring cost £ 800 per hive. In addition, Arnia charge £ 120 per year subscription to their data storage and visualization service. Our bespoke system is markedly more affordable to small-scale farmers or beekeepers than the commercial one.

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Discrimination of Environmental Factors Affecting Strawberry Yield[1]

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Abstract. This paper investigates the importance of various environmental factors that have a strong influence on strawberry yields grown in greenhouse using various pattern recognition methods. The environmental factors influencing the production of strawberries were six factors such as average inside temperature, average inside humidity, average CO2 level, average soil temperature, cumulative solar irradiance, and average illumination. The results of analyzing the observed data using Dynamic Time Warping (DTW) showed that the most significant factor influencing the strawberry production was average inside humidity, while it was found that average illumination was the lowest influential environmental variable. In addition, an increase in the level of co2 significantly affects the decrease in strawberry yield. Therefore, in order to increase the harvest of strawberries cultivated in the farms, it is necessary to manage the environmental factors such as thoroughly controlling the humidity and maintaining the concentration of CO2 constantly by ventilation of the greenhouse.

Keywords. Strawberry yields, environmental factors, graphic analysis method, dynamic time warping, inside humanity, CO2 level

1. Introduction

Strawberry is an important fruit crop in the Korea, and is a highly nutritious and very popular food source. In addition, strawberry is a fruit that can be utilized in various aspects such as cake making, dessert menu and juice making, so it is very high value added fruit. This trend is increasing the demand for strawberry. Therefore, strawberry cultivation has become a value-added business for farmers, and more attention has been paid to high-quality, high-yielding cultivation techniques.

For this reason, famers are therefore very interested in developing smart farming technology that can improve strawberry yields by combining agriculture and internet of things (IoT) technology. Utilizing the IoT technology, we measure the growth of crops and environment information from various observation sensors in real time. In addition,

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by using the extracted information, an optimal growth management system is constructed, technologies that can increase the productivity and the quality of the crops by automatically managing the crops are developed dramatically.

Previous studies related to these technologies until now are given as follows. Using a generalized randomized block design, Estrada-Oritz at al. [1] evaluated the effect of different percentages of phosphite added to the nutrient solution on the concentration of total P in leaves and the activation of the antioxidant system, which determines the concentration of anthocyanin, yield, pH, electrical conductivity, and strawberry fruit size. They suggest that supplying 20% phosphite in the nutrient solution improved strawberry fruit performance and that supplying 30% phosphite activated dense mechanisms in the plants, which increased the concentration of anthocyanins and improved fruit quality.

Letourneau et al. [2] had performed a field-scale experiment to simultaneously evaluate the impacts of three irrigation management scales and a pulsed water application method on strawberry yield and water use efficiency. The results of their experiment showed that spatial variability of the soil properties at the experimental site was important but most likely not enough to influence the crop response to irrigation practices.

Boyer et al. [3] carried out studies to investigate whether arbuscular mycorrhizal fungi (AMF) could improve strawberry production in coir under low nitrogen input and regulated deficit irrigation. Application of AMF led to an appreciable increase in the size and number of class 1 fruit, especially under either deficient irrigation or low nitrogen input condition.

Fan et al. [4] had evaluated the effects of plastic mulch (PM) and plastic mulch with row covers (PMRC) versus the conventional MRS, on total yield, yield per plant, average fruit weight, soluble solids content, treatable acidity, firmness, fruit postharvest quality, total phenolic content, total antioxidant content, oxygen radical absorbance capacity and phenolic composition analyzed by high-performance liquid chromatography in strawberry selection ‘SJ8976-1’ at different harvest times during the growing season.

Therefore, based on previous studies, we proposed a method to identify the various environmental factors affecting strawberry production using various pattern recognition methods. First, the relationship between production volume and environmental factors will be roughly examined through various graphs. Second, we will use the dynamic time warping method (DTW) to determine the interrelation between strawberry yield and environmental factors. Finally, based on the results of the analysis, a new cultivation method will be proposed to increase the strawberry production.

2. Dataset and Methods

2.1. Dataset

The data used in this study were based on data observed from three farms grown in the Gyeongbuk area in South Korea. The observed data consist largely of both the production of strawberries and the measurements of six environmental factors, respectively, given at the three farmhouses. These six environmental factors are average inside temperature, average inside humidity, average CO2 level, average soil temperature, cumulative solar irradiance, and average illumination.

The observation period was 38 observations from the first week of September, 2016 to the third week of May, 2017. Therefore, the data used in the analysis consist of both 7 variables including the yield, six environmental factors, and 38 observations. The specific variable names and units of measurement used in the analysis are given in Table 1 below.

Table 1. The list of variable names and measurement unit

Response and Environmental factors	Variable name	Measurement unit
Response factor		
The weekly cumulative yield	y	kg/m^2
Environmental factors		
Average CO2 level	X_1	ppm
Average inside temperature	X_2	℃
Average inside humidity	X_3	%
Average illumination	X_4	lx
Cumulative solar irradiance	X_5	mW/㎠
Average soil temperature	X_6	℃

2.2. Methods

First, the Dynamic Time Warping algorithm (DTW) has earned its popularity by being extremely efficient as the time-series similarity measure which minimizes the effects of shifting and distortion in time by allowing elastic transformation of time series in order to detect similar shapes with different phases [5]. Given two time series $X = (x_1, \cdots, x_N)$, $N \in \mathbb{N}$ and $Y = (y_1, \cdots, y_M)$, $M \in \mathbb{N}$ respectively by the sequences of values DTW yields optimal solution in the $O(MN)$ time which could be improved further through different techniques such as multi-scaling. The only restriction placed on the data sequences is that they should be sampled at equidistant points in time.

If sequences are taking values from some feature space Φ than in order to compare two different sequences $X, Y \in \Phi$ one needs to use the local distance measure which is defined to be a function:

$$d : \Phi \times \Phi \to \mathbb{R} \geq 0. \quad (1)$$

Intuitively d has a small value when sequences are similar and large value if they are different. Since the Dynamic Programming algorithm lies in the core of DTW it is common to call this distance function as the cost function and the task of optimal alignment of the sequences becoming the task of arranging all sequence points by minimizing the cost function.

Algorithm starts by building the distance matrix $C \in \mathbb{R}^{N \times M}$ representing all pairwise distances between X and Y . This distance matrix called the local cost matrix for the alignment of two sequences X and Y :

$$C_l \in \mathbb{R}^{N \times M} : c_{i,j} = \| x_i - y_j \|, i \in [1:N], j \in [1:M] \quad (2)$$

Once the local cost matrix built, the algorithm finds the alignment path which runs through the low-cost areas – valleys on the cost matrix. This alignment path (or warping path, or warping function) defines the correspondence of an element $x_i \in X$ to $y_j \in Y$ following the boundary condition which assign first and last elements of X and Y to each other, Figure 1.

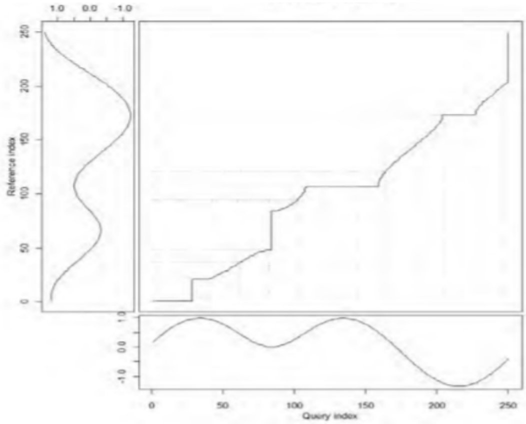


Figure 1. The optimal warping path alignment time series.

3. Experimental Results

First, Figure 2 and Figure 3 below are line graphs to roughly determine how the strawberry yields produced in the three farms A, B, and C are affected by the six environmental variables. From Figure 2 we can see that the yields of farms B and C are similar, while the yield of farm A is different from that of the other two farms.

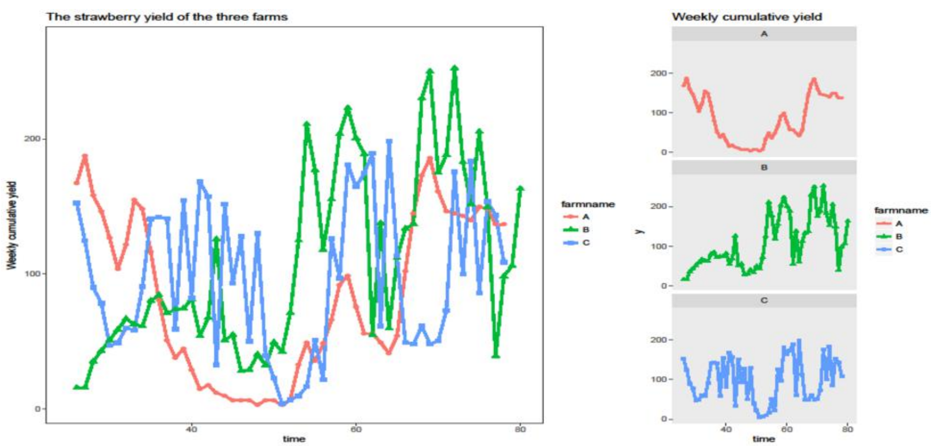


Figure 2. Strawberry production in three farms A, B, C

Also, from Figure 3 for six environmental variables, we can see that the level of CO_2 in farm B is very different from that in other farms, and that farm A has a remarkable difference from two farms with different cumulative solar irradiance.

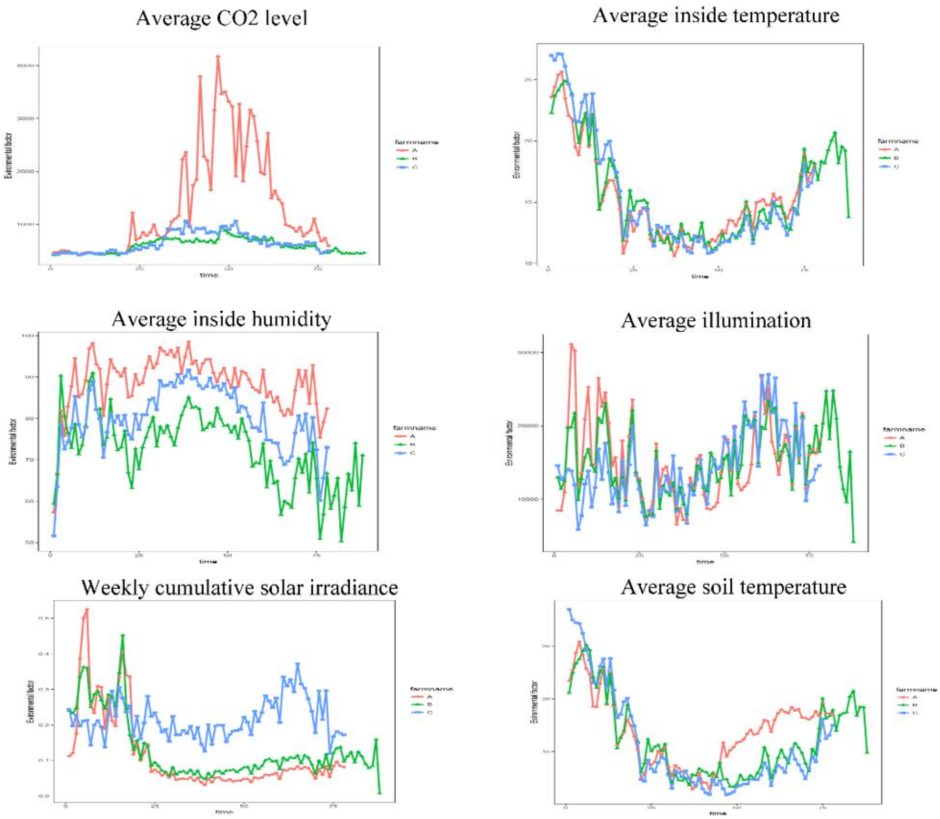
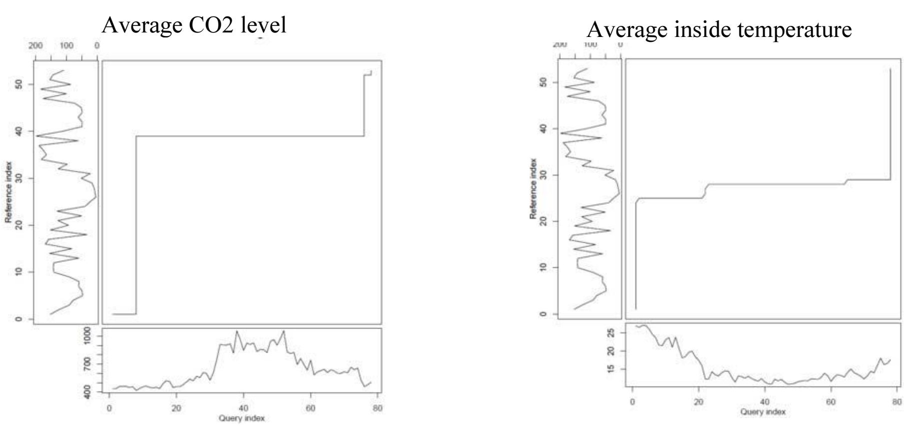


Figure 3. Measured values of six environmental variables.

Next, the results of applying the dynamic time warping method to obtain the relationship between the yields of strawberries produced in farms A, B and C and the six environmental variables are given as in Figure 4, 5 and 6.



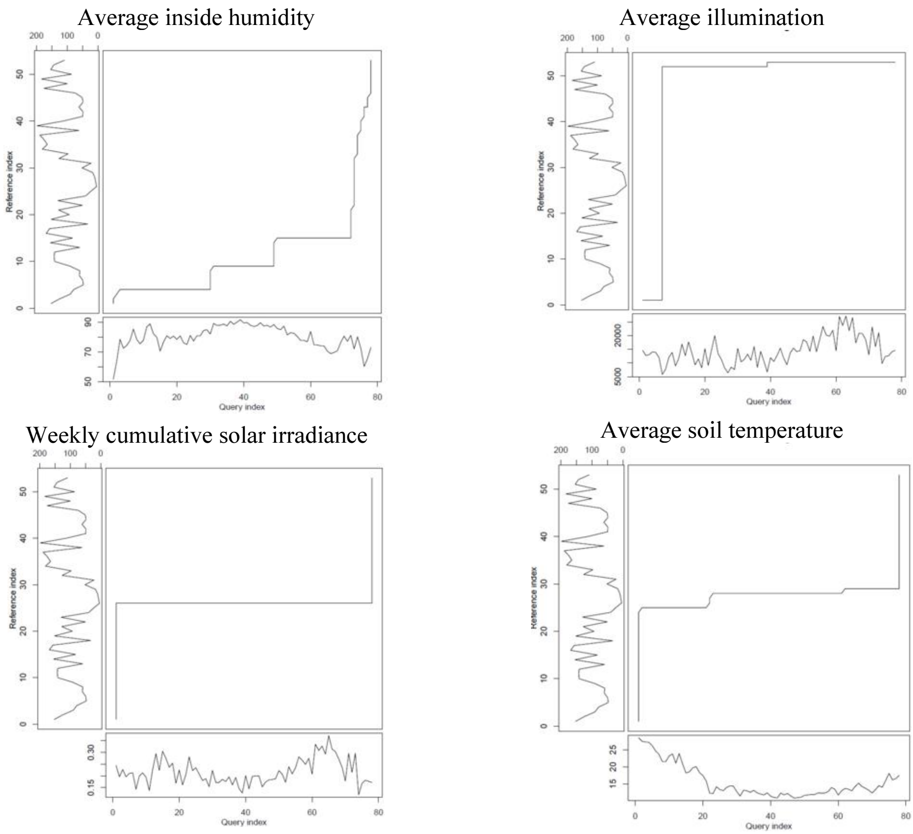
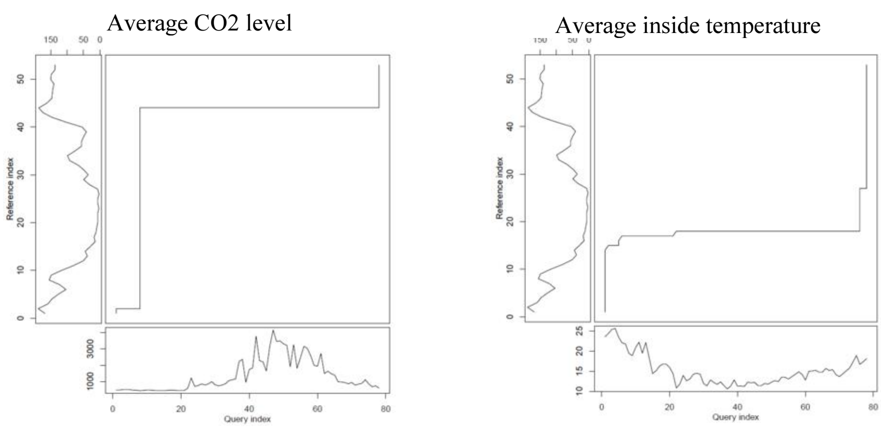


Figure 4. Effect of environmental variables on farm A

From the results in Figure 4, the most relevant environmental variables of yields of farm A were average inside humidity (x3), cumulative solar irradiance (x5), average inside temperature (x2) and average soil temperature (x6).



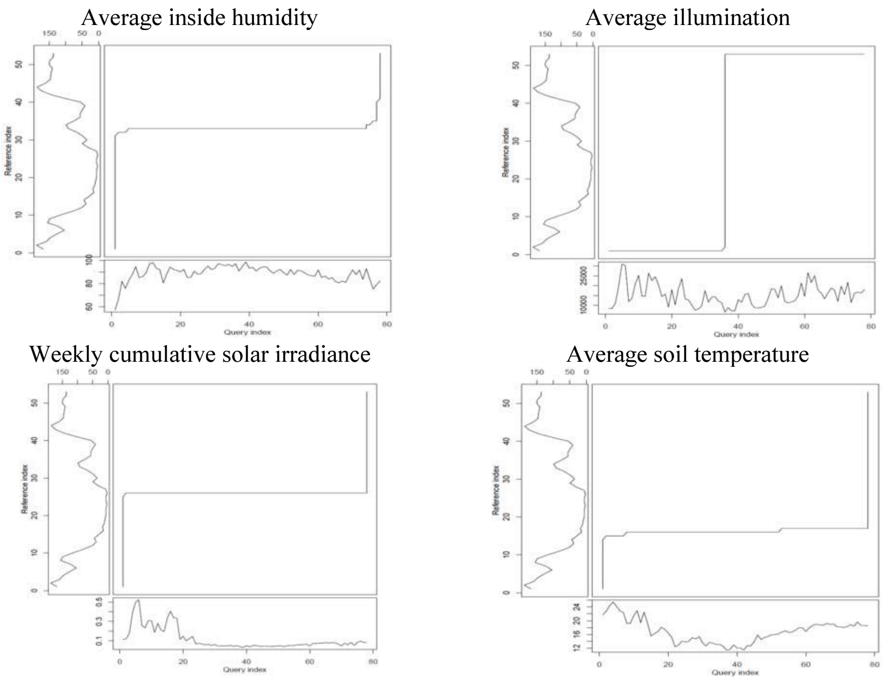
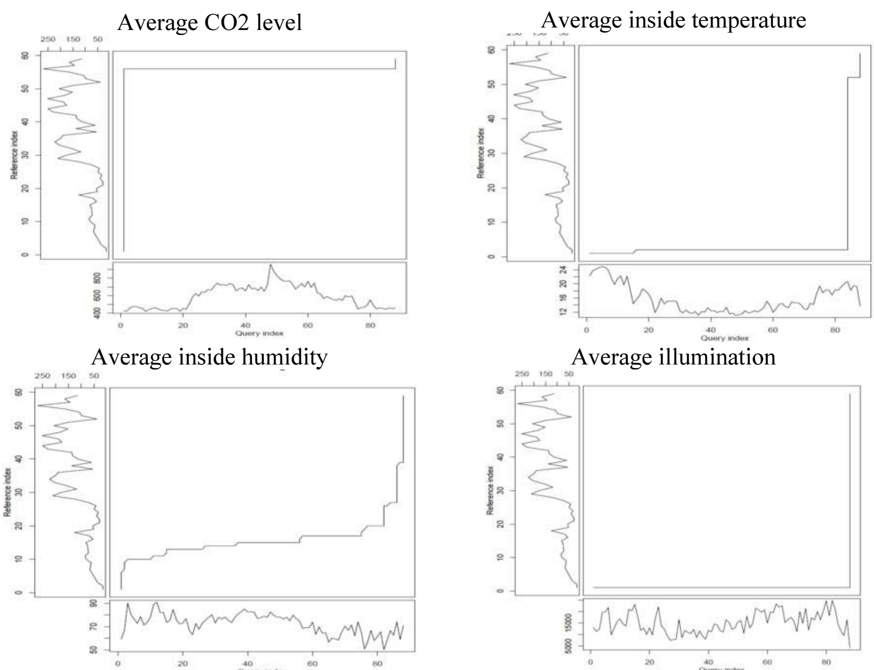


Figure 5. Effect of environmental variables on farm B

From the results in Figure 5, the most relevant environmental variables of yields of farm B were average humidity (x3), cumulative irradiance (x5), average soil temperature (x6) and average inside temperature (x2).



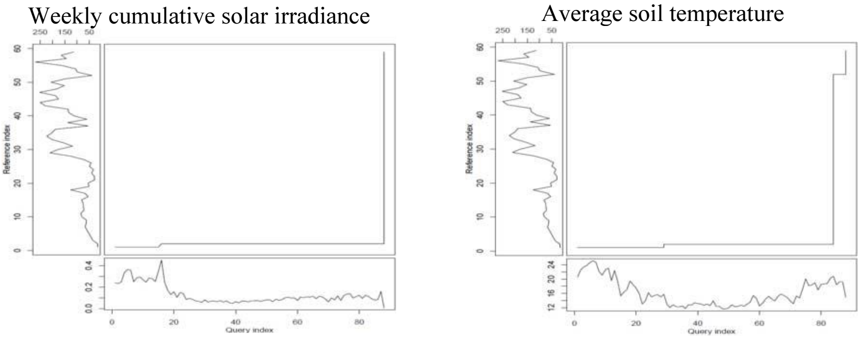


Figure 6. Effect of environmental variables on farm C.

From the results in Figure 6, the most relevant environmental variables of yields of farm C were cumulative solar irradiance (x5), average inside humidity (x3), average inside temperature (x2), and average soil temperature (x6). Therefore, when we compare the six environmental variables that affect the yield of the three farm, the average inside humidity is the most important environmental variable, while the least influential environmental variable is the average illumination.

4. Conclusion

In this paper, we analyzed the effects of six environmental variables affecting strawberry yields using real data collected from the three farms. The facts from the experimental results are as follows. First, the environmental variables that have the greatest influence on the strawberry yield are average inside humidity, average inside temperature, and cumulative solar irradiation. Second, average CO2 level greatly influence the increase and decrease of yield. Third, from the experimental results by comparing the strawberry yields in three farms, it is proper environmental variable management methods to maintain the concentration of CO2 constantly by ventilating the vinyl house thoroughly, and to thoroughly control the humidity in order to improve the strawberry yield of the greenhouse.

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The Analysis of Tweets to Detect Natural Hazards

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Abstract. During times of disasters, users can act as powerful social sensors, because of the significant amount of data they generate on social media. Indeed, they contribute to creating situational awareness by informing what is happening in the affected community during the incident. In this context, this article focuses on the text-processing module in CASPER, a knowledge-based system that integrates event detection and sentiment tracking. The performance of the system was tested with the natural disaster of wildfires.

Keywords. Twitter, social sensor, topic categorization, sentiment analysis.

1. Introduction

Hazards and disasters give rise to three main types of costs: (a) human cost, since they cause significant suffering and loss of lives, (b) economic cost, since they may result in damage and loss of property, and (c) environmental cost, since they can destroy natural habitats or release pollutants. Because of the increasing public concern on this issue, social media play an active role in disaster detection, tracking, response and assessment. In fact, results from an American Red Cross [1] survey indicated that half of the adults who use social media channels would report emergencies on these channels, and more than two-thirds of the respondents agreed that response agencies should regularly monitor and respond to postings on their websites. For example, *USA Today* reported that, after Houston city officials had warned in August 2017 that emergency services were "at capacity", flood victims decided to use Twitter to ask for help, as shown in the following message:[2]

(1) I have 2 children with me and the water is swallowing us up. Please send help.

As noted by Crowe [2], "initiating protocols and systems to monitor social media conversations—particularly during disasters—is critical for both emergency public information and situational awareness". In fact, for situational awareness, the collection and review of social media information at real time can help emergency managers provide an efficient and effective response to the incident by mobilizing in-situ stakeholders such as fire fighters, police officers or medical staff, among others.

In this context, our research led to the design and development of CASPER (CAtegory- and Sentiment-based Problem FindER). Indeed, this article continues previous research by the authors, where the system was primarily oriented to problem

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[2] https://www.usatoday.com/story/news/nation-now/2017/08/27/desperate-help-flood-victims-houston-turn-twitter-rescue/606035001/

detection with Spanish tweets [3]. Following a symbolic approach to topic categorization and sentiment analysis, this new version of CASPER involves not only constructing further resources to analyze English micro-texts but also, and most importantly, enhancing the system to specifically detect hazardous and critical situations that could help guide emergency managers in decision making. According to the EU Vademecum on civil protection,[3] disasters fit into two broad categories: natural disasters (e.g. avalanches, earthquakes, floods, forest fires, hurricanes, storms, tsunamis, and volcanic eruptions) and man-made disasters (e.g. chemical spills, industrial accidents, marine pollution, war and terrorist attacks). This article evaluates the performance of CASPER in relation to the environmental hazard of wildfires. The remainder of this article is organized as follows. Sections 2 and 3 briefly describe some works related to social sensors and the approach of our research, respectively. Section 4 explores the knowledge base developed for the system, whereas Section 5 provides an account of the procedure to detect hazards from micro-texts. Finally, Section 6 evaluates the research, and Section 7 presents some conclusions.

2. Related work

The use of social sensors for the development of emergency response systems has become a relevant research topic over the last decade [4]. Sakaki et al. [5, 6] presented one of the first applications to use Twitter as a medium for social sensors to detect real-time events. They devised a support vector machine (SVM) classifier of tweets based on features such as the keywords in a tweet, the number of words, and their context. Moreover, a probabilistic spatio-temporal model was used to find the center of the event location. As a result, they developed a reporting system to promptly notify people of earthquakes in Japan. Likewise, Liu et al. [7] described a tweet-based system used by the U.S. Geological Survey to rapidly detect widely felt seismic events. The algorithm essentially scans for significant increases in tweets containing the word "earthquake", or its equivalent in other languages, and sends alerts with the detection time, tweet text, and the location where most of the tweets originated. It is important to note that most of these systems are trained to detect a single or a few events, e.g. grassfires and floods [8] or swine flu [9], among others.

3. The approach

In this research, hazard detection is going to be addressed as an issue of classification, being comprised of two complementary tasks: topic categorization and sentiment analysis. In this regard, researchers are likely to take one of the following two approaches: a machine learning approach, which is usually implemented through a supervised method, and a symbolic approach, which is primarily based on a knowledge base. A supervised machine-learning method (e.g. Naïve Bayes or SVM) requires a training dataset, that is, a collection of text data that have been manually annotated as positive or negative with respect to the target event (i.e. the hazard). This training dataset should not only be carefully tagged but also be sufficiently large and representative, which actually conflicts with the development of a system like CASPER, which is intended to classify new tweets on the ground of multiple hazards. The effort to expand a given training dataset to fit new categories makes the portability

[3] http://ec.europa.eu/echo/files/civil_protection/vademecum/index.html

of the system to new domains a non-trivial task. This fact actually became a great challenge for the performance of the system, since "successful results depend to a large extent on developing systems that have been specifically developed for a particular subject domain" [10]. For this reason, the solution was aimed at dealing with hazard detection from a knowledge-based approach.

4. The knowledge base

The degree of success of knowledge-based approaches is closely dependent on the quality and coverage of the lexical resources involved in the system. This section describes the most important resources that were built for our research, i.e. HAZARD, EMERGENCY, SENTIMENT, NEGATION, MODIFIERS and ABBREVIATIONS.

4.1. Hazard, Emergency and Sentiment

CASPER has been designed for two scenarios, i.e. (i) problem detection in general, and (ii) hazard detection in particular. This article is concerned with the latter, which is more likely to take place when tweets are submitted to an emergency management agency, where they should be automatically classified on the basis of the type of incident and the level of emergency. The hazard-detection mode requires three types of lexicon, i.e. HAZARD, EMERGENCY and SENTIMENT, which are briefly described in the remainder of this section.

HAZARD holds lexical descriptors for each hazard (e.g. flood, hurricane, etc), so that their presence in micro-texts leads to topic categorization. For example, some of the descriptors of *wildfire* are *burn, flame*, *grassfire* or *inferno*.

EMERGENCY takes the form of a collection of words that are not specific to any given hazard but are commonly perceived as lexical triggers to activate an emergency response. This dataset was constructed from the keywords in CrisisLex [11] and EMterms [12] after stopwords were removed and was expanded by means of morphological derivation. For example, some of the words in EMERGENCY are *accident*, *dead* or *victim*.

SENTIMENT contains those words that are related to a single sentiment (i.e. positive or negative) regardless of the context in which they are used. This dataset originated from SentiWordNet [13, 14]. SentiWordNet is the result of automatically annotating all synsets (i.e. synonymous sets of words) in English WordNet 3.0 according to their degrees of positivity, negativity and objectivity, where each of the three scores ranges from 0 to 1 and the sum of the three scores is 1 for each synset. In particular, SENTIMENT was originally populated with (i) positively marked words extracted from those terms whose positive score is equal to or higher than 0.8 and the negative score is 0 in SentiWordNet, and (ii) negatively marked words extracted from those terms whose negative score is equal to or higher than 0.8 and the positive score is 0 in SentiWordNet. Those words semantically linked to the resulting synsets were also taken into consideration. Finally, we manually validated the dataset, because it cannot include ambiguous nor context-dependent polarity words. On the one hand, there are words whose polarity is ambiguous when considered out of context, since not all their meanings reflect the same type of sentiment. For example, this is the case of *lofty*, whose sense of "morally good" is positive but its sense of "arrogant" is negative, as illustrated in (2) and (3), respectively.

(2) She was a woman of large views and lofty aims.

(3) He has such a lofty manner.

On the other hand, there are words whose polarity depends on the context, rather than on the meaning. For example, *long* refers to "a large amount of time" in both (4) and (5), but it becomes a positively marked word in the former and a negatively marked word in the latter.

(4) The battery of this camera lasts very long.

(5) This program takes a long time to run.

Therefore, words such as *lofty* and *long* are not included in SENTIMENT. By contrast, some of the words that are actually found in this dataset are *admirably, glad, support* [positive] or *cruel, grief, wreck* [negative].

It should be pointed out that some of the words in HAZARD and some of the words in EMERGENCY can also be found in SENTIMENT. However, no word in HAZARD can be included in EMERGENCY, and no word in EMERGENCY can be included in HAZARD.

4.2. Negation and Modifiers

NEGATION and MODIFIERS compose the main source of knowledge for valence shifters [15], i.e. words and phrases that can affect the values of the hazard, emergency and sentiment attributes of the ngrams in the micro-text.

NEGATION holds negative cues, where most of them can invert the truth value of phrases or sentences (e.g. *lack of*); however, we also found a few of them that do not actually convey negation (e.g. *nothing but*). Therefore, negative cues are classified as negative or non-negative, in addition to specifying the direction of their scope (or impact region), i.e. following or preceding the valence shifter. Negative cues were extracted from different resources: the SFU review corpus [16], Morante's [17] analysis of the negation cues that occur in the BioScope corpus [18], Morante et al.'s [19] analysis of the negation cues that occur in two Conan Doyle's stories (i.e. *The Hound of the Baskevilles* and *The Adventure of Wisteria Lodge*), and NegEx triggers [20].[4]

The valence shifters in MODIFIERS are classified as intensifiers or diminishers, i.e. expressions that increase or decrease, respectively, the degree of polarity of the ngrams to which they modify (e.g. *barely*, *significantly* or *very*). The scope of modifiers must also be determined. Modifiers were collected from the English grammar [21].

4.3. Abbreviations

ABBREVIATIONS holds the abbreviations (and their full forms) that are commonly used in social media, such as *btw -> by the way* or *thx -> thanks*.

[4] NegEx triggers can be downloaded from https://github.com/mongoose54/negex/blob/master/negex.python/negex_triggers.txt

5. Discovering hazards with CASPER

This section describes the seven stages that take place in CASPER when trying to assign a score to a given tweet in relation to its degree of relatedness with hazards.

In the first stage, the tweets are pre-processed to produce clean texts for natural language processing: (i) reduction of a sequence of three or more repeated characters by means of regular expressions (e.g. gooooood -> good), (ii) spell checking with NHunspell,[5] a library that implements Hunspell [22] for the .NET platform, (iii) transformation of abbreviations into their full-word equivalent with the aid of ABBREVIATIONS, and (iv) removal of hashtags (i.e. any word starting with #), references (i.e. usernames headed by @) and URL links by means of regular expressions.

In the second stage, each micro-text is split into sentences, and then each sentence is tokenized and POS-tagged by using the Stanford Log-linear Part-Of-Speech Tagger.[6] At this point, a tweet is represented as the vector $T_m = (w_{m1}, w_{m2}, \dots w_{mp})$, where w_{mn} represents an object for every word that occurs in the tweet and p is the total number of words. Each w_{mn} is defined with attributes such as the position in the micro-text, the word form, the lexeme, the POS, the hazard (h), the emergency (e) and the sentiment (s), where the values of the latter three are discovered in the next stages. We employed the LemmaGen library for lemmatization [23].[7]

The third stage consists in detecting significant ngrams with respect to a given hazard. The weight 1 is assigned to the attribute h of every w_{mn} in T_m whose ngram is found in HAZARD, together with its corresponding POS. The default value is 0.

The fourth stage is aimed at discovering emergency-related ngrams. The weight 1 is assigned to the attribute e of every w_{mn} in T_m whose ngram is found in EMERGENCY, together with its corresponding POS. The default value is 0.

The fifth stage consists in detecting significant ngrams with respect to the sentiment. Thus, the system attempts to assign the values +1 or -1 (for positively and negatively marked ngrams, respectively) to the attribute s of every w_{mn} in T_m according to the polarity of the ngram in SENTIMENT, where the POS of the ngram is also taken into consideration. The default value is 0.

In the sixth stage, valence shifters are applied to neighbouring words within the micro-text. Negation cues make all the ngrams involved in their scope be no longer significant for hazard, emergency and sentiment, so the values of their attributes h, e and s are re-computed to 0. By contrast, intensifiers and diminishers change the degree of polarity of the ngrams involved by multiplying the values of the above attributes by 3 or 0.5, respectively. Whereas negation cues are applied to all the words within the scope, modifiers act only on the first polar expression that is found in the scope. The impact region of the valence shifters is three words, where the direction of this scope is determined by the information included in NEGATION and MODIFIERS.

In the final stage, a problem-relatedness perception index (PPI) is calculated not only to measure how reliable we can feel that a given tweet deals with a problem about a given hazard but also to set alert thresholds from which the severity of the problem could be rated. The computation of the PPI involves three steps. On the one hand,

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[5] NHunspell was downloaded from https://sourceforge.net/projects/nhunspell/
[6] The Stanford POS Tagger was downloaded from https://sergey-tihon.github.io/Stanford.NLP.NET/StanfordPOSTagger.html
[7] LemmaGen was downloaded from http://lemmatise.ijs.si

considering that the lexical descriptors for a given hazard form a vector of features (i.e. $f_1, f_2, \ldots, f_k$), cosine similarity is used to assess the degree of relatedness between the tweet and the hazard. Since we deal with the binary values of the attribute h and the number of distinct hazard-related ngrams in the tweet T_m is equal to or less than the number of lexical descriptors for the hazard, the hazard-relatedness function can be simplified to the Eq. (1).

$$rel_h(T_m) = \frac{\sum_{n=1}^{p} w_{mn}}{\sqrt{\sum_{n=1}^{p} w_{mn}} \times \sqrt{\sum_{j=1}^{k} f_j}} \tag{1}$$

Therefore, a tweet is related to a given hazard if the similarity score is greater than 0. On the other hand, a logit scale is used to compute the sentiment score, as shown in the Eq. (2).

$$\begin{gathered} rel_s(T_m)' = \log\left(\frac{P+0.5}{N+2D+0.5}\right) \\ \text{if } rel_s(T_m)' < 0, \text{ then } rel_s(T_m)'' = -rel_s(T_m)' \\ \text{otherwise, } rel_s(T_m)'' = 0 \end{gathered} \tag{2}$$

where P and N refer to the total value of positively and negatively marked ngrams in T_m, respectively (calculated from the attribute s), and D refers to the number of emergency-oriented words in T_m (calculated from the attribute e). The normalized value is derived from the Eq. (3).

$$rel_s(T_m) = 1 - \frac{1}{\log(rel_s(T_m)'' + 2)} \tag{3}$$

Finally, as shown in the Eq. (4), the PPI is computed as the geometric mean of the values returned by rel_h and rel_s so as to reach a proportional compromise between topic categorization and sentiment analysis.

$$PPI(T_m) = \sqrt{rel_h(T_m) * rel_s(T_m)} \tag{4}$$

6. Evaluation

This research was evaluated with a corpus of 1,200 tweets posted during a devastating series of wildfires that occurred in Colorado throughout June, July and August 2012 [24].[8] The tweets in this dataset were labeled by crowdsourcing workers according to three parameters: informativeness (e.g. related and informative, related but not informative, not related, or not applicable), information type (e.g. affected individuals, infrastructure and utilities, donations and volunteering, caution and advice, sympathy and support, other useful information, not applicable, or not labeled), and information source (e.g. eyewitness, government, NGOs, business, media, outsiders, not applicable,

[8] The dataset was downloaded from https://github.com/sajao/CrisisLex/tree/master/data/CrisisLexT26

or not labeled). Table 1 presents the distribution of tweets with respect to informativeness, which is the only parameter relevant to the research in this article.

Table 1. Informativeness in the 2012 Colorado wildfires dataset.

	Related and informative	Related but not informative	Not related	Not applicable	Total
Tweets	685	268	238	9	1,200

At first sight, it might be thought that only "related and informative" tweets could really be useful for the task at hand, since they are supposed to be the only ones that help understand the crisis situation on the ground. However, this proved to be a rather subjective category, as shown in examples (6) and (7), which were manually categorized as "related and informative" and "related but not informative", respectively.

(6) Theres like 7 fires in colorado right now....

(7) Ack! A fire now in Boulder!

In this experiment, CASPER managed to identify 633 fire-related tweets, whose distribution with respect to informativeness and PPI scores is shown in Table 2 and Figure 1, respectively.

Table 2. Informativeness in the experiment results.

	Related and informative	Related but not informative	Not related	Not applicable	Total
Tweets	474 (74.88%)	146 (23.06%)	12 (1.90%)	1 (0.16%)	633 (100%)

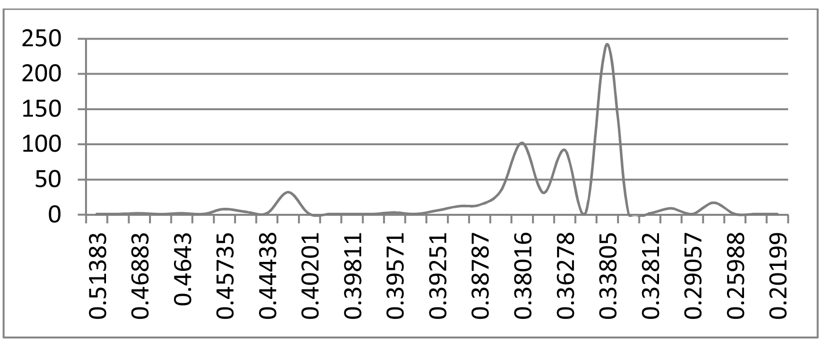

Figure 1. PPI scores in the experiment results.

We employed precision to evaluate the performance of the system, as formulated in Eq. (5).

$$Precision = \frac{TP}{TP+FP} \quad (5)$$

Precision is a key issue in the development of emergency-response systems, since an excessive number of false-warning messages can increase anxiety in decision makers, forcing them to allocate unnecessary resources to monitor problems that are not indeed actual problems. The manual validation of the results revealed that precision was 0.8073. To prioritize hazardous and critical situations for effective emergency management, we chose to automatically rank tweets by arranging them from the highest PPI score (i.e. 0.51383) to the lowest PPI score (i.e. 0.20199), whose corresponding micro-texts are shown in the examples (8) and (9), respectively.

(8) Colorado fire: 41,140 acres burned, 1 dead: Firefighters were hoping to get control Tuesday of a fast-moving wildfire in northern Colorado

(9) Please RT! Help My Friends in CO .Great way to help support Colorado Fire

To this end, we employed five ranges (i.e. R1-R5) to organize the 33 distinct PPI scores. Figure 2 serves to illustrate the amount of tweets found within each range for each informativeness value.

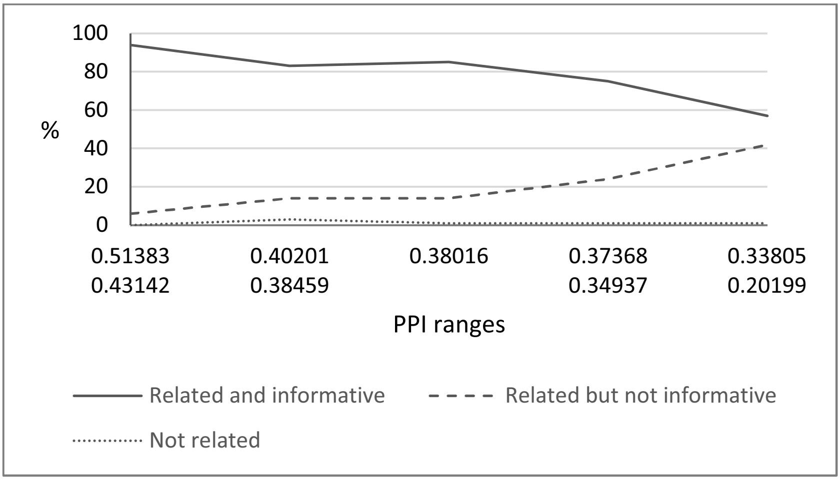

Figure 2. Informativeness in PPI ranges.

It can be noted that the graph lines in Figure 2 reflect a gradual distribution of informativeness, which is in line with the discriminating power of positioning critical situations at the top of the rank, while minor or non-existing problems concentrate closer to the bottom of the list. This is demonstrated in Table 3, which shows the cumulative precision along the ranges, together with the number and percentage of tweets in each range.

Table 3. Cumulative precision in PPI ranges.

Range	Precision	Tweets
R1	0.9074	54 (8.53%)
R1-R2	0.8984	128 (20.22%)
R1-R3	0.8913	230 (36.33%)
R1-R4	0.8627	357 (56.40%)
R1-R5	0.8073	633 (100%)

In this manner, for example, when CASPER retrieves the top-ranked 128 tweets, i.e. about 10% of the 1,200 tweets analyzed, precision is near 0.9, which contributes to developing an effective notification system for emergency managers.

Figure 3 displays the duration of the ten wildfires that occurred in Colorado throughout June and July 2012 (horizontal bars). The dashed line represents the average PPIs derived from the tweets submitted on each date (vertical bars). This chart demonstrates that the peak areas of PPI are located in the first halves of the two most destructive fires: High Park (9 June–30 June) and Waldo Canyon (23 June–8 July).

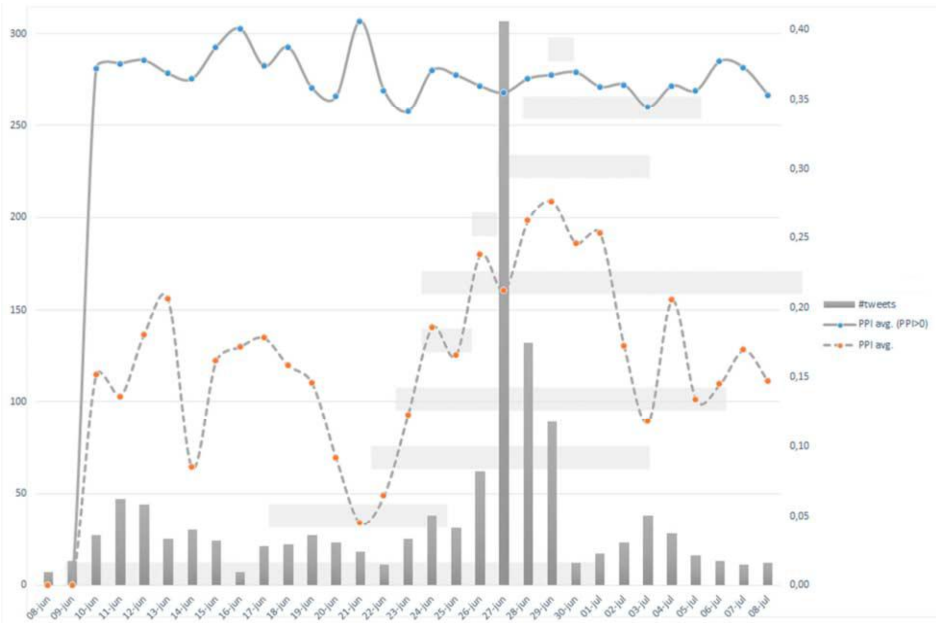

Figure 3. PPI scores over time.

7. Conclusion

During and after disasters, people use microblogging services (e.g. Twitter or Facebook) to communicate actionable information that can help emergency responders gain situational awareness. In this regard, we described both the knowledge base and the natural language processing techniques that allowed us to develop a system that serves not only to classify micro-texts according to particular types of hazards but also to compute a score (PPI) for each micro-text to assess the disaster impact (i.e. damage to people, property or environment). Indeed, the evaluation of the research demonstrated that PPI scores can be used to effectively select the most relevant tweets to emergency response and recovery.

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A Preliminary Study to Solve Crop Frost Prediction Using an Intelligent Data Analysis Process

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Abstract. Precision agriculture has created new opportunities to solve problems in the field of agriculture by balancing investment with higher returns. This paper focuses on the problem of frost in stone fruit crops. These frosts occur due to the large temperature changes caused by climate change, which anticipate the blooming of stone fruit trees due to high temperatures at midday, but damage these flowers with temperatures below zero that occur at night in the last days of winter. The aim of this paper is to perform a preliminary study to predict, with the least possible error, the possible frosts that can occur in crops. Data for this initial study have been obtained from three meteorological stations belonging to the Murcia Institute of Agricultural and Food Research and Development. The purpose of this paper is addressed using two of the techniques offered by intelligent data analysis. Specifically, the M5P regression tree for temperature prediction and the C4.5 decision tree to classify, whether or not there is frost, have been used. Initial results are satisfactory with more than 89% accuracy in classification and an error less than 0.5 degrees Celsius in temperature prediction. In addition, the results identify the most relevant attributes to predict temperature, being some of them dew point, vapor pressure deficit and maximum relative humidity.

Keywords. frost crop, precision agriculture, intelligent data analysis, classification, regression

1. Introduction

In agriculture, the use of new technologies is being implemented to improve productivity, efficiency and cost savings. These new technologies offer a collection of information of various types (graphics, sensors, positioning, etc.) in a fast way that allows to take decisions and act at the right time. Until recently, capturing information from a farmer usually consisted of seeing how the crop grew in the neighbor's field. Agriculture was based on observing the behavior of the fields based on the experience of older farmers. Farmers also relied on the advice of agronomists, but no analyses were carried out on the type of soil, type of crop or farming area to solve problems more precisely, more efficiently and more environmentally responsible. Currently, on the medium-sized farm, the system has not changed much, and although it is an information capture and management system that can function fairly well, it is far from effective. In the midst of the digital age agriculture area is one step behind in these computational issues, being the availability and management of information at least as important as in other sectors such as industry or services [4]. Spanish farmers were generally very reluctant to take systematic data on their farm, as they understood this process to be costly in time and resources with no short-term reward, so they considered it as an uninteresting investment. However, more and more farmers are interested in modernizing their crops using new technologies. For this they are allowing the installation and implementation of applications of sensors, cameras, drones, among other elements that utilize the communications and advantages offered by Internet of Things [19]. These elements allow the capture of data for later analysis and decision making based on them.

In southeastern Spain, farmers have recently suffered heavy crop losses due to inclement weather. Specifically, the damage is occurring due to sudden changes in temperature, during the daytime temperatures exceed 15 degrees Celsius and at night negative temperatures occur. These temperature changes cause stone fruit trees to bloom prematurely and the negative temperatures end up by freezing these flowers, resulting in fruit loss [5,6]. Specifically, this paper is focused on stone fruit trees. To mitigate the effects of a frost in stone fruit trees, there are some techniques that can reduce losses depending on the intensity of the frost. Among techniques to mitigate these effects are included the following:

- Protective covers: The covers can be plants, straw or plastics.
- Artificial fog: This fog is produced by forming smoke by burning cheap waste (straw and by-products) or chemicals such as paraffin.
- Fans: This technique is based on air agitation to break the thermal inversion. The use of fans mixes hot and cold air and breaks the thermal inversion.
- Stoves: The cold protection action is due to two complementary phenomena: the emission of infrared radiation when the device is hot and the heating of the air by conduction.
- Sprinkler irrigation: This technique is applied by watering the crop with sprinklers before and during frost because the water freezes the heat and the temperature does not drop below 0 Celsius degrees, but this must be continuous throughout the event.
- Application of chemical treatments: This technique is applied to cause delays in the development of crops or to increase the cold resistance of plants/flowers.

The problem that arises with crop frost is the need to know in advance if a frost will occur or not to prepare the material or workers needed to combat frost using any of the techniques described. In this paper several Intelligent Data Analysis (IDA) techniques are applied to help us to predict frosts in stone fruit trees. For this purpose, data from different weather stations are used in order to predict, with the least possible error, when a frost will occur. In addition, an analysis of the models is performed to determine the most important climatic variables to predict the temperature. Given that in this paper a preliminary study is performed, the techniques applied help us to define elements that allow us to build a decision support system for farmer.

This paper is organized as follows: Section 2 presents a review of the works related to precision agriculture and how the IDA process is applied in this field. Section 3 describes the data used for temperature prediction to detect frost and the IDA techniques used to make that prediction. Furthermore in this section results are also shown and discussed. Finally in Section 4 conclusions and future work are presented.

2. Background

Precision agriculture is a concept that was born in the mid-1980s [15], although it is being used in recent years to a greater extent. This concept involves the use of technologies to help solve agricultural problems. Precision agriculture allows us to perform agricultural tasks correctly, in the right place, at the right time and in the right way [16]. Precision agriculture generally involves a better management of agricultural inputs such as fertilizers, herbicides, seed, fuel, etc. This type of agriculture, unlike conventional agriculture, offers a personalized attention to each type of crop. In this way, precision agriculture trend to optimize the profitability, sustainability and to reduce the environmental impact maximizing the crop productivity [13]. Thus, precision agriculture can be defined as a production system that promotes variable management practices within a field, according to site conditions. This system uses tools and information sources that can be provided by various technologies such as global positioning system, geographic information systems, yield monitoring devices, soil, plant and pest sensors, remote sensing, and variable-rate technologies [22]. In addition to the technologies used for data collection, it is important to consider the techniques needed to analyze all the information collected to provide rules, actions or decisions for better results in the precision agriculture process. Data mining (DM) offers a set of computational techniques to treat and manage these amounts of data and to solve the specific and general problems that appear in agriculture [14].

In [17] a perception system for agricultural robotics with a multispectral camera is presented to automatically perform the tasks of detection and classification of crops and weeds in real time. Two different convolution neural networks are applied. The first for segmentation of camera images and the second to classify between crops and weeds using the pixels extracted from that segmentation. In this study authors present the components needed to capture the data as well as the DM techniques to analyze them. In [24] a visible and near infrared reflectance spectroscopy is used to collect data on soil organic carbon. These data are pre-processed using the random forest technique and analyzed by multivariate regression models in order to predict soil organic carbon.

Predicting diseases in crops is another area where precision agriculture can be used. Thus, the authors in [25] propose the development of a model to predict groundnut pest, specifically Thrips and Bud Necrosis diseases. To achieve this goal, the authors deployed a network of sensors to obtain real-time weather parameters such as temperature, humidity and leaf wetness. Using these data, the authors propose the use of DM techniques such as Gaussian Naive Bayes and Rapid Association Rule Mining to detect hidden correlations in data that help detect these diseases in crops. Another paper where DM techniques are applied to detect plant diseases is presented in [2]. In this study an automatic detection and classification of leaf diseases has been proposed. This method is based on K-means as a clustering procedure and a neural network as a sorting tool using a set of texture characteristics.

DM techniques have also been applied to weather forecasting from data obtained from meteorological stations. Within this scope there are works in which the prediction of temperature, wind speed, abnormal events such as hurricanes or storms, prediction of fog or forecast of rainfall is carried out. This weather prediction is important when making decisions in agriculture, such as estimating the probability of fires, crop diseases or managing elements such as irrigation. Thus, among the other works that carry out the temperature prediction, in [12] authors perform the estimation of the average, minimum and maximum temperature of one day from the data of previous years. They carry out regression through k-nearest neighbor (kNN), decision trees, rules, neural networks and additive regression. In [20] from the maximum temperature of several days earlier, predict the next day's temperature. Authors take the maximum daily temperature of a dataset by performing the imputation of unknown values. The prediction is made with a support vector machine (SVM) and a multilayer perceptron obtaining better results with SVM. In [10] the kNN technique is used to predict the weather (temperature, humidity, rain, ...) of a region from the nearest neighbors in a historical dataset.

Rainfall plays a very important role in agriculture, especially in areas where water is a scarce resource and good management is necessary, hence the importance of predicting it and therefore there are works focused on this objective. Thus in [23] a multiple linear regression technique for the early prediction of rainfall is developed. In [11] the authors carry out the prediction using a Bayesian classifier obtaining good results with 7 attributes for large datasets.

Short-term weather warnings are becoming increasingly important. Predicting the existence of low cloud cover is important in agriculture as a local flood warning. To this end, the authors in [3] develop an study of fog and low cloud cover prediction from meteorological data using CRISP-DM methodology. In the paper they only carry out the initial stages of the methodology, such as data analysis and cleaning. Although the reliability of weather stations has improved recently, there are still faults that lead to data loss. Thus, in [1] the imputation of these values using data obtained from neighbouring stations is performed.

3. Intelligent data analysis process for predicting frost crop in agriculture

This section describes the different phases of the IDA process that have been carried out with the aim of studying various useful elements for the implementation of a decision support system for the farmer. This system should help farmers to take the right actions to protect their crops from frost. The IDA process starts from the meteorological dataset available from several weather stations in a close environment and after performing a data preprocessing to obtain the minable view, two DM techniques based on decision trees are applied. One of them solves the regression task and another solves the classification task. Finally, the results obtained are shown and commented.

3.1. Data Collecting

The dataset used for this study have been obtained from three meteorological stations belonging to the Murcia Institute of Agricultural and Food Research and Development, [9]. These three stations have been selected because they are surrounded by stone fruit crops and therefore the results obtained are interesting to prevent frost on these crops.

The three stations whose data are used in this study are located in the following geographical coordinates: Lat: 38 14'7.43" Lon: 1 18'35.57", Lat: 38 19'11.3" Lon: 1

19'27.58" and Lat: 38 17'2" Lon: 1 29'46,84", being the altitude of each of them 282, 341 and 244 meters and their acronyms DS_{CI22}, DS_{JI81} and DS_{CI42} respectively. Each station is equipped with the following sensors and ephemeris: weather vane, radiometer, rain gauge, data-logger and thermo-hygrometer.

The dataset used for this study range from 1 January 2012 to 31 January 2018 for each weather station. For each day there are a total of 24 values, one for each hour. Each instance of the dataset, used for this preliminary study, is composed of 16 attributes detailed in Table 1.

Table 1. Attribute Description

Attribute	Description	Attribute	Description
STATCODE	Weather station code	ACCRAD	Accumulated radiation
DATE	Date of data reading	MEANWS	Mean wind speed
HOUR	Hour of data reading	MEANWD	Mean wind direction
RHMEAN	Mean relative humidity	MAXWS	Maximum wind speed
MAXRH	Maximum relative humidity	RFALL	Rainfall
MINRH	Minimum relative humidity	DEWPT	Dew point
MEANRAD	Mean radiation	VPD	Vapor pressure deficit
MAXRAD	Maximum radiation	TMIN	Minimum temperature

3.2. Data Preprocessing

Given that the main objective of the IDA process is the frost crop prediction, first a selection of instances is carried out to obtain a data subset describing situations close to frost. In this way, all instances with a value TMIN > 7.0 are eliminated. Also, there are some attributes that are irrelevant for the analyzed problem, such as the attributes STATCODE, DATE and HOUR. These attributes are eliminated.

On the other hand, the datasets considered in this work contain information that is stored chronologically in constant time periods. They contain information with special characteristics due to the temporal relationships between the data. These characteristics can not be directly addressed by traditional DM techniques [8]. There are two ways to approach this problem:

- The development of specific techniques to address this kind of information without any transformation.
- The transformation of information so that it reflects these intrinsic characteristics and can be treated by non-specific DM techniques.

In this work the second option is followed, carrying out a data transformation that captures this temporal relationship using traditional DM techniques. Thus, the initial attribute set is extended with one numerical attribute and one nominal attribute:

- TMIN_{DIF}: which indicates the difference between the minimum temperatures of the two readings prior to the current one.
- CLASS: label assigned to the instance that can take two possible values {FROST, NOFROST}. To carry out the label assignment, the following decision rule has been applied: "if TMIN$\leq$ 0 then CLASS=FROST else CLASS=NOFROST".

Once the minable view of the DS_{CI22}, DS_{CI42} and DS_{JU81} datasets is obtained, a new dataset is created (DS_{all} dataset) composed by the joint of the three previous datasets. The dataset description that constitutes the minable view of data is shown in the Table 2.

Table 2. Dataset Description

		Attributes	
Dataset	Instances	Numerical	Nominal
DS_{CI22}	4206	14	1
DS_{CI42}	5995	14	1
DS_{JU81}	7953	14	1
DS_{all}	18154	14	1

3.3. Data Mining

Once the data minable view is obtained, the DM phase applies techniques on these data in order to solve regression or classification tasks. In this paper, two techniques are applied to the available data: the M5P technique to carry out the estimation of the numerical attribute TMIN (regression task) and the C4.5 technique to carry out the estimation of the nominal (categorical) CLASS attribute (classification task). The implementations of these techniques are provided by Weka package [7].

Decision trees model the linear/nonlinear relationships between the attributes and, in addition, they are interpretable and understandable. In general, techniques generate decision trees for a dataset by recursive partitioning. A decision tree is grown using a depth-first strategy. Techniques consider all the possible attributes that can split the data in each node and select the one that gives the best value for a given measurement. From a built decision tree, the decision or inference process for a new instance starts at the tree root. The instance is then evaluated at one node and takes the appropriate branch to its outcome. The process continues through several internal nodes until it finds a final leaf. The decision is represented by these leaves.

J48 is a C4.5 decision tree implementation. To build each node, C4.5 [18] selects the attribute that gives the best information gain. Leaves represent the values (labels or categories) of the class attribute. M5P [26] builds regression trees, whose leaves are composed of multivariate linear regression models and whose nodes are built over the attributes that minimize the expected error (deviation) respecting the output attribute.

To carry out the inference of the TMIN and the CLASS attributes different subsets of the datasets described above have been considered. The subsets are selected in order to analyze how important is the temporal relationship in the data and the importance of the mean values against the extreme values of a measure. With this information we can understand better the intrinsic relationships in the data and improve the data collection phase, focusing it on the collection of the most relevant values for the problem in study. The subsets are obtained as follows (in all of them the CLASS attribute is eliminated when the regression task is carried out and the TMIN attribute is eliminated when the classification task is carried out):

Conf_1: Configuration with the highlighted attributes of the Table 1 by adding the TMIN/CLASS and TMIN_{DIF} attributes (14 attributes).

Conf_2: Configuration with the attributes of Conf_1 where MEANRH, MEANRAD and MEANWS attributes are eliminated (so that only the extreme values of these measures are used in the instances) (11 attributes).

Conf_3: Configuration with the attributes of Conf_1 where MEANRH, MEANRAD, MEANWS and TMIN_{DIF} attributes are eliminated (10 attributes).

3.3.1. Regression task

To carry out the inference of the TMIN attribute, the M5P regression tree has been applied to the different configurations of the four datasets. The measures used to analyze the results are the following:

- the root mean square error (RMSE)
- the mean absolute error (MAE)
- the Pearson correlation coefficient (CC) that measures the statistical correlation between predicted data (Y) and real ones (X). It takes values between [-1,1]. CC is defined according to $CC(X,Y) = \frac{Cov(X,Y)}{\sigma_X \sigma_Y}$ where $Cov(X,Y)$ is the covariance between X and Y, and σ_X, σY are the standard deviations of X and Y, respectively. The different possibilities from this parameter are the following:
    - If CC$=1$: total dependency between predicted and real values (direct correlation).
    - If $0 <$CC< 1: positive correlation.
    - If CC$= 0$: not lineal correlation.
    - If $-1 <$CC< 0: negative correlation.
    - If CC$= -1$: total dependency between both values (inverse correlation).
- the determination coefficient (R^2) that measures how well data fit a statistical model (proportion of the variance in the dependent attribute that is predictable from the independent attributes). It is defined as $R^2 = \left(1 - \left(\frac{\sum_i (X_i - Y_i)^2}{\sum_i (X_i - \bar{X})^2}\right)\right)\%$.

The results obtained are shown in the Table 3. The values obtained to these measures for a 5-fold cross-validation are indicated to each dataset.

When analyzing the results it is observed that both the coefficients of correlation and determination are very good in all the models (for each model and each configuration of the dataset, the correlation between the TMIN attribute and the rest of the attributes, and the proportion of explained variance are very high).

Appreciably better models (they get higher correlation/determination coefficients with a lower error) are obtained using the DS_{JU81} and DS_{all} datasets, regardless of the configurations.

Since M5P obtains a tree model whose leaves are multivariate linear models, an analysis is carried out to know which attributes are part of the test nodes of the tree (internal nodes) and which attributes are part of the multivariate linear models of the leaves. This analysis is performed on the DS_{all} dataset with the three configurations defined. The analysis indicates that the models obtained with the three configurations have a similar structure and certain attributes in common. Specifically, they share the DEWPT, VPD, MAXRH and MAXRAD attributes that are used in the main tree branches. It should

Table 3. Results with M5P technique and a 5-fold cross-validation

	Dataset	CC	R^2	MAE	RMSE
with $Conf_1$ (14 attributes)	DS_{CI22}	0.9814	96.31%	0.2487	0.3513
	DS_{CI42}	0.9904	98.09%	0.2411	0.3328
	DS_{JU81}	0.9930	98.60%	0.2155	0.3070
	DS_{all}	0.9910	98.21%	0.2286	0.3244
with $Conf_2$ (11 attributes)	DS_{CI22}	0.9814	96.31%	0.2492	0.3515
	DS_{CI42}	0.9900	98.01%	0.2420	0.3394
	DS_{JU81}	0.9927	98.54%	0.2156	0.3135
	DS_{all}	0.9909	98.19%	0.2285	0.3260
with $Conf_3$ (10 attributes)	DS_{CI22}	0.9815	96.33%	0.3505	0.2487
	DS_{CI42}	0.9899	97.99%	0.3410	0.2420
	DS_{JU81}	0.9927	98.54%	0.3134	0.2158
	DS_{all}	0.9909	98.19%	0.3263	0.2292

be noted that the DEWPT and VPD attributes appear in the main tree nodes, indicating that they have a greater power of data discrimination for this regression task. Because these attributes are important in the models, they can also be considered important in the problem studied. In addition to the good fit of the models obtained in the different configurations, the error obtained is very affordable since it is less than 0.5 Celsius degrees. This error can be assumed as it is the default error of the different temperature measuring instruments.

3.3.2. Classification task

To carry out the inference of the CLASS attribute, the decision tree J48 has been applied to the DS_{all} dataset with the three designed configurations. To solve the classification task, the TMIN attribute is eliminated and now the CLASS attribute is considered.

The measures used to analyze the results are the following:

- The accuracy of the model.
- Area under the ROC curve of the model (the perfect model will get a value of 1).
- The f-measure (harmonic mean of precision and recall), evaluated in [0,1] (the best model will be indicated with a value of 1).

The obtained results are shown in Table 4. The table shows the average of these measures to a 5-fold cross-validation.

As can be seen in the results obtained, the three models learned have a similar behavior. Again (as with the regression models), analyzing the decision tree nodes, the attributes that are common to the three models are: DEWPT, VPD, MAXRH, MAXRAD, MEANWD and MAXWS. As in the regression analysis, the DEWPT and VPD attributes appear in the main nodes of the trees, indicating that they have a greater power of data discriminating for the classification task.

Table 4. Results for DS_{all} dataset with J48 technique and a 5-fold cross-validation

Configuration	Attributes	Accuracy	ROC area	f-measure
$Conf_1$	14	89.03%	0.930	0.890
$Conf_2$	11	89.41%	0.934	0.894
$Conf_3$	10	89.17%	0.938	0.892

Considering the attributes highlighted in the estimation of the TMIN attribute and those highlighted in the classification of the CLASS attribute, it can be concluded that the attributes DEWPT, VPD, MAXRH, MAXRAD should be considered of special relevance in the problem of crop frost prediction.

The prediction results obtained in both classification and regression are very interesting in order to make a temperature prediction to prevent frost. This first preliminary study indicates the most relevant climatic variables to carry out a local study in other plots and thus create a web application that alerts farmers when a frost is going to occur, either by providing the temperature or by indicating whether a frost can occur or not. Thus, the next model to study would be to perform a temperature prediction at least 2 hours in advance.

4. Conclusions and Future Work

In this preliminary study, the temperature prediction is carried out based on the values of certain attributes that the data mining models have detected as most relevant. To perform this prediction, regression and classification tasks have been performed. The results obtained for both tasks are very satisfactory with an error of less than 0.5 Celsius degrees. Therefore, the models obtained can be used to construct a decision support system to predict low temperatures and classify if a frost will occur. In addition, these models indicate that the DEWPT, VPD, MAXRH and MAXRAD attributes are important in the resolution of the crop frost prediction problem. As future work, the objective will be to carry out the temperature prediction with at least two hours in advance, time in which farmers can take measures to protect their crops in the case that the prediction indicates the threat of a frost. This, together with the obtaining of the local values of the attributes detected as relevant in the study, will give rise to a system that takes advantage over the systems that are currently used based on the capture of the local temperature by means of a sensor and warning farmers if a frost is occurring. Moreover in the classification task, the instances have been labeled using a simple decision rule. As future work, these labels will be obtained through the use of clustering techniques or fuzzy/crisp discretization. In addition, for the obtaining of the models, DM techniques that allow the treatment of imperfect data will be used. These techniques allows us to model the errors committed by the instruments for obtaining measurements

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Plant Volume Estimation Based on Multi-View Stereo and Piecewise Segmentation for Precision Agriculture

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Abstract. Piecewise segmentation approaches of plant volume estimation methods are presented. The primary 3-D reference shape of a target plant is obtained through the 3-D point cloud generation using multi-view stereo techniques. Then, the entire shape region is segmented into multiple pieces to calculate the plant volume. Two different segmentation method of i) slice-based and ii) cell-based are adopted. In the slice-based model, the entire point cloud is horizontally split into slices, whereas in the cell-based model, it is divided into small cubical cells. After that, volume estimation procedures for the two models are applied. Various experiments were performed to test validity of presented methods. Experiments to find the proper number of segments for the methods were also performed.

Keywords. Plant Volume Estimation, Multi-View Stereo, Precision Agriculture

1. Introduction

The cubical shape reconstruction of plants provides rich information for precision agriculture studies. Although attaining the 3-D model is expensive, the data could be a crucial feature for environmental control of farmlands. Plant volume estimation is one of the keys to achieve precision controls and to provide the forecasting on possible occurrence of disease.

For example, the occurrence of insects or disease lowers the growth rate of plants and it results for the volume of plant not to increase or to decrease. However it is somewhat difficult to find it at the early stage. When a farmer finds the abnormality, the crop has already suffered irreparable damage. Monitoring plant volume changes can significantly reduce this kind of risk.

As the first step to estimate volume of plants, a 3-D shape model is necessary. However, reconstructing 3-D shape is very complicated and computationally intensive. It usually requires expensive equipment such as 3-D scanners. In the purpose of plant volume estimation, there is no need to reconstruct the target plant shape very accurately but only detecting the rough volumetric shape is adequate to obtain the size of volume within the

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allowable error range. A computationally effective or cheap solution for plant volume estimation is necessary to develop practically applicable devices on the farmlands.

A volume estimation method for a plant is presented. The multi-view stereo technique is used to obtain cubical shape reference points called 3-D point cloud. Then, entire shape reference region is segmented into multiple pieces to calculate the volume. Two different segmentation methods of i) slice-based and ii) cell-based are adopted. In the slice-based model, the entire point cloud is horizontally split into slices, whereas in the cell-based model, it is divided into small cubical cells. Then, volume estimation procedures for the two models are applied.

2. 3-D Modeling

2.1. 3-D Point Generation

To generate 3-D point clouds, a bundle of cameras could be used. The multi-view stereo technique adopts the binocular disparity method into 3-D point cloud generation. Basically in this approach, the point which is detected by more than 3 cameras would be registered to point cloud. By this characteristic, it is known that using more images improves the quality of 3-D model. But there should be a nice compensation with processing time.

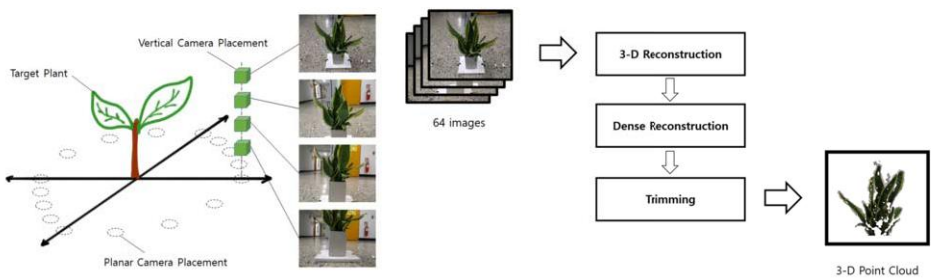

Figure 1. 3-D point cloud generation using Multi-View Stereo

Simple object that even have no need to be accurate use a few images [1,2]. The steps of multi-view image capturing and 3-D point cloud generation are shown in Figure 1. Total 64 images are used to generate 3-D point cloud. For experimental purpose, 16 circular locations were chosen. Also images were captured at four different heights of each locations.

Some empirical research have been conducted to get more accurate model by multi-view stereo [3,4]. Basically A method using more pixels and images gets better results. In particular, it is recommended to use combined images of full and detailed images. And then using more wider depth of field would be good. In fact, the blurry background images got worse results than the other in this research. Also taking various horizontal angles was better than taking various vertical angles too.

The 3-D point cloud usually does not have absolute scale or base location. So an appropriate scaler or affine transformation is necessary to normalize 3-D point cloud [2,5]. Therefore, in this paper, a board-shape pedestal is used as a scale reference. On the other hand, location reference is not considered in the experiment, as normalizing the location of point cloud is not required for volume estimation.

2.2. Volume Estimation

A simple way to estimate volume of a plant is setting a primitive shape of target, such as sphere, cone, cylinder or predefined shape [5,6,7]. For example, if a sphere can perfectly fit on point clouds of a plant, the volume of plant is estimated by the sphere volume. However such a good fitting case may be very rare.

To improve the volume estimation accuracy, entire point cloud can be divided into several point clouds. This sub-region approach provides better fitting of external shape and reduces fitting errors than original whole region. Using well divided point cloud, structural properties of plants can be reflected in volume estimation. However there also be an information loss that caused by not enough points in a sub-region. Therefore an appropriate degree of division is required.

The degree of segmentation is determined by the complexity of a plant and the number of points. The more complex the shape of the plant, the greater the degree of splitting. However, a sufficient number of points are required in order to increase the number of divisions. The more points are necessary to get high estimation accuracy.

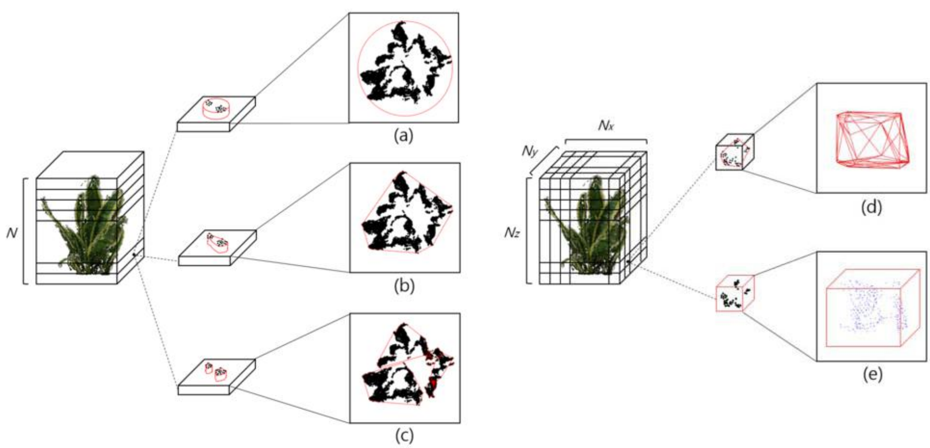

Figure 2. Volume estimation methods; For the slice-based model (a) Cylindrical Approximation, (b) Polygon Approximation and (c) Clustering Approximation. For the cell-based model (d) Polyhedron Approximation and (e) Dense Cell Selection

Two different segmentation methods are adopted: i) slice-based model and ii) cell-based model. In the slice-based model, the entire point cloud is horizontally split into N slices as [8], whereas in a cell-based model, the entire point cloud is divided into several cubical shapes. Then, several different volume estimation procedures for the two models are applied.

As shown in Figure 2, total five different methods are used in this paper. The methods (a) Cylindrical Approximation, (b) Polygon Approximation, (c) Clustering Approximation are applied to the slice-based model. The methods (d) Polyhedron Approximation and (e) Dense Cell Selection for the cell-based model.

2.2.1. Slice-Based Model

In the slice-based model, the volume is thought of a stack of slices. In Figure 2, left bound-box model is sliced *N* times horizontally and then all the points in each slices are projected on the bottom surface. Then the volume of each slice is estimated by multiplying the volume of surface and height of slice. Suggested surface volume estimation methods are (a) Cylindrical Approximation, (b) Polygon Approximation and (c) Clustering Approximation.

In the (a) Cylindrical Approximation model, the shape of the plant is assumed to be cylindrical. In the circle a center and radius can be easily attained using Welzl's algorithm. The processing time has also proven to be linear. In the (b) Polygon Approximation model, the convex-hull based polygon model will be used to reduce the incorrect estimation. A convex-hull is a set of points in outer edges. Then a 2-D polygon can be generated from the convex-hull. Generally convex-hull calculation is conducted by Graham's scan algorithm. Its time complexity is O($nlogn$).

If the subsection of a plant is not cylindrical annulus or similar shape, empty space are contained in the approximated circle or polygon. The estimated volumes includes large errors because of this phenomenon. Segmented point clouds are grouped and getting convex-hull estimation for each group. The accuracy of the estimation would increase but it pays the computational cost.

For the (c) Clustering Approximation, density-based cubical clustering of application with noise algorithm (DBSCAN) is chosen. The DBSCAN uses the information about density rather than distribution by adopting ε parameter. Also the noise can be reduced by ignoring lower density region that has less points than predefined minimal points.

The estimated volume varies on the parameter *N*. The accuracy would get better with more precise slicing until a degree of accuracy. But when the clustered points are regarded as noise, the accuracy will get worse.

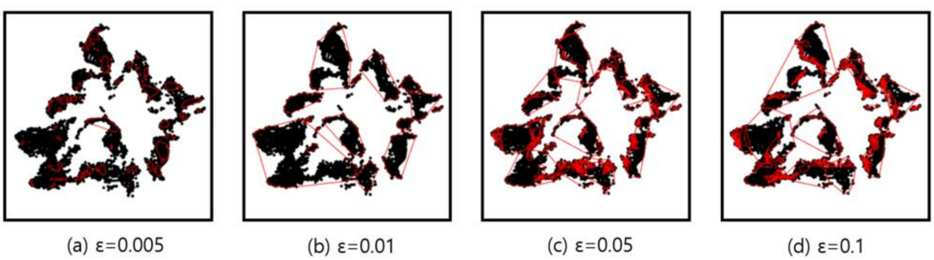

Figure 3. Clustering result according to ε change

Figure 3 shows an example of clustering results with various ε, a density control parameter. As ε is increased, the size of a cluster generally increases. If a tiny value is chosen for ε, then the cluster will not form properly as in (a) case of Figure 3. However, using larger ε includes the empty regions that are not part of the plant body as shown in (c) and (d). So ε should be chosen appropriately to improve the clustering results.

Table 1. Experimental results of volume estimation

Applied Method	Estimated Volume (cm^3)	Processing Time (sec)	Error (%)
Ground-Truth	15,840		
Whole-Polyhedron	20,323	0.04	28.3
(a) Slice-Cylindrical($N = 1000$)	22,470	0.96	41.9
(b) Slice-Polygon($N = 8$)	17,589	0.02	11.0
(c) Slice-Clustering($N = 2, \varepsilon = 0.01$)	17,435	39.8	10.1
(d) Cell-Polyhedron($N_{x,y,z} = 2$)	13,327	0.06	15.9
(e) Cell-Selection($N_{x,y,z} = 5, m = 125$)	17,101	0.04	7.96

2.2.2. *Cell-Based Model*

In this model a point cloud is divided into large number of small cells. Then the volume can be estimated by calculating volumes of each cells independently. Volume estimation of each cell is done as shown in (d) Polyhedron Approximation and (e) Dense Cell Selection of Figure 2.

Figure 2-(d) shows the point cloud of a cubical cell and the generated polyhedron of the cell. The same method used in the (b) Polygon Approximation model of the slice-based model is used to generated the polyhedron. In the (e) Dense Cell Selection method, the cell volume itself is used as the unit of volume measurement, In this method, the number of dense cells are used to estimate the volume. The dense cells are selected if there are sufficiently large number of 3-D points in the cell.

3. Experiments

Various experiments were performed to test presented volume estimation methods. Experiments also has been done to find out how the proper number of segment affect the estimation accuracy of each methods. The computing devices are equipped with 3.40GHz Intel i7-4770 CPU, 28GB RAM, running on MS-Windows 10. Also MatLab R2016b was used for the implementation of volume estimation methods.

To generate useful 3-D point cloud, the multi-view stereo technique is used. Three 3-D point cloud are generated from each 64 2-D images. The result gets worse with the more complicate shape plant. An useful results were come out at least using 128 images. Normally for making point cloud, 3-D reconstruction and dense reconstruction are conducted. At last a little correction is made to make useful point cloud. In this experiments, *VisualSfM*[9,10], *CMVS*[11] and *MeshLab*[12] are used to perform 3-D reconstruction, dense reconstruction and point cloud retouching each.

Three different plants are selected to make 3-D point clouds: (a) Sansevieria, (b) Aerides Japonicum Reichb and (c) Schefflera Arboricola. Figure 4 shows the images of plants and their generated point clouds. 64 images are used to synthesize 3-D model for each plant.

The quality of the generated 3-D point clouds got worse in the order of (a), (b) and (c). The number of each generated points without flowerpot are approximately 13,000, 7,000 and 500 respectively. However these results are not enough to use in volume estimation. So with extra 64 images to (a), total 128 images are used to generate new point cloud. At the result, the number of points are about 76,000 that is enough to use in experiment.

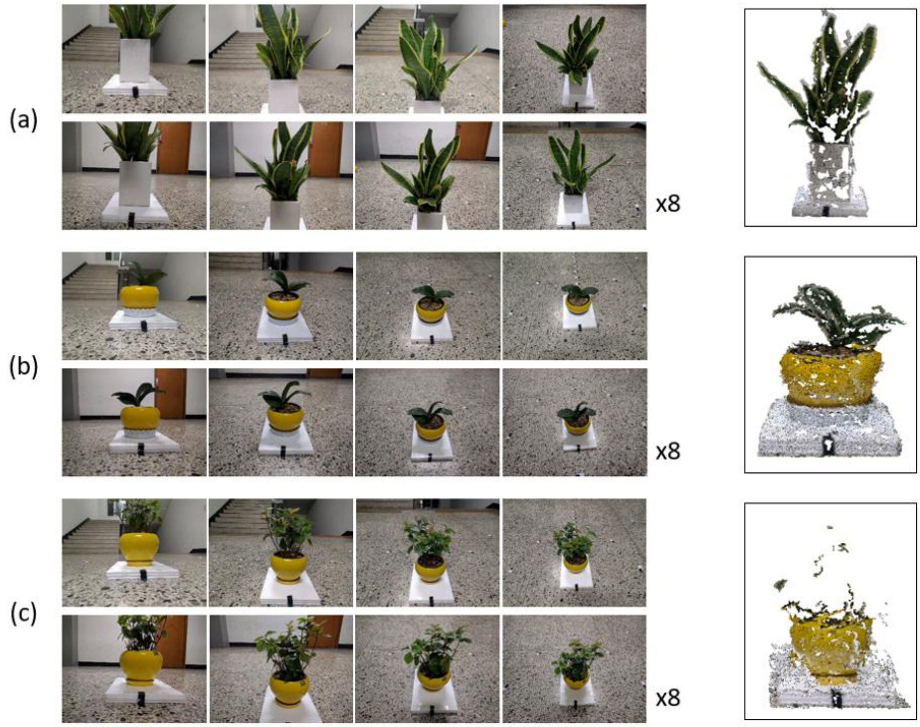

Figure 4. Generated 3-D point clouds

In this experiment, images are captured at the same distance for research purpose (about 50cm). However using images captured on combined distances was more effective to get high quality result. Also variation of camera planar placement was better than variation of camera height in the experiment.

According to proposed volume estimation methods, the results are compared in Table 1. There are great disturbances to measure and estimate exact volume of a plant. Thus the error is expected to be large. The ground-truth is measured manually based on the area of surface and height measurement of the body, since measuring the exact volume is impossible without extracting the plant body itself from the pot. The volume is about 15,840cm^3 except the pot volume shown in Figure 4-(a).

To compare with proposed division model, a mesh where whole points surfed is estimated as (b) which is the same with [13]. This model was chosen because it has better estimation accuracy then any primitive shape estimation method such as sphere. As a result, the volume was overestimated as 28.3%.

In the slice-based model, (b) Slice-Polygon method got better estimation result than (a) Slice-Cylindrical method although cylindrical approximation method is used with more split. This demonstrates the limitations of cylindrical method for overestimation. Moreover in cylindrical approximation method the error is significant even though N is much larger than other methods. This shows the sliced area of the plant should not be assumed to be a circle. On the other hand, (c) Slice-Clustering method yielded the best result among all proposed slice methods. However it takes more times than other methods because of clustering.

For the cell-based model, (e) Cell-Selection method has better estimation results than the other proposed methods. Also (d) Cell-Polyhedron method has worst estimation results than other proposed methods except (a) Slice-Cylindrical method. This is caused by not considering the inter-connectivity among adjacent cells. The inter-cell volumes are lost and the amount is excluded in the final volume estimation. On the other hand, in cell-based selection method, the inter-connectivity was fully considered so the result got better.

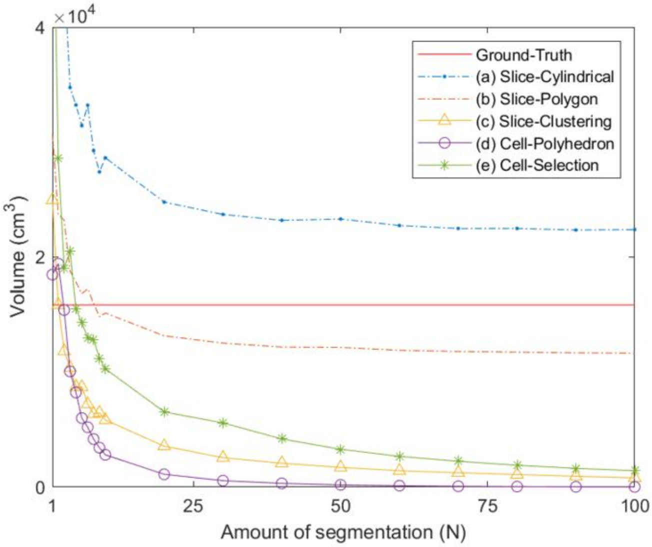

Figure 5. Estimated volume by the number of segments

Along with the number of segments in the slice-based and cell-based approaches, the estimated volume accuracies are compared in the Figure 5. The ground-truth is provided for comparison with the actual value. In the (c) Slice-Clustering method ε and minPts are chosen by 0.01 and 5 respectively that is from several empirical experiments. Also in the (e) Cell-Selection method m is defined as N^3.

For all slice-based methods, the volume is somewhat overestimated when the number of slices is small. However, as the number of slice becomes larger, the estimated volume decreases and seems to be converge to some errors. Furthermore, it is obvious that the estimated volume will decrease drastically, when there are not enough points on the slices.

The DBSCAN uses noise concept and this may occur information loss. The graph of (c) Slice-Clustering shows how much information is lost compared to the (b) Slice-Polygon method. This estimation method, however, may takes a role of normalization by eliminating all of points whose membership information is unclear.

The cell-based method has weak inter-connectivity among adjacent cells. This leads to underestimate a volume. So when using this method, a scaler should be adopted properly. On the other way, the (e) Cell-Selection method has more larger inter-connectivity than (d) Cell-Polyhedron method. The estimation results is better too because of it. However the cell-based method is vulnerable to increasing slices. It is harder to maintain sufficient points in a cell and the inter-connectivity gets more weaker as the number of slice increases. This shows the need to set an appropriate compensation for the amount of slicing in cell-based method.

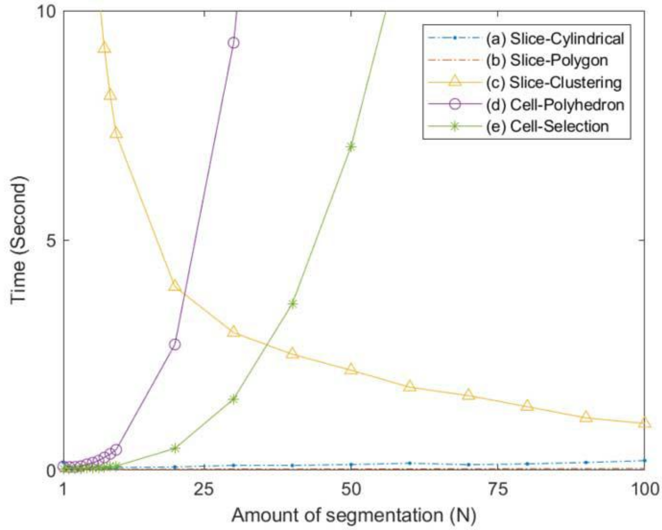

Figure 6. Processing time by the number of segments

The computation time of (a) Slice-Cylindrical and (b) Slice-Polygon are almost same as shown in Figure 6. They are already proved to be linear. While the computation time of (c) Slice-Clustering method is inversely proportional to the number of slices. This is because the smaller number of slices, the more points there are in a cluster, and the more time it takes to be finishing the clustering process.

Unlike slice-based methods, the required processing time increases exponentially in the cell-based method. Two cell-based methods should register each point in the appropriate cell, which results in significant time consumption proportional to the N^3. Furthermore (d) Cell-Polyhedron method spends more time for convex-hull calculation. Thus the value of N should be minimized when adopting a cell-based method.

4. Conclusion

Several piecewise approaches of plant volume estimation methods are presented. The results of estimation were compared to figure out the strength and weakness of each method. Generally properly chosen split number got better result than naive whole volume estimation. The presented approaches can provide cost-efficient solutions of plant or crop volume estimation for precision agriculture, though it has limitation for the control parameters to be tuned.

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Semi-Automatic Ontology Population for Online Quality Assessment of Particulate Matter Sensors

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Abstract. The increasing coverage and heterogeneity of sensor-based systems due to the low acquisition cost, ease of deployment and data collection makes the range of possible applications in the context of smart cities bigger. This makes the process of quality measurement of the generated data as well as anomaly detection some of the toughest challenges to overcome. The absence of a common mean to express general information about the sensor deployment, measurement capabilities, output data and the conditions, under which the sensor could produce anomalies, casts a big shadow over the trustworthiness of the data. The large number of low cost sensors makes the description of their context information even more difficult. We propose an architecture that enables the semi-automatic creation of context information about the sensors through the use of available information about the output data and the available information about the deployment. The definition of the sensor with its relevant context information is done by populating ontology instances for every sensor using the SSN and SWEET ontologies. We take the use case of the luftdaten.info platform with particulate matter sensors. This architecture with its implementation lay the groundwork for further steps such as including anomaly detection rules and quality measurement conditions into the sensor model. The ontology instance produced is the input used for automatic generation of data stream processing queries with data quality assessment.

Keywords. Data Stream Processing, Data Quality, Sensor Networks, Ontologies, Context Modelling

1. Introduction

In a time where the industrial development enabled the increase in the production of cheap and accessible sensors, a wide range of applications are made available at a low cost. These sensors help generate a lot of data about the sensed environment and make the prospect of using their data in smart city use cases a really good prospect.

The assembly of some sensors is so simple that people with next to no knowledge can assemble a sensor after following a simple documentation on how to put together the building blocks of the sensing device. A good example of such devices is Particulate

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Matter (PM) sensors provided by the OK Lab Stuttgart for the luftdaten.info Citizen Science project[2]. The project is part of the "Code for Germany" program[3]. The PM sensor system can be built in a short amount of time and provides data about the particles of types PM10 and PM2.5 in addition to the current temperature and humidity. The goal of the project is to enable the participation of citizens in the collection of data about the air quality in one of the biggest and most air-polluted cities of Germany (Stuttgart), to cover the largest possible area of the city and provide extensive information about the current air quality. More of these sensors are also spread over different areas in Germany. Those sensors are easy to build and deploy and provide simple access to air quality data for the community and city management. However, they become faulty under certain circumstances. Furthermore, they do not have enough installation information, which means very low context information is available for every sensor.

Anomaly detection and quality measurement are closely related to the context of the sensors. Context can be any information that describes directly or indirectly the conditions of the sensor with regards to its deployment area and the sensing process. The huge number of sensors, coupled with a lack of provenance and context information makes the anomaly detection and the quality assessment a tricky task. We propose an architecture to create ontology-based context information about the sensors from the available resources in the internet, which makes the ontology model instantiation for every sensor occur in a semi-automatic manner. The instances created for every senor can then be used to generate queries for online quality assessment to run on a customizable Data Stream Management System called Odysseus [1].

The rest of the paper is structured as follows: In the second section we discuss the related work about ontology based approaches to describe context, define anomaly detection rules, instantiate ontologies and describe quality assessment methods. The third section describes in detail the use case we take to implement our approach where we describe the environment and situation of the sensors. In the end of the section we derive the requirements from the use case. In the fourth section we present the approach and the underlying architecture of our solution. The fifth section contains the evaluation of the architecture in terms of feasibility and impact. Finally we discuss the achieved work so far with the future steps.

2. Related Work

Batini et al. offer an interesting view on the data quality dimensions and their respective definitions in [2]. The definition of Batini covers the most important dimensions of data quality that sensor data need to have like accuracy, completeness and timeliness.

Work in the area of data quality and data anomaly using Ontology-based solutions is available and has provided solutions that use ontologies to describe the quality metrics. Geisler et al.[3] propose a Data Quality ontology-based framework for data stream applications, where they define quality metrics for content, queries and applications that use the data. The framework uses an ontology to define all the meta-data for the data quality

[2]http://luftdaten.info/
[3]https://codefor.de/

metrics. The framework offers the option of describing the sensors and their quality metrics through semantic rules, but all the meta-data about the sensor need to be provided. Kuka et Nicklas [4] provide a solution for general quality-aware sensor data processing, that uses probabilistic processing to provide continuous data quality values for the incoming data. In [5], kuka enhances the process by adding a description of the context by using the SSN ontology [6] to describe context information about the sensors used.

The issue of Automatic Ontology Instantiation was addressed by Shchekotykhin[7], where they present a comprehensive ontology instantiating system that mainly instantiates information provided in tables. Makki et al. [8] propose a semi-automatic ontology instantiation in the domain of risk management, where they use *Natural Language Processing* to extract knowledge and information. Alani et al. [9] achieve ontology population by linking a knowledge extraction tool to an ontology to provide the information extracted in a machine readable format. The work in the area of ontology instantiation did not cover the cases of sensor data and is limited to some specific use cases.

The use of ontology-based solutions for anomaly detection rules description is presented by Sarno and Sinaga [10]. Roy and Davenport [11] develop a maritime domain ontology backed by automated reasoning service for anomaly detection, classification of vessels and identification of threats. An often used field of application for anomaly detection and context are in the area of intrusion detection in Network surveillance. Some attack scenarios are only detectable by interpreting the network metrics given the Context information like network load by time of the day [12]. From the above contributions it becomes apparent that ontology based solution to describe anomaly detection rules for sensors is missing. We note also the lack of mechanisms to populate automatically or semi automatically ontology based descriptions of deployed sensors.

3. Use Case

Sensors are known in general for their faulty behavior. We can get information about the behavior and data quality of the sensor from:

- Data sheets containing conditions, under which it functions properly. It also specifies the extreme conditions that cause the sensor to provide erroneous values and give anomalies.
- Learned dependencies between the deployment environment and the sensor; the accuracy of the values of a sensor can also depend on other values like external factors, which could impair its accuracy. In a previous work[13], we have shown that historical data from people counting sensors and distance sensors can be used to find correlations that are used to determine the accuracy of the former sensor based on the distance measured by the other.

Both sources count as context information and its inclusion in online processing of the sensor data helps to improve quality measurement and to detect anomalies. There are a couple of possible use cases for the deployment of context information through ontologies. Context information like weather, location or time can be used to evaluate the measurements given by the sensor nodes. This information defines ranges of acceptable data points. An example is the particulate matter sensors (called PM sensor for the rest of the paper) of the OK Lab Stuttgart. The sensor nodes have a maximum survival range related to the humidity of the environment. Such knowledge can be introduced into a context representation through ontology instantiation of the sensor, which can be then used to generate data stream queries that perform anomaly detection on the incoming data. Context information is also valuable, when it enables the use of data fusion to measure the quality of the sensors. Considering the sensors used in the luftdaten.info, we know that the humidity affects considerably the accuracy of the particulate matter values. In the used sensors systems, the used particle meter is the SDS011 of Nova Fitness[4]. The data sheet describes a Humidity upper bound of 70% for a working environment. If the humidity rises above this value, the quality of data decreases, and more anomalies can occur. On some sensor platforms are PM sensor installed together with humidity and temperature sensors. For these sensor platforms the anomaly detection rule derived from the data sheet could be used with the on-board humidity sensors. The rule specifies a relative error of 15% ($\pm 10\ \mu g/m^3$) in a humidity less than 70%. Above this range the quality is undefined. Since these values also come from cheap unreliable sensors they need verification and cannot be used alone to check the PM values for anomalies. We need to use other data sources like the weather stations located in an acceptable range of the deployed sensors to perform data fusion to closely check, whether the sensor have the normal conditions to function properly and to check the accuracy of the values of humidity. Fig.1 shows how the weather stations within a close range from the sensors can be related to each other and later used as data source for quality assessment and anomaly detection of the sensor measurements.

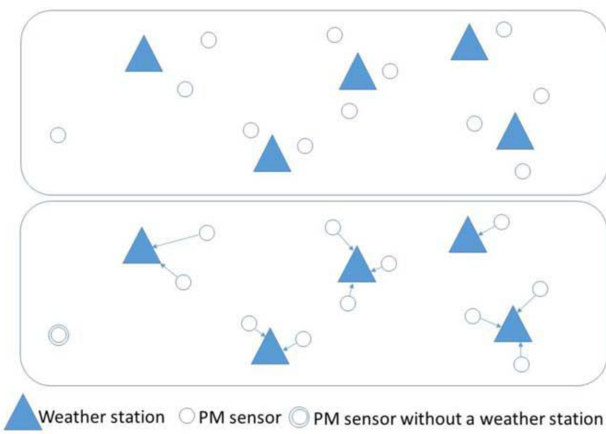

Figure 1. Linking of the sensors to the weather stations based on location

For the sensor platforms without humidity sensors, the context information (location of the nearest weather station and how to access its data) provides the possibility to deploy the anomaly rule. The deployment location of the sensor can also influence the measurements. If a sensor is deployed indoors, then we get constantly values that are far from the reality. The quality of a sensor data can be measured by using such a query operator in Listing1

[4]https://inovafitness.de/shop/sds011/

```
output= QUALITY({ATTRIBUTES = ['PM10'],
PROPERTIES=['Accuracy']},FoI:PMSensor)
```

Listing 1: Query Operator to Measure the Accuracy of PM10 values

Such a query operator can measure the accuracy of the sensor, but it needs information on how to estimate the accuracy. This information must be at least provided once (in the case of fact sheet about the working conditions of the sensor), or be regularly updated if the sensor makes behavioral changes. If such information has to be entered every time by a human user for a new sensor or for an update of an existing one, then the whole process of quality assessment becomes burdensome and unwieldy.

Since those sensors are assembled and put into use completely independently by end users, the task of estimating the quality of their data becomes very difficult without an automatic or a semi-automatic process. Such quality assessment operators can be kept simple, if the ontology instantiation of every sensor is created and maintained with the needed information about the sensor and its dependencies.

From the description of the sensors and used we can derive the following requirements:

- We need to serialize location information of the sensors based on the available information.
- For every sensor, we need to find data sources like weather stations or neighbouring sensors to compare the reported values of every sensor.
- The ontology based population of every sensor must contain information about the output schema.
- The ontology instantiation of every sensor should also describe directly the data sources related spatially to the sensor.

The next sections present the approach adopted and the system implementations to populate the ontology for every sensor, while adhering to the requirements set from the use case.

4. Approach

4.1. Architecture

The architecture consists of two parts as shown in Fig. 2: the Ontology Processing Engine (OPE) and the Stream Processing Engine (SPE). The first part is concerned with collecting the context information about the sensors and weather stations to generate instances of the ontologies. Ontology instances express all the needed information about the sensor. This information is gathered from three main sources: information about the sensors from the data sheet, information about weather stations, and the data generated by the sensor. The first source gives the location of the sensor, minimal working conditions of the sensor and data quality related conditions. The second gives a full list of the existing weather stations and their coordinates. The third one helps to extract the schema and the types of every attribute in the data. The Stream Processing Engine receives data

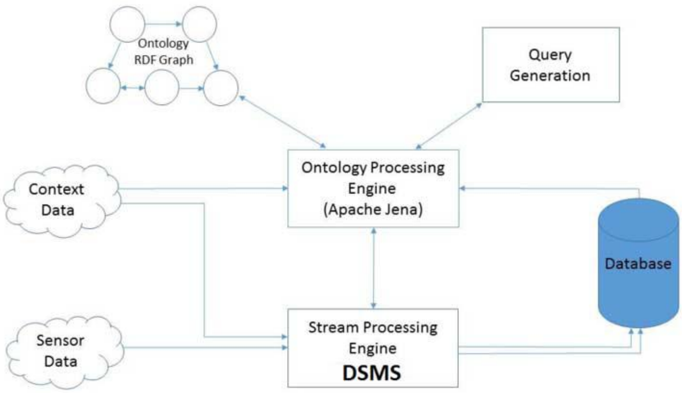

Figure 2. Architecture of the ontology population system

streams from the sensors and pulls information about the weather stations and their data. It prepares the data for storage and writes it to the database.

The OPE is the main component that takes the information described above and generates the ontology instances for the sensors. It stores the instances in an RDF Graph and sends the model (ontology instantiation) of every sensor to the query generator. The generated queries measure the quality of the sensor data based on the sensor model described by the ontology instance. The queries can be deployed on a Data Stream Management System like *Odysseus*, where the data from the sensors come in a continuous stream to be assessed.

4.2. Ontologies

Ontologies have an important role in the architecture. The OPE must have a clear set of base ontologies that satisfy the requirement of giving full details about the sensor, its data quality requirements and the possible reference data sources in the form of weather stations. We use a combination of SWEET ontology[14] from Nasa and SSN ontology [6]. The SWEET ontology is used to model context information while the SSN ontology mainly models information about the sensor node. The SWEET ontology consists of nine top level ontologies and 200 sub ontologies with around 6000 concepts. The top level ontologies describe different concepts like matter, processes, relationships, phenomena, human activities, properties and states.

The Realm ontology, is one of the top level ontologies. It describes location related concepts with a great degree of precision. The main context information we use for our use case is weather data provided by the German Weather Service. Since we need to specify the location information about the involved weather stations, *the Realm* ontology fits perfectly the need for a complete description.

The SSN ontology only allows us to model the sensors with its technical data and output schema. However, the sensor platforms and observations are a bit abstract, thus, not intended to describe domain concepts like the actual type of measurements and the physical properties they measure e.g. fine dust and its corresponding measurement $\mu g/m^3$. The SWEET ontologies provide also a solution for this problem. To model concepts like measurements, we use the Representation sub ontology.

4.3. Implementation

The Ontology Processing Engine is responsible for populating the ontology and storing it on a linked data graph. It runs on the basis of Apache Jena framework[15]. Jena is a good choice mainly, because it provides next to its RDF data manipulation, features for RDF Graph storage, spatial search and querying. It receives data from PM sensors through the Stream Processing Engine and from the German Weather Service (DWD) about all weather stations.

The SPE, implemented using a DSMS, gets weather stations' data by querying the GeoServer of the DWD through a simple http-get-request, it formats the data as JSON data (id,location, and measurement data) and forwards the id and location to the OPE. The aforementioned JSON data contains all weather stations. Weather stations are instantiated using *the Realm* ontology with its location information and stored into the RDF Graph. The SPE receives the sensor data as JSON and inputs it into our Data Stream. We transform the JSON data to relational data and write it into a database. Upon receipt of JSON data containing basic information about the sensor like ID, the data is passed to the OPE to check if the sensor node is already available in the RDF Graph of the ontology, then, the node is instantiated and added to the Graph. The JSON data is parsed and location information and working conditions of the sensor are extracted and modelled using the classes of the SSN ontology.

To link the sensors to the nearest weather stations, we use Apache Jena ARQ API. It combines simple spatial querying with SPARQL[16]. This search is done using a spatial index created by Apache Lucene[17] from the spatial information provided by the input data. The weather station location is represented by a polygon through a *bbox* and the PM sensor has a geolocation, thus, a spatial SPARQL query is issued for every sensor to find the nearest weather station. The SPAQL query could yield more than one station. If this happens the centroid of the polygon given by the weather station is computed and the weather station with the nearest centroid is assigned to the PM sensor. After the sensors and the weather stations are linked, the RDF Graph now contains all the information about every sensor with the related weather station.

With the RDF Graph available, the Query generator creates for every sensor a query that measures the accuracy of the PM and Humidity values. The query is then started by *Odysseus*, where Humidity data streamed by the weather station is fused with the data from the related sensor. From humidity values of the weather station, the humidity of a sensor is directly checked, whether it's accurate or not. Furthermore, the continuous query reports a drop in the accuracy of PM values as soon as the humidity rises above 70%. Anomalies are also detected, if a sensor keeps sending high humidity values, although the station reports a dry weather.

5. Evaluation

5.1. Feasibility and Impact

We measure the feasibility by the requirements set in the use case. The first requirement is fulfilled, since all the available information about the sensor is integrated into the RDF Graph and can be used to generate the queries. We get in important parameters on the working environment like the humidity, the temperature and the geolocation. We also manage to use every weather station in Germany when it is applicable to the target sensor. This approach is semi-automatic because the selection of the classes and relationships to use to create the instances and relations in the ontology has to be done beforehand for each type of sensor. The PM sensors and the weather stations have to be modelled so that the JSON can be used as concrete input data to instantiate a specific sensor in the ontology. The output schema of the sensors and the weather station can be inferred automatically due to the schema inference capability, which makes the process of schema extraction completely user-independent. The generated ontology instance of every sensor has a direct link to the related weather station with the its data schema and how to access the data.

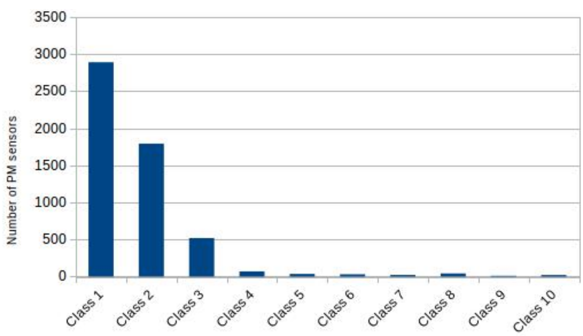

Figure 3. Classes of coverage in 20KM intervals

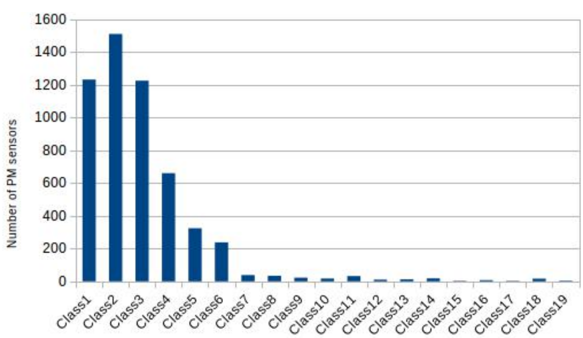

Figure 4. Classes of coverage in 10KM intervals

Given the overall huge number of sensors deployed throughout Germany and the available weather stations in Germany (912), we used a sample of 5410 PM sensors. The coverage quality is measured using 2 different ranges, with every range having up to 20 classes. Every class stands for a radius of the next available weather station for every sensor. The first class stands for the nearest weather stations and the next classes mean that the next possible station is further away. In the histogram depicted in Fig. 3, we see that with a an increasing radius of 20 kilometers coverage, 53% of the available sensors find a weather station within a radius of 20 kilometers and 33% are within 40 kilometers of the next weather station. Starting from the third class, the coverage can no longer be reliable and the weather stations can no longer be used to assess the quality of the sensors. Using a stricter range of 10 kilometers, we managed to get a good coverage too. Fig. 4 shows that 23% are within 10 kilometers of a weather station, 28% of the sensors find a weather station within 20 kilometers and 23% within 30 kilometers.

5.2. *Performance*

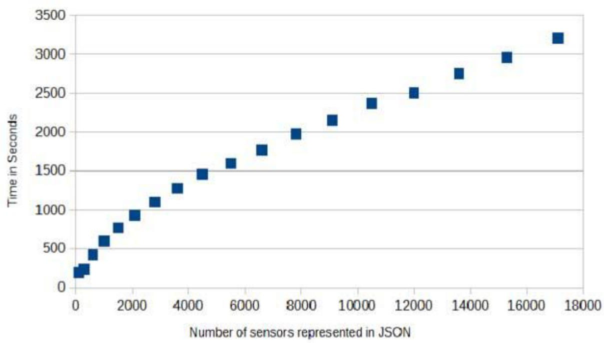

Figure 5. Time needed to create the RDF Graph depending on the number of sensors

We tested the architecture to see how it performs when faced with a huge load of sensors. The computer used for the experiments has the following specifications: Intel(R) Core(TM) i5-2520M @ 2.50 GHz (4 Kerne) with 8GB of RAM and the OS used is Ubuntu 16.04.3 LTS. Fig. 5 shows how the instantiation time evolves with the increase in the number of sensors to process. The run time becomes linear after 4000 sensors, which means that the performance will not suffer much if the sensors increase gradually.

6. Conclusion and Future Work

The proposed work lays the foundation for an online and adaptive quality-aware processing of PM sensors based on the context information available on the sensors. We extract all the available information about the sensors and relate them to the neighboring weather stations to get reference data to measure the quality of the sensors and to also detect predefined anomalies. The work achieved so far is a preparation for the next step that is the automatic query generation for different streaming systems. The fact that sensors with their quality conditions and anomaly detection rules are modelled through ontologies makes the automatic query generation possible, and also for different streaming systems. We have focused on the ontology instantiation and want to try to generalize it for other types of sensors. The next step is to integrate a Data Stream Management System, which runs the generated queries and informs the OPE if any changes in the anomaly detection rules or quality conditions occur. Since tasks in the Stream Processing Engine can be parallelized, we can deploy it on a cluster to have a better performance.

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Dealing with Imbalanced Data Sets for Human Activity Recognition Using Mobile Phone Sensors

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Abstract. In the recent years, the wide spreading of smart-phones that are daily carried by humans and fit with tens of sensors triggered an intense research activity in human activity recognition (HAR). HAR in smartphones is seen as essential not only to better understand human behavior in daily life but also for context provision to other applications in the smartphone. Many statistical and logical based models for on-line or off-line HAR have been designed, however, the current trend is to use deep-learning with neural network. These models need a high amount of data and, as most discriminative models, they are very sensitive to the imbalanced class problem. In this paper, we study different ways to deal with imbalanced data sets to improve accuracy of HAR with neural networks and introduce a new over-sampling method, called Border Limited Link SMOTE (BLL SMOTE) that improves the classification accuracy of Multi-Layer Perceptron (MLP) performances.

Keywords. human activity recognition, smartphone, over-sampling, class imbalance problem, context-aware computing, Ambient Intelligence

1. Introduction

Human Activity Recognition from wearable sensors and in particular smartphones has been subject of an intense research and industrial activity this last decade [1]. Many learning algorithms have been used to classify physical human activities such as *Running, Walking, etc.* as well as interactive and social activities (chatting, talking, playing, etc.). HAR is useful for health monitoring, senior care and personal fitness training as well as for providing context to smartphone applications. Physical human activities are generally classified from recorded sensor data (e.g. accelerometers, GPS, audio, etc.) which are embedded into wearable devices (e.g. smartphones and smart watches).

HAR systems performances are highly dependent on the classification model (Decision Tree, Support Vector Machine, Multi-Layer Perceptron, etc.), the feature used, the number of classes and the size of the datasets available for training [1]. However, another aspect that plays an important role in this domain is the lack of an uniform collection of different activities. In fact, this is the case for most smartphones datasets (e.g. *Running* = 4% and *Walking* =40% distribution). This is called the Class Imbalance Problem that is known to have a serious influence on the performance of learning algorithms, because most standard algorithms expect balanced class distributions [2].

In the past, research on HAR based on wearable sensor did not systematically handle the class imbalance problem. Therefore, in this paper we introduce a generic framework that integrates active learning with over-sampling method based on MLP to overcome this problem. We also introduce a new over-sampling method, called BLL SMOTE - an extension of SMOTE [3] - which can apply to non-convex spaces.

Contributions. Our contributions are summarized as follows. (i) A framework integrating MLP and active learning with over-sampling. (ii) A new over-sampling method, BLL SMOTE. (iii) Experiments with 2 available datasets that show the impact of taking the class imbalance problem into account in the learning.

The paper is organized as follows. Section 2 presents a summary of the state of the art in HAR and in learning techniques with imbalanced data. The overall framework and the BLL SMOTE method are detailed in Section 3. Several experiments are reported in Section 4. The paper ends with a short discussion and an outlook of future work.

2. Related Work

Human Activity Recognition from wearable sensors data is a very rich domain of research. We restrict here in presenting the main work regarding the classification models being used, the available datasets and the techniques to deal with imbalanced class distribution in data.

Regarding the classification models, there have been many approaches to deal with HAR from wearable sensors. Over the last decade, the most common approach is to process windows of data streams to extract a vector of features which will in turn be fed to a classifier. Many instance-based classifiers have been used in the field, such as Bayesian Network [4], Decision Trees [4,5], Random Forest [5], Artificial Neural Network (ANN) [4,6], Support Vector Machines (SVM) [4,7], etc. Since human activities can be seen as a sequence of smaller sub-activities, sequential models such as Conditional Random Fields [5], Hidden Markov Model [8] or Markov Logic Network [9] have also been applied. However, since the advent of Deep Learning, ANN have become of the most popular model in HAR from wearable sensors [10,11].

Machine learning is highly dependent on datasets. It is even more the case with Deep Learning. The survey by [1] presents a large number of datasets acquired from a smartphone. However, it also shows the lack of uniformity in tasks, sensors, protocol, time windows, etc. It is worth to notice that most of the datasets are restricted to inertial sensors such as accelerometers. The audio sensors are largely ignored while being among the only ones that are always found on a smartphone. It is also worth noticing that some are very imbalanced since the distribution among classes are very different. For instance, in the ExtraSensory Dataset [12], sitting represents 44.2% of the data while running only 0.3%. In this case, the learning approach should consider the class imbalance problem.

Imbalanced data has a serious influence on the performance of learning algorithms, because most standard algorithms expect balanced class distributions, as reported in [2]. Hence, datasets exhibiting imbalanced class distribution make these algorithms fail to correctly represent the distributive characteristics of the data. As a consequence, it would produce mis-classification of minority classes higher than mis-classification of majority classes, and leads to a decrease in the overall accuracy of learning algorithms. In fact, in HAR, a few studies coped explicitly with this problem such as [13] who proposed Weighted Support Vector Machines (WSVM) to improve learning of minority classes. However, the approach is based on a scheme that put more weight on the errors on the minority classes than on the majority classes. Therefore, this approach is highly dependent on the instances of the minority classes.

In general, in order to deal with imbalanced data, several other approaches were introduced in [2] such as over-sampling and active learning. For the former approach, some methods were proposed such as SMOTE [3] or Borderline SMOTE [14] which works by generating new synthetic instances of minority classes. Their studies showed that over-sampling techniques succeeded to enhance the classification accuracy for imbalanced datasets. For the latter approach, [15] introduced a SVM-based active learning framework in which SVM starts to train on a given training dataset, then selects the most informative instances from a pool of training samples, afterward adds the newly selected instances to the training set and finally trains SVM again. This approach has been pursued in the VIRTUAL framework [16]. The study showed that active learning can efficiently handle the class imbalance problem. However, all above-mentioned studies did not combine together in order to settle the imbalance data problem. Therefore, in this paper we introduce a generic framework to cope with this overall issue. More details will be provided in Section 3.

3. Oversampling and active learning framework for HAR

Our objective is to improve the learning of HAR model in case of imbalanced datasets. The problem can be defined as follows : Let $A = \{a_1, ..., a_k\}$ be the set of all activities, given a set $T = \{t_1, ..., t_m\}$ of m equally sized time windows, and a set of sensors $S_i = \{S_{i,1}, ..., S_{i,q}\}$. Given a feature space $X \in R^n$, an instance $x \in X$ extracted from sensors S_i at time frame t_j is to be classified, e.g. attached an activity label from A.

In this paper, we focus on the classification problem. Our goals are (1) to find a learning algorithm $f : X \to A$ returning a label $f(x) = a^*$ as close as possible to the actual activity performed during $t_i \in T$, (2) to enhance the classification task using active learning, and (3) to improve the recognition task by over-sampling to balance the imbalanced training set.

In this section, we present the general framework to reach these objectives, and then detail each of its components in the subsequent sections.

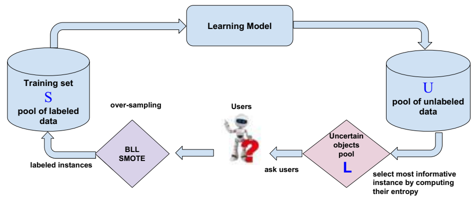

Figure 1. The active over-sampling framework

3.1. Proposed Framework

The framework, as shown in Figure 1, is an extension of VIRTUAL [16] to integrate active learning with over-sampling method to overcome the imbalance problem.

First of all, the learning is initiated with a pool of training instances S, which is used to learn a classification model. Then, to choose the most relevant sample to add in the training set, the entropy of each instance from pool of unlabeled data U is computed using the classifier output by using Equation (1). From this, a small pool of uncertain samples L is created by grouping the instances that maximized the Shannon entropy. After that, the small pool L is removed from U and user is queried for its labels.
Secondly, once L is annotated, our specific over-sampling method, called BLL SMOTE (cf. Section 3.4), looks for minority instances inside the pool L and generates new artificial instances of these minority classes. The original pool L plus the generated instances of the minority classes are added to the training set S and the training restarts. This means that at each iteration, the training set is bigger but less and less imbalanced. Each part of this framework is detailed in the following sections.

3.2. Classification model: Multi-Layer Perceptron

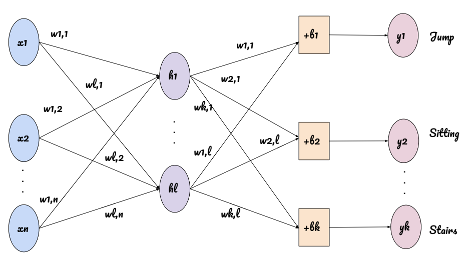

Figure 2. Multilayer Perceptron

For activity classification, many existing techniques such as SVM [7] or Random Forest [5] can be used. Among them, MLP is one of the most common methods used in HAR systems. In the rest of this paper, MLP is used as classification model. This choice is, on the one hand, justified by the fact that it demonstrates high performances on the task as well as high promises of improvement and, on the second hand, by the incremental learning strategy that fits well with active learning.

MLP can be seen as a class of feed-forward neural network composed of at least three layers of nodes, namely input, hidden and output layer. MLP can be learned using the back-propagation method, an efficient optimization method that operates iteratively. More precisely, our MLP network is designed as follows. Given inputs $X = \{x_1, ..., x_n\}$ are the features extracted from the sensors, the hidden layer nodes $H = \{h_1, ..., h_l\}$ and the output layer nodes $Y = \{y_1, ..., y_k\}$ are computed as follows:

$$\begin{bmatrix} h_1 \\ . \\ . \\ . \\ h_l \end{bmatrix} = \begin{bmatrix} w_{1,1} * x_1 & +... & +w_{1,n} * x_n \\ . & . & . \\ . & . & . \\ . & . & . \\ w_{l,1} * x_1 & +... & +w_{l,n} * x_n \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ . \\ . \\ . \\ y_k \end{bmatrix} = \begin{bmatrix} w_{1,1} * h_1 & +... & +w_{1,l} * h_l \\ . & . & . \\ . & . & . \\ . & . & . \\ w_{k,1} * h_1 & +... & +w_{k,l} * h_l \end{bmatrix} + \begin{bmatrix} b_1 \\ . \\ . \\ . \\ b_k \end{bmatrix}$$

This is shown in Figure 2, where $\{w_{1,1}, ..., w_{l,n}\}$, $\{w_{1,1}, ..., w_{k,l}\}$ and $\{b_1, ..., b_k\}$ represent weights and bias.

3.3. Active Learning

The principle of Active Learning (AL) is to learn to label unknown instances by selecting (querying) some specific instances and ask an external system (e.g., a human operator) to label them. It has become an emerging research topic with applications in many fields such as image segmentation [17], data clustering [18] and interactive data analysis [19]. Applying AL in HAR is thus an interesting approach since it can further boost up the accuracy by involving humans in the classification task, especially for hard to classify activities. Moreover, its scheme provides a natural way to cope with data imbalance by exploring some most uncertain data spaces, as pointed out in [15].

Typically, an active learning algorithm chooses objects that their labels are among the most uncertain ones to query users for. Uncertain instances can be chosen in many different ways [20]. Our technique is built upon the uncertainty sampling technique [20] whose principle is that the most relevant instances to be selected for annotation are the ones for which the estimates are the less certain. Thus, after MLP training, we predict the labels of U using the training output Y of MLP. Y can be seen as a vector of probability of labels. Then the instances in U are ranked according to their decreasing Shannon Entropy, because the higher entropy of an instance is, the more uncertainty there is on its class. Therefore, the most uncertainty instance can be picked up by maximized Shannon entropy [21] using Equation (1):

$$x_H^* = arg \max_x - \sum_i P_\theta(y_i|x) \log P_\theta(y_i|x) \tag{1}$$

where x is an instance, $P_\theta(y_i|x)$ is the probability of all possible labels on the instance.

3.4. Over-sampling Border Limited Link SMOTE Method

While classical active learning methods only add in the training set the uncertainty instances, that were labeled by a user, our method also performs over-sampling on queried data. This makes it possible to put new information into the training set and tackle the class imbalance problem.

Over-sampling consists in adding new sample to a training set, whether they are synthetic or real. For instance, SMOTE [3] generates a new synthetic instance, using Equation (2):

$$x_{new} = x_i + (x_i^\theta - x_i) * \lambda \tag{2}$$

where x_{new} is the new sample generated from $x_i \in S_{min}$, with S_{min} is the samples of minority class, x_i^θ is one of the k-nearest neighbors of x_i: $x_i^\theta \in S_{min}$, and $\lambda \in [0, 1]$ is the random number, which allows to randomly generate the new synthetic instance x_{new} along the line between x_i and x_i^θ.

However, this method is not relevant in case of non-convex spaces. For instance, imagine a space as represented Figure 3. If x_i and x_i^θ are two samples of the green (circle) class, a direct application of Eq. (2) would produce a new sample x_{new} which would not be in the right space.

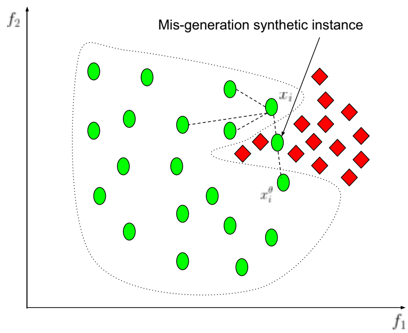

Figure 3. Example of mis-generation synthetic instance in non-convex dataset

To avoid the mis-generation of synthetic instances in the case of non-convex dataset, we introduce the BLL SMOTE method described as follows. The method uses Eq. (2) but calculates the distance from x_{new} to each of the k-nearest neighbors of x_i, denoted as $d_j = d(x_{new}, x_i^\theta)$, $j = 1, ..., k$, where d is the Euclidean distance. Then, the distance of the artificial instance x_{new} with its nearest instance $x_{diff} \notin S_{min}$ such that $x_{diff} \in S$, denoted as $d_{diff} = d(x_{new}, x_{diff})$ is computed. Finally, each d_j is compared to d_{diff}. If any d_j is greater than d_{diff}, then this artificial instance x_{new} is not accepted to be generated. Otherwise, x_{new} is accepted.

An advantage of BLL SMOTE is to avoid the mis-generated new synthetic instance in non-convex datasets

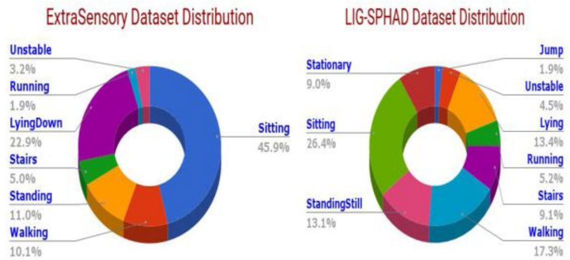

Figure 4. Distribution of the activity labels over the datasets

4. Experimental Evaluation

4.1. Dataset

To perform HAR, we restricted ourself to comparable datasets that contain at least audio data and accelerometer data which are the only sensors that are guaranteed to be found on any smartphone. We selected the LIG Smart Phone Human Activity Dataset (LIG-SPHAD) [5] and the ExtraSensory Dataset [12] which are both publicly available, do contain continuous audio and accelerometer data and are annotated using physical human activity labels. As it can be seen from Figure 4, the two datasets are imbalanced. For instance, in the LIG-SPHAD, *jump* is the smallest distribution class (1.9%) compared to the highest one *sitting* (26.4%). For the ExtraSensory Dataset, *running* (1.9%) is a minority class while *walking* (45.91%) is by far the most frequent one. The datasets were randomly split into training set and test set for classification task.

4.2. Baseline results with the MLP

The MLP we implemented is composed of three layers as described in Section 3.2. The TensorFlow library was used to implement MLP. The experiment conducted on a workstation with 3.2Ghz CPU and 16GB RAM.

The learning results are presented in Figures 5 for the two datasets. The blue line correspond to the F1 score on the test set. On LIG-SPHAD the overall score is 68% F1 while it is about 65% on the ExtraSensory Dataset. In the beginning of the learning phase, the F1 score of minority classes are very low while the F1 score of majority classes are high. At the end of learning, the F1 of majority classes still have a high score while the F1 score of minority classes steadily increase but stay below the overall score. It shows that, as every discriminative learning that does not naturally take the imbalance class problem into account, the learning favors majority classes.

4.3. MLP learning with BLL SMOTE

The MLP was then learned using the BLL SMOTE method. In this experiment, BLL SMOTE is parametrized using a query budget limitation σ of 950, a query size of $\alpha = 50$ and a neighborhood size k of 6. Different learning tasks were carried out using either: (i) A random AL: the instances are picked up randomly from U

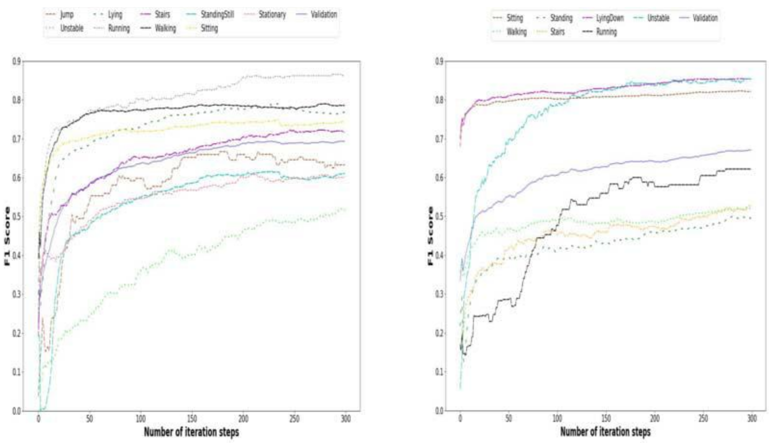

Figure 5. Baseline learning curve of the MLP on LIG-SPHAD (left) and ExtraSensory Dataset (right).

and added in S; (ii) AL without over-sampling: only the most uncertain instances with largest entropy are chosen and added to S; (iii) AL with SMOTE: the most uncertain instances are chosen, then new instances of the minority classes are created without taking (non-)convexity of the instances space into account. Then they are added to S; (iv) AL with BLL SMOTE: our method. Unless specified otherwise, the parameter values are the same for all methods.

The Figure 6 shows the F1 score curves of the four methods on the test set of the two datasets. For LIG-SPHAD on the left side of Figure 6, BLL SMOTE gave the best performances reaching 80% far better than the original 68%. For the ExtraSensory dataset, BLL SMOTE also gave the best result reaching 76%, which is better than the previous performance of 65%. However the difference wrt the other methods is less pronounced. In any case, these results show that AL and over-sampling greatly improve global performances in case of imbalanced data.

BLL SMOTE also has an effect on the classification performance of each class. On Figure 7, the MLP performance on LIG-SPHAD at the last step of active learning with over-sampling BLL SMOTE, demonstrates that the minority classes such as *Jump, Unstable* can achieve nearly 0.7 and 0.65 F1 score respectively, that is much higher than the MLP performance in the Figure 5 where F1 score are 0.6 and 0.5 respectively. On the ExtraSensor dataset, the right side of Figure 7 also illustrates that minority classes such as *Running, Stairs* can reach an F1 score of 69% and 65% respectively higher than in the right side of Figure 5, where the same classes achieved 60% and 50% F1 score respectively. Hence, BLL SMOTE makes it possible to increase minority class performance in a discriminative setting.

5. Conclusion

In this paper we introduced a generic framework which integrates active learning with over-sampling method based on MLP to overcome the class imbalance

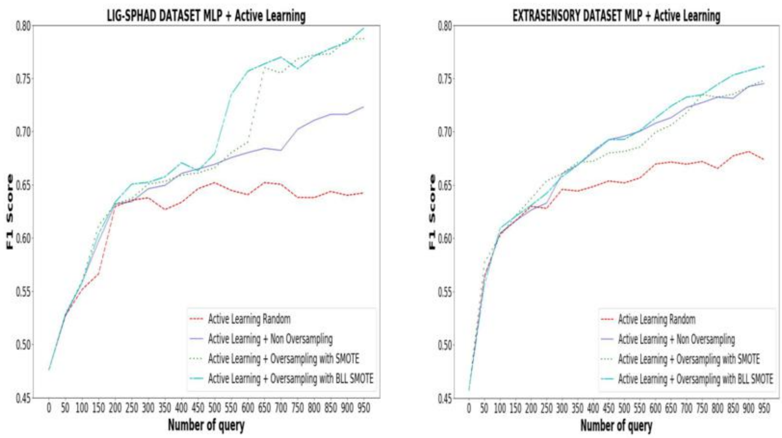

Figure 6. MLP + Active Learning on LIG-SPHAD (left) and ExtraSensory Dataset (right).

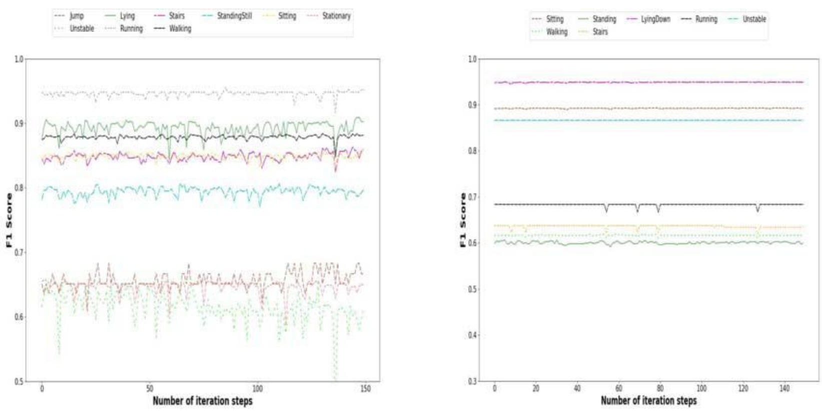

Figure 7. Last step of Multilayer Perceptron after last query of Active Learning and Over-sampling BLL SMOTE on LIG-SPHAD (left) and ExtraSensory Dataset (right)

problem. We also introduce a new over-sampling method, called BLL SMOTE - an extension of SMOTE [3] - which can be applied to non-convex spaces.

The experiments carried out on two different datasets demonstrated that using active learning with over-sampling to tackle the imbalance distribution of class can increase the global F1 score of the two datasets by about 15% absolute over the baselines. In each case BLL SMOTE shows slightly higher performances than using SMOTE plus Active learning. In addition, BLL SMOTE is able to increase the classification performance of minority classes. Another important point of this study is the fact that our method prevents the mis-generation of synthetic sample, thanks to its capacity to manage non-convex datasets.

These results show two advantages over classical approaches: the method makes it possible to improve overall and local performances and does not require extra external data. This last advantage is important in a domain such as smartphone HAR where data collection is costly and available datasets might differ too much in term of target, features or time resolution.

Acknowledgment

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A Framework for Human Recognition and Counting in Restricted Area for Video Surveillance

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Abstract. We introduce a multi-process framework for human counting and recognition that exploits the combination of multiple deep neural networks. Deep networks have advanced the state of the art in many fields and play an essential role in computer vision for detection and recognition. However, very deep networks are still slow at inference time, and they require a substantial amount of hardware to perform complex operations. Real-time recognition from video source is still an issue due to complexity of scenario and the amount of data to process. In this paper, we propose an approach that combines multiple neural networks, that is fast and accurate.

Keywords. Video Surveillance, Human Recognition, Deep Learning

1. Introduction

Detection and recognition of people in restricted areas is an important task to prevent or persecute theft of data and objects. Offices and laboratories are locations which can contain valuable documents or devices, and it is not difficult for an unauthorized person to enter in non-secured areas and act freely. In the recent years new technologies allow to control restricted areas, and video surveillance technologies are frequently used for control and detection. Even if accuracy of non-invasive systems is increasing, the problem of recognition is still a hot research topic. This paper addresses the problem of recognizing authorized humans in a restricted area, while preserving real-time processing and high accuracy.

Human detection problem has been widely studied in the past decades. A successful algorithm based on histograms was introduced by Dalal et al [**7**]. More recently, with the advent of Deep Learning technologies, Convolutional Neural Network (CNN) algorithms had improved the accuracy rate in particular for the important task of pedestrian detection [**3**].

The problem of human recognition has been explored by analysis of locomotion properties [**24**], or additional invasive hardware [**16**]. More recently, computer vision algorithms have shown successful result in the recognition of human from faces [**23**]. However, a minimum resolution and sufficient angle of observation is required.

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The main contribution of this work is a human recognition system which combines multiple neural networks to discern visitors from accredited people. The system shows high accuracy rate and is able to analyze real-time stream data.

This paper is organized as follow: Section 2 briefly reviews the related work in the area. The system overview and technical details are discussed in Section 3. Finally, the experimental results are demonstrated in 4. Section 5 concludes the paper.

2. Related Work

Accuracy of human and object detection increased significantly (i.e. [**11**, **26**]). In particular the advent of parallel computing offered the possibility to compute complex data and extract information at pixel level. While semantic segmentation is gaining accuracy and importance [**14**], collecting a relative sufficient amount of categories may be expensive [**22**]. Even if instance segmentation has become more common after the work of Hariharan et al. [**13**], and performance increased considerably [**2**], expensive hardware and high computation time are limitations. For specific task, such as human detection and recognition, bounding box segmentation reached high level of performance [**25**], and recently Cao et al. shown a very high speed algorithm for human parts detection [**4**].

Convolutional and recurrent operations became important building blocks for many research applications. For long-range dependency modeling, recurrent operations [**6**, **15**], are the dominant solutions. For image data or temporally local data, accurate results are obtained by convolutional operations [**10**, **21**]. Convolutional network shown high accuracy in face recognition [**28**].

While the reliability of recognition by image analysis is increasing as shown in [**28**], proper facial alignment is an important requirement for accurate results. Face detection has been deeply studied as shown in the milestone work of Viola and Jones [**32**]. More recently, the problem of face alignment has successfully addressed by a cascade of convolutional networks [**35**].

3. Proposed Recognition Method

The baseline of our propose system follows the conventional information retrieve systems. We chose our system by following these considerations: an observed scene contains important information for a limited period of time, and it is necessary to collect the maximum number of frames from the observable period. The whole system is shown in Fig. 1. We propose a distributed system which performs real-time operations and offline operations to take benefit of both high speed, lower accuracy algorithms, and higher precision but slower algorithms.

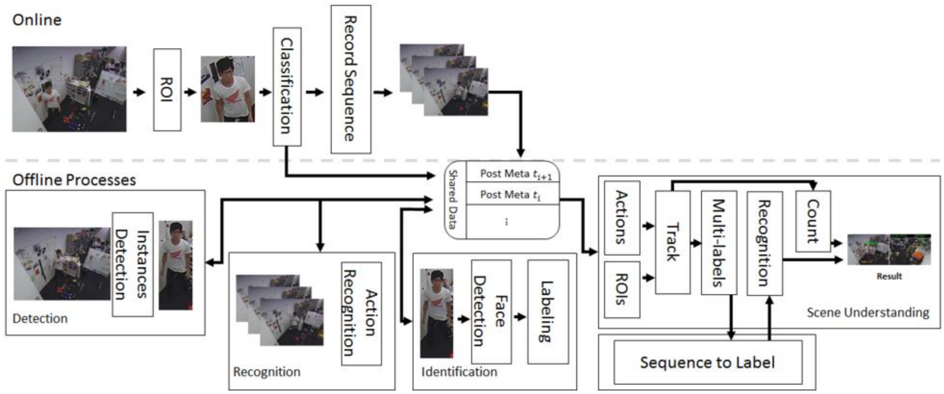

Figure 1. The proposed system pipeline. The data is analyzed temporally from left to right, in real-time (online), or as soon as available (offline).

3.1. Human Detection

Common location for video surveillance cameras allow a clear observation of a human target for a limited number of frames. In order to analyze the largest number of data, we use a fast preprocessing of each captured frames. As shown in [**3**], CNN can be used to perform a pedestrian/human detection with high accuracy rate and low computation time. We opted for a background subtraction algorithm with a Disjoin-set data-structure, to partition nearest blobs and to estimate Regions of Interest (ROIs) in real-time. Each ROI is converted in grayscale and rescaled to a 32x32 pixel size. For each ROI, we perform a dual class (*human/other*) classification. A 3 layers CNN connected by 3 max-pooling layers and a dense layer, all with Rectification Linear Unit (ReLU) activation function are used. An example of input source and topology of the network is shown in Fig.2. Data augmentation has been used to artificially enlarge the training set and reduce the over fitting. We used several image transformation (similar to [30]), to increase our relative small training set to 33000 images from the observed scenario. The classes are equally balanced, batch size of 64, and learning rate of 0.001 for 25 epochs.

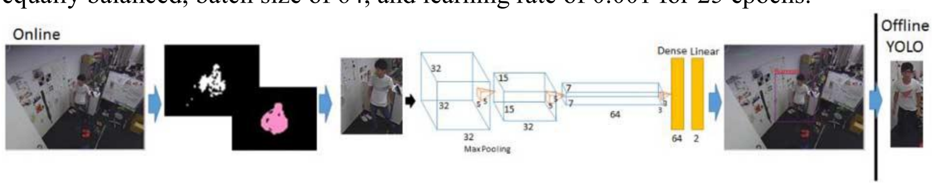

Figure 2. Detected human in the scene.

In our scenario, the video source is acquired at 30Hz. The online preprocessing works at a computation time of about 20ms, which guarantees a real-time acquisition. It is important to avoid loss of frames due to the small number of frames in which valuable information can be extracted.

Since shadow and human persistence in the same position alter the size of ROIs, we use an accurate and fast, but not real-time, algorithm described in [**25**] for an offline analysis. The algorithm is used to refine the regions detected and perform instance segmentation of humans in each frame where a ROI containing a human has been detected.

3.2. Face Detection and Labeling

We rely on a face recognition algorithm as primary method to recognize the people in the scene detected in 3.1. A face may result in partially visible or totally occluded. We consider that even if the face is not completely visible, the region of the head can still contain considerable amount of information. We use a joint detection algorithm [**35**] to align the head when visible and a cascade of CNN [**28**] for recognition (Fig. 3).

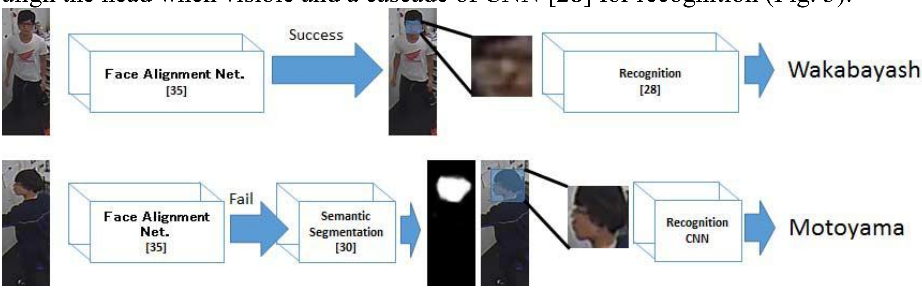

Figure 3. Flow of face alignment and recognition. Detection of the face succeeds and recognition (Top). In case of failure, a head segmentation is performed and a CNN used for recognition (bottom).

We trained the recognition on images of 128x128 pixels without margin, due to the low resolution of the source. We used a set of 3500 images for the training divided in seven different classes. Each class represented a person and about 500 images for each person is used.

We use a semantic segmentation algorithm (Teichmann et al. [**30**]) to find the areas expected to contain side faces and head in the selected ROIs. The network uses a VGG-16 architecture [**27**], and it is refined with 200 manually segmented images from the observed environment. In order to recognize the extracted region, we used a simplified class recognition of popular architecture [**1**]. The architecture is shown in Fig. 4.

Input
Conv + ReLU Kernel: 3x3, channel: 64, padding: 1
Max Pooling (kernel: 2x2, stride: 2)
2 x (Conv + ReLU) Kernel: 3x3, channel: 64, padding: 1
Max Pooling (kernel: 2x2, stride: 2)
Fully Connected + ReLU channel: 512
Dropout (rate: 0.5)
Fully Connected + softmax channel: 3
Linear (channel: # classes)

Figure 4. Convolutional Neural Network Architecture.

We trained the model with a set of about 500 images for each individual for a total of seven people. We performed data augmentation to obtain a training set of 30000 images. A 90/10 training test set shown an accuracy of 98.5% and loss of 0.098.

3.3. Action Recognition

Long short-term memory (LSTM) networks has shown great results in the recognition of sequences, where early inputs remain in memory instead of being forgotten [**15**]. The recognition of an action gives an additional information on the persistence of an object in the memory of the system.

Many highly accurate architectures have been proposed [**34**]. In our scenario, we consider a simple dictionary for the possible actions: *{enter, leave, walk around}*. For this reason, a simple and relatively fast architecture to compute is used (Fig. 5). The architecture has the advantage of use a single stream of images, requiring limited memory and minimal preprocessing.

Deep features from every five frames are extracted using a pre-trained Inception V3 [**29**]. We used the last pool layer of the InceptionV3 network as feature source for the LSTM network.

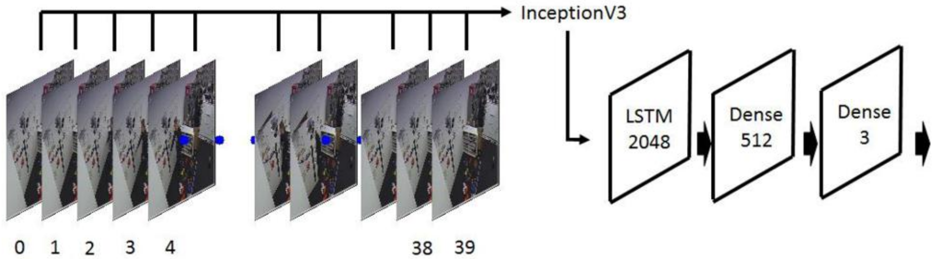

Figure 5. Action recognition from an observed period of time.

We trained the action recognition with a set of 600 sequences of 40 frames for each sequence. We used a set of 200 sequences for each type of action (enter, leave, walk around). Each frame is resized at resolution of 300x300 pixels. With the described architecture an accuracy of 84% is obtained.

3.4. Tracking multiple views

Each human instance detected at time *t* is associated with previously detected object. We opted for a Siamese network solution similar to the idea described in [**19**]. Instead of computing the Euclidean distance as suggested in [**12**], we observed that we could obtain good performances by training a linear regression over the estimated composition of the convolution networks. While other tracking algorithms such as [**8**] can perform well in sequential images, we consider that ROIs can be paired by different space-time information, since a human can be detected in a different position after long time or from different video sources. We associate a tracker for each detected human, and for each new frame, we compare the tracker ROIs' human image with current frame ROIs (Fig. 6). Two convolution layers are used to generate the features, and combined to estimate the similarity between the images.

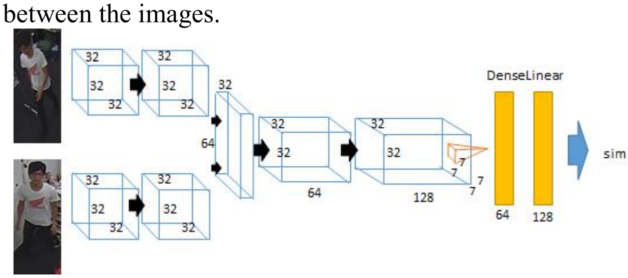

Figure 6. Head detection in unaligned faces.

Our goal is to pair new detected objects with previously tracked objects by estimating the similarity between images. We calculate the similarity between all the tracked objects and new observed objects (1).

$$O_i = \begin{cases} created \quad if\ |E| < |N| \\ removed \quad if\ |N| = \emptyset \wedge O_i\ leave \\ j \quad if\ j \neq \emptyset \wedge \underset{j \in N}{\operatorname{argmax}} \left(sim(x_i, x_j) \right) \end{cases} \tag{1}$$

where $sim(x_i, x_j) \in [0,1]$ is the similarity function obtained by the CNN networks, E is the set of existing tracked objects from previous frame, N is the set of new ROIs from the current frame, and O_i the object to track where $O_i \subseteq E$. We trained our model with a set of 60000 different pairs of images from different sequences equally balanced between similar and different. We calculated a RMSE of 0.091. A tracker is not immediately removed if the human tracked disappeared. We chose for a temporal threshold of 1 second to remove lost tracked objects.

The same subject can be visible from multiple views and generate multiple tracked objects. By following the idea of Varga et al. [**20**], we performed a projective transformation to align the human centroids (Fig. 7).

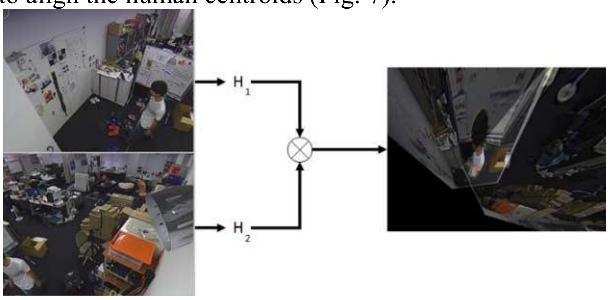

Figure 7. Projective transformation around the common observed area. Body center of mass is coincident.

Two tracked objects are merged together if they share the same centroid projected inside the overlapping areas.

3.5. Sequence Recognition

Sequence of multiple labels of an observed tracked human may contain spurious values. We consider that a failure in the proper recognition is a possible event. However, if multiple observations of the same person are performed, it is possible that the correct label is associated. We propose the use of variable length sequence classification, inspired by the problem of learning from multiple labels [**16**], and by the model described in [**18**].

We consider a tracked object history as a sequence of assigned labels and likelihood associated. Let $\hat{x}_i$ be the input sequence for the i-th training sample, and C_i the associated classes. We define an encoding function φ so that each new instance of a class is a normalized index of the cardinality of C_i (2).

$$\theta_i = \varphi(\hat{x}_i, |C_i|) \tag{2}$$

Our goal is to estimate a set of parameters $\lambda \in \Lambda$ in the class of models M so that we can predict **y** and the likelihood associated $\mathcal{L}$ for a test input $\hat{\boldsymbol{x}}$, where y has the highest probability to be a member of the set C.

$$\bar{\lambda} = \underset{\lambda}{\operatorname{argmax}} \prod_i p(y \in C_i | \theta_i, \lambda) \tag{3}$$

Since our training set is limited, we consider the adoption of shown in Gated Recurrent Unit (GRU) [**18**]. These recurrent neural network shown the ability to converge to the solution with a smaller training set compared to LSTM. The full sequence recognition is shown in Fig. 8.

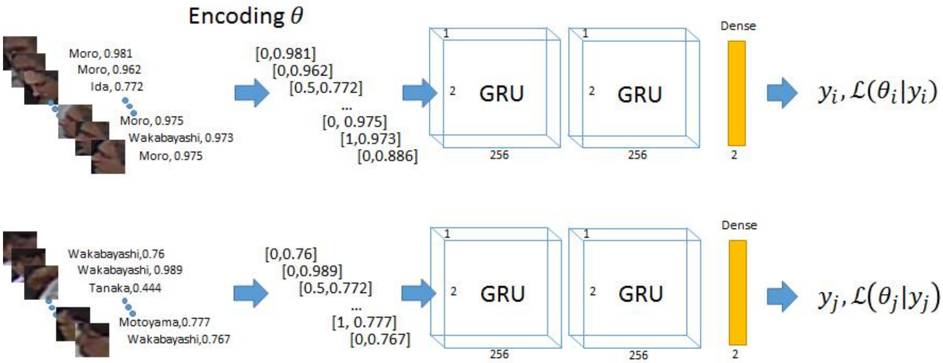

Figure 8. Multiple labels are combined in a sequence to recognize the correct name.

Even if promising results are given by RNN, as shown in [**35**], the network lack robustness in learning optimal label orders. In order to increase the robustness, we perform data augmentation by randomly shuffle of the training sequences. We generated a set of 20000 synthetic sequences and calculated a loss function of 0.02.

3.6. Scene Understanding

The observed scene is described by analyzing of available meta-data collected by the online and offline processes. We use a queue concept to elaborate the content of each frame. Even if partially completed meta-data can be analyzed, we prefer to elaborate only the completed frames meta-data. This solution guarantee a sequential analysis, and an easier evaluation and interpretation. The flow of the data analysis, recognition and counting of human in the environment is shown in Fig. 9.

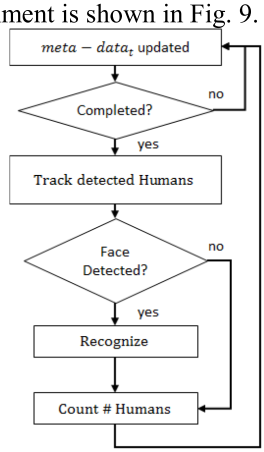

Figure 9. Flow chart of the analysis of the collected data. Only completed data is elaborated. The recognition is update only when new biometric information exist.

Since the detection and recognition from the side of the face is prone to error, we used a weighted value for the recognized sequences:

$$\bar{y} = w_1 y_1 + w_2 y_2$$
$$\bar{\mathcal{L}} = w_1 \mathcal{L}_1 + w_2 \mathcal{L}_2 \quad (4)$$

where $y_1, \mathcal{L}_1$ are the label and likelihood associated to the face recognition based on [2], and $y_2, \mathcal{L}_2$ with the face recognition from side. We consider a person recognized if the likelihood is greater than 0.5.

Recently, a promising counting algorithm based on the direct scene analysis has been described in [**5**]. In indoor environment, however, a person can be invisible to the camera (too far, occlusion) and a single frame analysis is prone to error. We counted the people by detection. Each active tracker is counted as single instance of human (Fig. 10).

Figure 10. An example of described scene. The action and # people in the scene is shown on the top. On the right the recognized human from the sequence. In the region of interest tracked (red), the current associated label (green) with relative likelihood, and similarity (yellow).

4. Experiments

The network models have been implemented in Tensorflow r1.5, Keras 2.1.4, and Cognitive Network Toolkit (CNTK) v.2.4. All models were trained only once and used for all result throughout the paper. We performed a specialized training for our networks with the exception of the offline human detection based on YOLO dataset. We used a GPU GeForce GTX 1080 Ti, and a GeForce GTX 980 for our experiments. Computation time for each frame is measured as follow: Human Detection based on [25] about 300ms, face detection and recognition about 200ms each. Semantic segmentation about 300ms, and 200ms for the action recognition. The proposed algorithm elaborates all the captured frames without frame loss. Offline analysis returns an accurate result with the output that has an incremental delay directly proportional to the number of frames collected. A normal observed sequence has an output delay of about 5 to 10 seconds.

To evaluate our proposed framework, we consider a laboratory as restricted areas. We used a set of 20 videos which do not belong of the training set for the evaluation. We calculated the correctness of the face recognition algorithm and the recognition with multiple labels on a total of 4317 frames where at least a person has been detected.

Table 1. The following table summarize the result of the framework parts used to describe the scene.

Recognition Method	True Positive (TP)	False Positive (FP)	False Negative (FN)
Face Detection [35]	57.46%	42.54%	0%
Face Recognition [28]	81.7%	18.3%	0%
Multi-Label (proposed)	90.63%	5.96%	3.41%
Count (proposed)	94.14%	3.81%	2.05%

Results in Table 1 show that the proposed algorithm increased the recognition performance by combining sequential information and recognition of human from images captured from side face.

We compare our proposed algorithm with the result obtained by using only a face recognition [28]. Since biometric information are available only when the face is clearly visible, we included the detection rate obtained with an angled image (Fig. 11). We experienced that the success in the recognition is strongly influenced by the correct detection of at least one face.

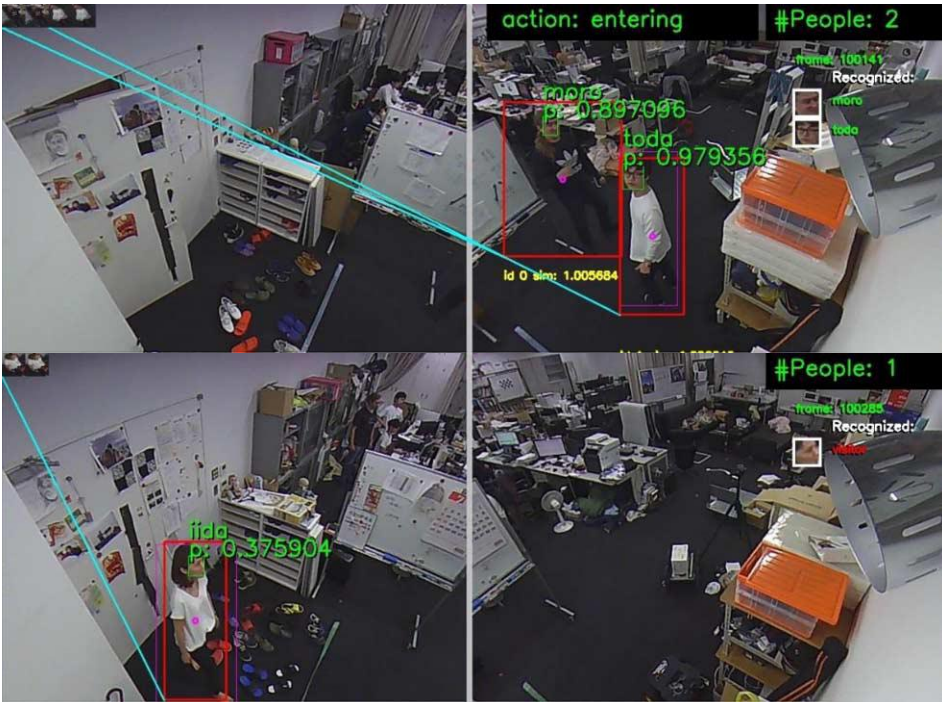

Figure 11. Example of successful detection, recognition, and counting of the observed scene. On the bottom, the subject is not in the training model, and she is correctly labelled as visitor.

5. Conclusion and Future Work

In this work, we studied the problem of recognizing and counting the number of occupant in a restricted area. We proposed a framework for analysis of an observed environment which combines the advantages of online and offline algorithms. We described a multi-label recognition to increase the robustness of recognized people in the scene. This framework is based on multiple neural networks which summarize the flow of each process activity at each frame. The proposed framework has the advantage that can be easily extended and distributed on multiple machines.

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Universal Map: A Concept and Recent Results of Cloud-Based Positioning Infrastructure System

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Abstract. This manuscript proposes a novel cloud-based localization infrastructure system for various mobile objects. All sorts of mobile objects, such as a robot, a smartphone, a card tag hanging around people neck, a drug cart in a hospital, and a vehicle in a warehouse, can be localized as a client of this system. The client only has to take a picture and send it to the server of this system. The server manages a 3D map and localizes the picture sent from the client in the map. This map, which is constructed beforehand, is coordinated with a real world so that the localization result is given as a 6-dimensional coordination including position and posture. Such a system includes several unsolved problems: what is a better map representation, how to localize a picture in the 3D map, how accurate does this system provide a result, how long to get the result? We have tackled these problems and solved them partly by developing a 3D-wireframe map and a similarity-based localization algorithm. We explain our solutions including map representation and localization algorithm with recent results.

Keywords. cloud computing, 1 shot localization, light edge

1. Introduction

The Internet of Things (IoT) is the network of physical objects embedded with sensors, actuators, software, and connectivity which enables these objects to connect and exchange data. The IoT is highly versatile technology and is expected to pervade so many situations and environment such as home, hospital, station, university campus, shopping mall so on. At the upper level, IoT technology connects supply and demand of services intimately so as to realize efficient operations. Of course, the grade of service has strong relevance to the granularity of understanding on the target that the system intends to give service to. If the system knows more details about the target, more finely tuned service may be given. The information that the system should be known includes both the condition and position of target. The condition is obtained easily by suitable sensing. However, the position information needs special effort according to a situation.

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When the target is indoors, where the signal from Global Navigation Satellite System (GNSS) are not reached, an alternative positioning technique is required. In the context of IoT, a positioning system should meet several requirements. Firstly, the computational load on a computer embedded in a mobile object must be as lowest as possible. Secondly, the running cost of whole system must be kept under realistic range. Because of these two requirements traditional localization technologies can not be applied as it is. In the robotics field, the Simultaneous Localization and Mapping (SLAM) technique, that only uses sensors embedded on mobile object, has been developed. The SLAM technology can be applied for unknown environment where a robot system visits first time. The SLAM problem was formulated and many practical algorithms were developed. Nowadays, the SLAM technology is going to appear as a key technology of self-driving vehicle. However, considering to applying for IoT applications, the large computational load on the mobile computer would be a bottleneck. On the other hand, an intelligent-environment approach, that needs minimum or none sensors on mobile object, is more suitable. By embedding sensors, beacon modules, visual markers, electrical markers, or physical guide on the environment, a mobile object only needs minimal or none sensors for positioning. Therefore, the computational load on the mobile object can be cut to the bone. Actually, the intelligent-environment approach is used in an automated factory and a large warehouse. However, the maintenance cost is never few and this approach can only be applied for good cost-effective situation. Although the intelligent-environment approach is introduced to a production site, it has a difficulty to introduce to a consumption site such as hospital, station, shopping mall. Consequently, there is no suitable positioning system for IoT context.

We propose a cloud-based positioning infrastructure system named Universal Map (UMap) for positioning mobile objects in the context of IoT. To guarantee the high accuracy of positioning result, we use a map-based localization approach. In contrast with the SLAM approach, using a precise well-prepared map enables the system to localize a target accurately. To reduce the computational load on a mobile object, cloud-based approach is adopted. Operating the heavy load calculation, like a position estimation, on the server side, the mobile object which is in client side only must do a light process such as sensing and WIFI communication. The point of our proposing UMap is that it never need physical infrastructure on the environment except for wireless communication. The character of physical maintenance-free meets the running cost requirements. Additionally the cloud-based system has an advantage in maintenance of software and database. The newest algorithm and dabas can be introduced by updating on some servers and the all clients receive favors of update. The UMap has a potential to become a really practical positioning system for pervading IoT technologies to our society. In this paper, we organize individual problems for realizing UMap and present our solutions.

In section II, related works of localization technologies are described under our original categorization depends on sensory-configuration. In section III, a conceptual configuration is given and its research issues are organized. In section IV, solutions at the moment for individual issues are described. Section V gives discussion about each solution and shows future works. In section VI, we summarize this paper.

2. Related Works

The localization problem or positioning problem have studied and developed for long-time. Here, we categorize them depends on the sensory-configuration, 1) a case embedding sensors only on mobile object, 2) a case embedding sensors both on mobile object and environment, and 3) a case embedding sensors only on environment. Then we highlight the difference from our approach.

1) Embedding sensors only on mobile object

This case has been studied in robotics research field. A robot has sensors like a camera or a LiDAR (Light Detection and Ranging) for observing surrounding environment and does not have prior information about the environment. In this case, the robot has to make an environment model (mapping) and localize itself in the environmental model (map). Since these processes are done simultaneously, this problem called Simultaneous Localization And Mapping (SLAM). The SLAM problem was formulated by Newman et al. [1] and organized by Thrun et al.[2], then so many slutions and algorithms have been proposed by many robotics researchers [3,4]. Although the SLAM technology is going to be used on autonomous-vehicle, it is difficult to apply for IoT context because of its large computational load.

2) Embedding sensors both on mobile object and environment

This case, sometimes called Automatic Guided Vehicle (AGV) [5], is most often appeared in industrial applications to move materials around a manufacturing facility or warehouse. A mobile robot easily recognizes an environment and its location due to markers or wires in the floor. Recently, AGVs for warehouse are pervading such as the Kiva system of Amazon robotics or Little Orange of STO express. The weak point of this system is the huge initial cost and running cost for maintaining the physical infrastractures.

3) Embedding sensors only on environment

Often used methods in this case are using a camera or laser range sensor on the environment [6]. The central research issues is to keep tracking multiple objects without confusion. This case also has weakpoint about the maintenance cost.

3. Universal Map: Concept and research issues

3.1. Concept

The conceptual figure of our proposing Universal Map: cloud-based positioning infrastructure system (UMap) is drawn in Fig. 1. This system consists of three subsystems; a central server which maintains a global map composed of universal landmarks; clients who access the server so that they obtain positions of themselves; agents who detect and report environment changes to the server. The client usually uploads its current sensing data, then the server localizes the sensing data in the global map, finally the localization result will be downloaded to the client.

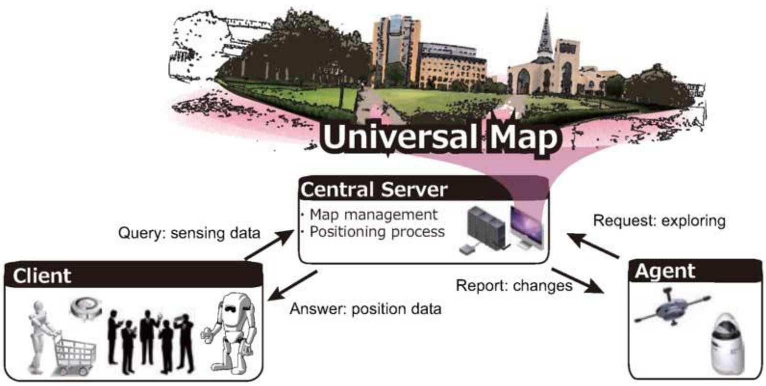

Figure 1. A concept picture of Universal Map: Client-server based positioning infrastructure system

This UMap system has many advantages. Since the global map is maintained on the server and the localization calculation is conducted on the server side, the client can conserve the computational resources as well as energy resources. The client also can avoid the maintenance for keeping the map new. In the position of the supervisor of this universal map infrastructure system, being unnecessary of physical maintenance other than a workstation machine and a communication infrastructure is a great benefit. By the contribution of the agents, the global map on the central server is always kept new so that this localization infrastructure system stays alive almost permanently. The contribution of such a system is not only involved in practical usefulness, but also involved academic benefit that obtains a huge environmental sensing data with accurate position information over the long term. Due to accurate position information, visual scenes of various time of date, various illuminance condition, various seasons, various situation, would start to be associated. Ultimately from such data association by grace of accurate position information, better landmarks will be born via machine learning techniques. Our ultimate goal is to develop a sustinable positioning infrastructure system.

3.2. Research issues

To realize the UMap, we have to solve all research issues as follows,

1. Constructing a global map
2. Developping a positioning algorithm
3. Developping a map retrieval algorithm
4. Developping a server-client system

We tackled issue 1 and 2. The following sections show our solutions.

4. Construction of global map

The most important question of the map based localization is that what is the best representation of the map. Since a map is an aggregation of landmarks, this question is equal to what kind of features is best for the landmark. The requirements of effectual landmark are time-invariant, densely existence, sensing universality, economical memory usage,

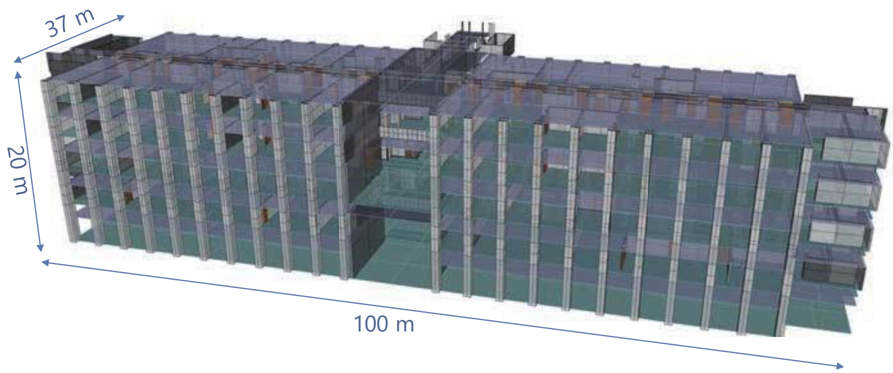

Figure 2. Constructed 3D CAD of O-building

and effective matching algorithm. There is a tradeoff between time-invariant and densely existence. For example, most of line-segments feature such as a boundary between wall and ceiling are meet time-invariant, but they exist sparsely. On the other hand, the visual point features such as Features from Accelerated Segment Test (FAST), Binary Robust Independent Elementary Features (BRIEF), Scale-Invariant Feature Transforms (SIFT), Speeded Up Robust Features (SURF), Accelerated KAZE (AKAZE), Oriented FAST and Rotated BRIEF (ORB) etc, can be found in relatively high amounts in messy room, but the goods in the messy room, that provide many point features, change position easily. In sum, the point features tend to lack time-invariance.

Facing to the trade-off problem between time-invariance and dense-existence, we proposed a novel global-map scheme that consists of stable landmarks and updatable landmarks on demand of environment changes [7]. This map takes time-invariant landmark as a base and accepts transient features as transient landmarks according to the situation.

So firstly, we have to develop a map consists of time-invariant landmarks. The time-invariant landmarks are boundaries between wall, ceiling, and floors. These boundaries are given as lines from a 3D CAD. So we developed a 3D CAD of a building that was a experimental environment. The constructed 3D CAD is shown in Fig. 2.

5. Localization

5.1. Naive lines matching

The problem of localization is that finding where the sensing data was taken in the global map. Therefore, localization method depends on sensing data type. Here, we explain our developed 2D-3D line-segments matching algorithm. Query images uploaded by clients equipped with RGB camera are 2D images. By contrast the global map we have developed on the server is 3D wireframe. So, the 2D image localization in the 3D wireframe map is an ill-posed problem. Against this problem, we took a simplest and naive approach. We first convert 3D wireframe map into various perspective 2D images based on the client's camera information, such as an angle of view and an image size, on ahead.

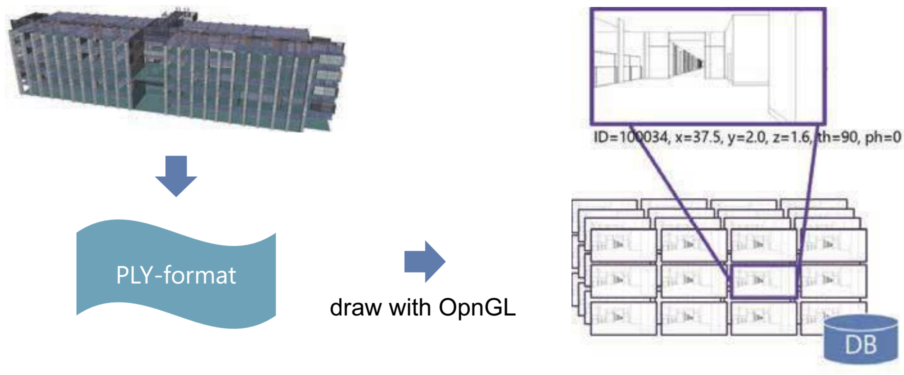

Figure 3. The data conversion flow from 3D CAD to 2D image DB of multiple-perspective

The conversion flow is shown in Fig. 3. These 2D images in the DB are line-segments images.

Then we calculate a logical conjunction between the query image and an image in DB one by one. The image in DB, which gives maximum number of pixels in its logical conjunction result, is the closest image to the query. Finally, the position of the closest image is selected as the position where the query image is taken. Note that a query image is subjected to dilation filter before the logical conjunction process in order to compensate the difference of optical distortion between the client camera and the OpenGL drawing system.

Let A_q, A^i_{db} and A^i_{lc} denote number of non-zero pixels of query image, i-th number of image in DB, and logical conjunction image, respectively. Then the matching similarity s^i is given as follows,

$$s^i = A^i_{lc} / \left(A_q + A^i_{db} - A^i_{lc}\right) \ . \tag{1}$$

The policy of the closest image selection is,

$$i_{best} = \arg\max_i \ s^i \ . \tag{2}$$

The drawback of this method is the tradeoff between the localization accuracy and the granularity of DB images. If you need more precise position, the granularity should be set to smaller. This setting bloats the DB size and usually lead to make calculation load large. However, by using parallel computing scheme, the logical conjunction matching process is conducted in short time. Next subsection validates the logical conjunction based localization approach.

5.2. Pilot experiment

We conducted a pilot experiment to evaluate our proposed positioning algorithm. Before the experiment, we prepared 50 number of pictures taken at various perspective in the filed with correct position data as input query data. We also prepared 40,000 number of DB images. Fig. 4 shows the experimental setups.

Fig. 5 shows one case in the process including a query image, a closest DB image, and a resulted logical conjunction image. In this case, the maximum simirality is

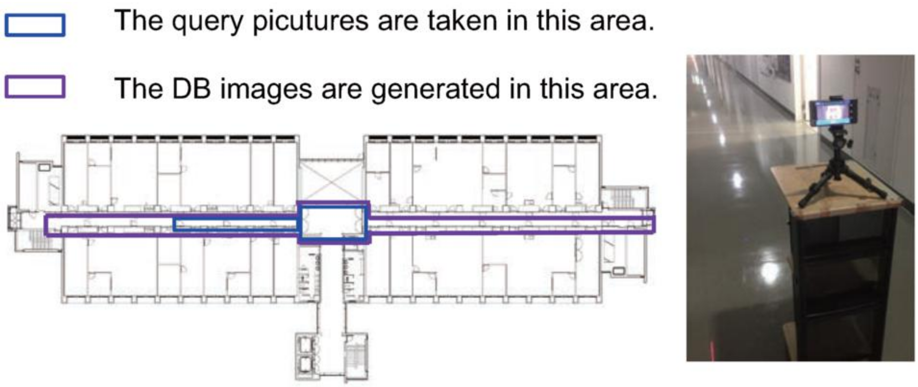

Figure 4. The client camera for experiment and the DB image generated area

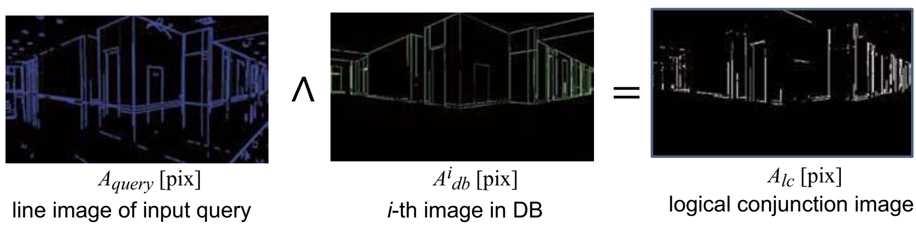

Figure 5. Images in naive lines matching process

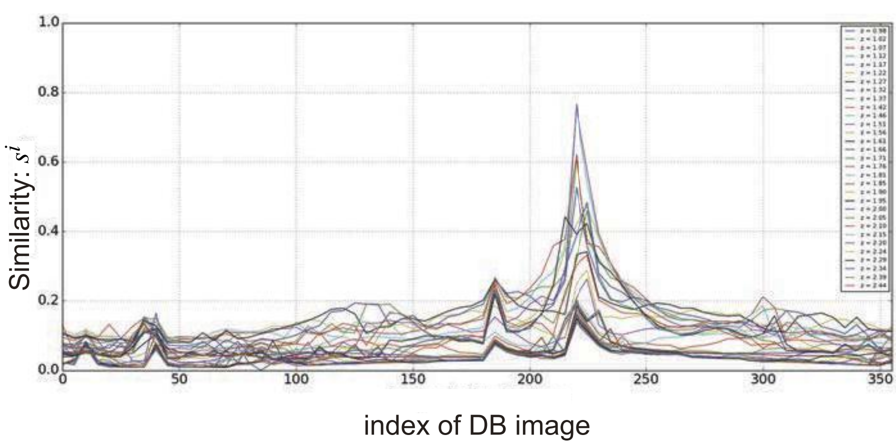

Figure 6. Matching results vs whole DB images

$s^{i_{best}=05661} = 0.74$. The matching results of the query image versus whole DB images are plotted in Fig. 6. From this graph it is confirmed that the closest DB image clearly differs from other DB images in similarity score. The average of root mean square error of all localization results is 0.21[m].

6. Summary

We proposed a novel positioning system named Universal Map (UMap) that is cloud-based system for reducing the computational load at client mobile objects. Since the all localization calculations are conducted on the server side, the client only has to do sensing and sending the data. This light computational load is suitable for IoT context. In the UMap prepared area, any mobile objects such as a robot, a smartphone, a card tag hanging around neck, a cart in a hospital, a vehicle in a warehouse, cane be localized precisely. Additionally, the UMap has a benefit in maintenance cost because this system never needs any physical device or module or marker on the environment. In this paper we organized the research issues to realize the UMap and showed the recent results including a construction of 3d-wireframe map and a similarity-based localization algorithm. The pilot experiment showed the potential that the UMap would become an effective positioning system.

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Human-Robot Personal Space Evaluated with Biological Information Emotion Estimation Method

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Abstract. Recently, interactive robots have been widely used around the world. In the field of this research, nonverbal communication is expected to play an important role in interactions between humans and robots. We hypothesized that if a robot maintains a comfortable distance to humans they will be more readily accepted. Generally, the idea of personal space (PS) is defined as the invisible boundary between humans, modifiable by intimacy. If violated the lack of personal space creates a feeling of discomfort. Human-robot personal space is not necessarily the same as human-human personal space. We focus on the human-robot personal space and seek to understand how people experience violation of personal space by robots. Previous studies investigated how people feel when a robot violated their personal space by observing their heart rate. However, specific feelings are difficult to determine just by using heart rate. This paper investigates the emotions generated when a robot moves into someone's personal space by using an emotion estimation method, which maps values obtained from heartbeat and brain waves to Russell's circumplex model of affect. A significant difference in the feeling of high valence and low arousal found between inside the personal space and outside the personal space. Further, a significant difference in the feeling of high arousal five seconds before and after the robot stopped was found between groups with different degrees of the person's interest level for robots. These results show the effectiveness of using biological signal based emotion estimation to evaluate the impression of a robot at the boundary of personal space.

Keywords. Human-robot interaction, Russell's circumplex model

1. Introduction

In recent years communication robots are widely used for the purpose of application to new services and intelligent entertainment. In the area of human-robot interaction research, the design of a robot takes into consideration that the robots behavior will

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affect the user experience. Nakata et al. showed that the user has a favorable impression of the robot when performing an interpersonal accepting action in robot contact [1]. Okada et al. improved user experience metrics such as activity, pleasure, affinity, intentionality, and continuity by actively performing greeting actions [2], showing the usefulness of active behavior. The basic idea in these methods is to investigate the subjective impression of a person when a robot displays basic patterns of human communication.

Personal space (PS) is an important part of human communication [3]. Interestingly, although the notion of personal space is associated with humans, it was first discovered in animals [18]. Computer Vision bases PS research in Non-verbal communication on estimation of PS as described by Amaoka et al. [4]. Against a virtual opponent in Second Life, which is used as one of the modalities [3] and which is an important research subject pertaining to nonverbal communication. However, PS for a human's robot has not been fully investigated. We think that the idea of PS is important in robot-human interaction. Robots that are physically present provide different experience to humans depending on their distance. For example, when a robot enters the personal space without considering human emotions, the experience of the robot may deteriorate. Considering PS is important to improve human experience of robots. We look to improve human experience of robots by deducing optimal PS interactions.

As a method of evaluating user experience, Nakajima et al. focused on the PS for the robot and investigated peoples PS with a heart rate monitor [13]. They found that when the robot intruded into the personal space at a speed of 0.8 [m / sec] or more, the heart rate became faster. However, it is difficult to identify emotions with heart rate. Specifically it has no resolution pertaining to the emotions “tense”, “excited” or “surprised”. Moreover, heart rate will change with breathing and exercise and is genetically variable between humans. It is important to estimate PS with the emotion more properly by discriminating detailed emotions with a more robust approach [7].

Ikeda et al. used physiological information such as brain waves and heart rates to estimate human emotion by Russell's circumplex model of affect and evaluate the method [8,16]. In the method, biological information is associated with Russell's two-dimensional coordinates [13], the emotions are estimated with the orthogonal x and y axes and adjectives of emotion are arranged in a circular pattern. Heart rate is measured by pNN50 and mapped to the x axes and the brain waves are mapped to the y axes. Using the four quadrants and the arranged adjectives of emotions in a circular pattern, they estimate the approximate emotion successfully. In the method, the pNN50 is used for measuring the fluctuation of heartbeat to classify the status of low valence state such as "tense", and high valence state such as “pleased”. The classification of the arousal is measured with the electroencephalography (EEG) [6,12]. Several studies have been done[14] to classify emotions using EEG and recent studies used machine learning to classify emotions[11].In this study, we aim at estimating emotion when a robot intrudes into someone’s PS and analyzing it by using the biological emotion estimation method based on the Russell classification model. We assume that the emotional reaction for the robot in the PS would be useful to determine the best location for the robot.

Based on this idea, we have developed a robot and evaluated its effect on PS at different approaching speeds of 0.2 and 0.4 m/s. The experiment results show that there is a significant difference both in whether or not the user is interested in the robot and

in the approaching speed of the robot. They also show that there is a significant difference between inside and outside of PS for low arousal and the high valence emotion “calm”. Furthermore, the high arousal and neutral valence emotional state "surprised" has a significant difference in whether or not the user is interested in the robot when the robot stops. Therefore, evaluating the experience of robots would be possible with biological-information-based emotion estimation at the boundary of PS.
The structure of this paper is as follows. Section 2 shows the evaluation method by emotion estimation, which is the proposal, the experiment and its consideration in Section 3 and the summary and future tasks in Section 4.

2. Emotion evaluation of robot approaching to PS

2.1. Emotion Estimation for Robot-Human PS

We first define PS as an invisible boundary surrounding a person's body, and its size varies depending on the intimacy with the partner [5]. This distance is said to have four distinct classifications: close distance (- 0.45 m), individual distance (0.45 m to 1.20 m), social distance (1.20 m to 3.60 m), and public distance (3.60 m) [5]. Within this boundary, people feel uncomfortable when the person or robot is approaching, and are also physiologically affected, such as increase of heart rate [18]. In this study, we aim at evaluating the person's detailed emotion when a robot moves to the PS boundary. In order to do this we use an emotion evaluation method based on biometric information. The method of estimating emotion based on biometric information is a method proposed by Ikeda et al. [8]. Ikeda et al. correlated the brain waves to the arousal of the y-axis of the two-dimensional coordinates called Russell's circular model and pNN50 of the x-axis as the indicator of comfortable, and identified the various emotions with the two parameters. Based on this proposal, our group has improved the accuracy by classifying emotions by adding vector decomposition analysis, and making it possible to estimate the emotion more than the validation of heart rate. It is possible to classify the emotions such as "tense" in high arousal and low valence state, "bored" in low arousal and low valence, etc. In addition, in emotion analysis of biological information, when comparing with the emotion estimation result by facial image analysis, they found that it is possible to estimate the emotion more reliably not depends on the features of the expression of the face [8]. Based on this understanding, we consider that it is possible to investigate the difference of individual emotions of robot-human PS.

2.2. Emotion Estimation Method with Biological Information

As described in the previous subsection, we apply [8] as a classification method of emotions. As we described in the introduction, two values of the measured brain wave and heart rate (pNN50) are treated as coordinates on the XY plane, and the angle with respect to the X axis is calculated from the origin of this coordinate. The angle is discriminated by applying the Russell annulus model to a classification model simplified to eight emotions. Also, in order to judge the magnitude of emotion, not only angle but also distance from the origin is calculated, and this distance is evaluated as the magnitude of emotion in this research. This method classifies emotions into eight categories using Russel's circular model to be simplified and approximated (Figure 1).

The measured values obtained with EEG are associated with a point in the two-dimensional plane. Subsequently, the calculated angle of the point from the x axis and the distance between the point and the origin correspond to the type and the approximate strength of emotion, respectively.

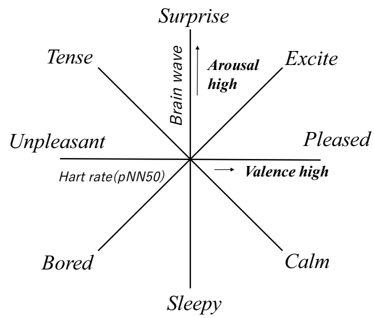


Figure 1 8 emotional classifications of Russell's circular model

3. Evaluation

3.1. Experiment Method

In this study we prepared the two evaluations for emotion estimation, one was emotion estimation by measurement of biological information that was described above and the other was statistical analysis by subjective questionnaire for the collaborators.

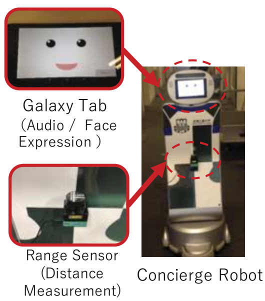
(1) Emotion estimation method by measurement of biological information: The value of the x axis is calculated using the pulse sensor [17]. This sensor measures the heart rate by the photoelectric volume pulse wave recording method, the evaluation index uses pNN50, which indicates the proportion of the heart rate at which the difference between the RR interval of the peak value of the heart beat and the adjacent RR interval exceeds 50ms from the continuous heart rate. In general, the RR interval is the ratio of the respiration and blood pressure, since it is assumed that there is constant fluctuation due to the influence, the higher the ratio of the RR interval, the more valent (comfortable) state is estimated. Therefore, to calculate the value of this ratio, it is said that the comfortable state can be judged by associating with the x-axis. The y-axis value was used for the measurement of brain waves by NeuroSky's MindWave Mobile [15]. The brain wave sensor provides the two metrics that are Attention and Meditation. Attention is associated with β wave, and Meditation is associated with α wave. The β states are associated with normal waking consciousness. The α waves originate from the occipital lobe during wakeful relaxation with closed eyes. Attention and Meditation are the values that remove noise from α and β waves, respectively. We use the two metrics' difference as to correspond to the y axis. In this study, we considered that it is possible to judge arousal level by this difference value.

(2) Subjective assessment questionnaire was conducted to answer the subjective feelings of the participant in the questionnaire selection formulas. It is a subjective questionnaire evaluation. In the subjective questionnaire, the eight axes of emotional classification model are "surprised", "excited", "pleased", "calm", "sleepy", "bored", "unpleasant" and "tense". The size of the emotions and the size of each emotion was

evaluated in six stages. In addition, as an attribute evaluation questionnaire of experiment collaborators, we asked questions about interests and interests to robots [9] and asked questions about interpersonal behaviors and the surrounding environment [1], respectively.

3.2. Experiment with a Robot

The purpose of this evaluation is to firstly measure the emotional change from biological information when changing the distance between the robot and the person. Next, we analyze the relationship between recalled emotions and attributes of experiment participants. There were 10 experimental collaborators (9 men in their twenties and 1 female in her twenties). The room temperature was set to 25 degrees. For the electroencephalograph, Mindwave Mobile [2] which is EEG of Neuro Sky [2] was used, and the heart rate meter was Pulse Sensor [17]. We use the robot "Concierge Robot" (Figure 2), that has an area sensor (URG - 04LX - UG 01) for measuring the distance data, a tablet for displaying the face and emitting voice. The Software architecture that we are developed was shown in the Figure 3.



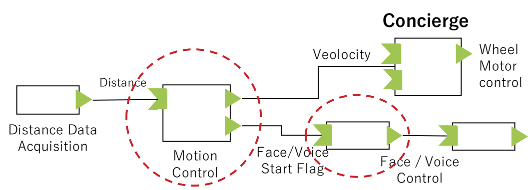


Figure 2. Concierge Robot Figure 3. Software Architecture (RT-Middleware)

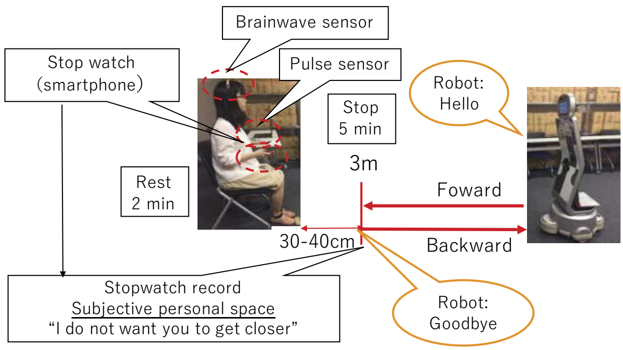
In order to measure the PS for the experimental collaborators' robots, the experiment collaborators were instructed to use the stopwatch function of the smartphone. This robot is developed by the Shibaura Institute of Technology.

3.3. Experiment Procedure

In the Figure 4, we illustrate the experiment situation. In front of the experiment collaborator, there is a robot. The experimental procedure is described as follows.
1. The robot waits at the position 3 m ahead from the collaborator
2. EEG and pulse sensor attached to the collaborator, rest for 2 minutes
3. Robot: After hearing "Hello", approaching linearly at a speed of 0.2 [m/sec]
4. The experiment collaborator starts a stopwatch as the approach starts
5. During approach, the collaborator gets lap at the point where the robot thinks "I do not want you to come any closer"
6. Robot stops for 5 seconds at 30 - 40 cm position with the collaborator
7. Robot: After saying "Good-bye", linearly retreat at a speed of 0.2 [m / sec]
8. During retreat, the collaborator stop the smartphone timer at the point where the robot thinks "I do not want you to separate any more"

9. After retracting to the movement start position, the robot stops
10. Fill out the questionnaire after robot operation finished
11. Repeat steps 3 to 9 at a speed of 0.4 [m/sec]

Considering the counterbalance, the order of the moving speed of the robot was 0.4 m/sec after five experimental collaborators at a speed of 0.2 [m/sec] and the remaining five experimental collaborators at a speed of 0.4 [m/sec] and then 0.2 [m / sec].



Motion of the robot within the range of close distance (to 0.45 m), Individual distance (0.45 to 1.20 m), Social distance (1.20 to 3.60 m) [1]

Figure 4. Experimental Situation

4. Evaluation

4.1. Experiment Result

Based on the biological information gathered through experiments, we try to analyze the emotion analysis results by the method. As shown in Figure 5, when the robot approaches at 0.2 m / sec, it can be confirmed that the emotions of high arousal and low valence emotions such as being "tense" and "unpleasant" have increased after the robot has entered the PS of the experiment collaborator A.

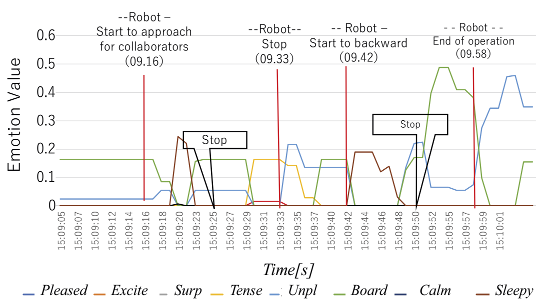


Figure 5. Emotion Transition of Experiment with Collaborator A（0.2[m/sec]）
stop: is the pushed time that the collaborator selects.

When the robot approached experiment collaborator B under similar conditions, the emotion of "surprise" became large after the robot entered the PS of experiment collaborator B from Figure 6. Next, when the robot approaches at 0.4 m/sec, as shown in Figure. 7, when the robot enters into the PS, the experiment collaborators A does not show the feeling of "surprise" or "tense", the emotion of “sleepy” rose a little. When the robot approached experiment collaborator B under similar conditions, the emotion of "tense" and "unpleasant" became large after the robot entered the PS of experiment collaborator B from the figure.

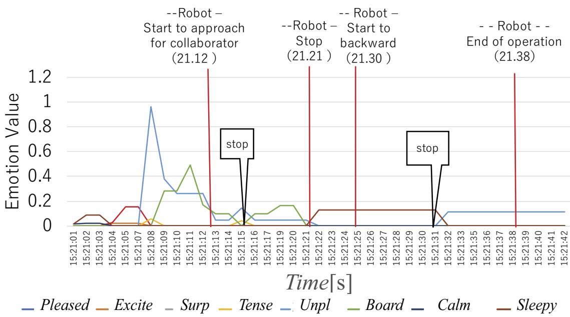


Figure 6. Emotion Transition of Experiment Collaborator B（0.2[m/sec]）

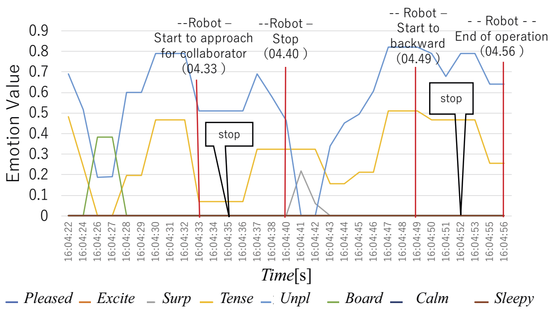


Figure 7. Emotion Transition of Experiment Collaborator A（0.4[m/sec]）

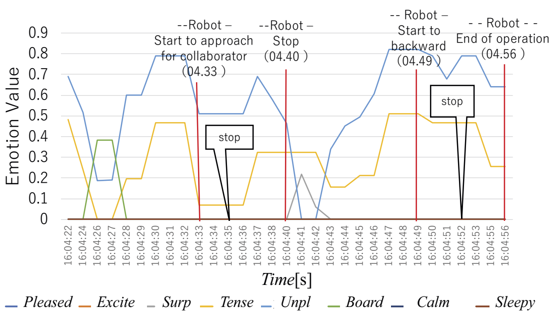


Figure 8. Emotion Transition of Experiment Collaborator B（0.4[m/sec]）

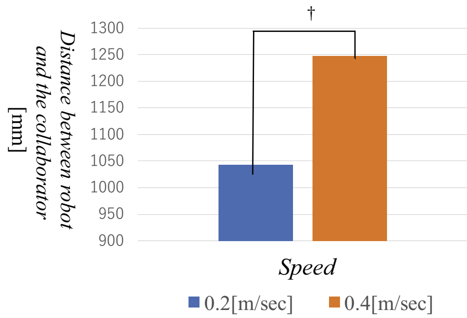


Figure 9. Difference of "unpleasant" in a group with high interest in the robot and a group with low interest.

4.2. Discussion

From the experimental results shown in Figures. 5 to 8, when the robot intrudes into the subjective PS when approaching, the emotions of "tense", "surprise", and "unpleasant" are high in both experimental collaborators. The feeling of A and B are considered that the psychological distance of subjective assessment with questionnaire results would be influences the emotion of "tense", "surprise", and "unpleasant".

Furthermore, in Figure 9, the emotion of "unpleasant" that is neutral in arousal and low valence in 5 seconds before and after stopping when the robot approached at 0.2 [m / sec] from the group with high interest in robot was lower than that in low group. We consider the result that the people who are interested in robots prefer robots that appear in science fiction movies etc. We have speculated the reason for this. The people who are interested in robots often prefer robots that appear in science fiction movies. Therefore, the expectation for the expecting image of the robot is high. In the experiment, when they saw the actual robot which came near, they would be feel the gap with the robot they expected (since our robot would not be so exciting compared with the SF robot characters). Therefore, we think that they felt uncomfortable with the robot.

4.3. Extended Experiment and Results

We increased the number of experiment collaborators by six and conducted experiments again. We had 16 collaborators in total. This is because the result of the experiments shown in Section 3.1, there are no significant difference at the statistical results of proximity distance and speed. Even if an increase in emotion of being "tense", "surprised", and "unpleasant" was observed at the time of approaching the robot.

The additional experiment was carried out in exactly the same way as the experiment that was described in previous section. In addition, as the analysis method, using the result of having the robot question whether interest in the robot is answered by the subjective questionnaire, the group in the reaction of the biological information is divided. As a result, it was possible to obtain results with significant differences that could not be obtained with 10 collaborators within the 16 collaborators. Figure 10-13 describes the experiment results and discussion, respectively.

The analysis results are obtained from the twelve people excluding cases where the data could not be acquired sufficiently. Figure 10 shows the difference in distance between the experimental collaborators and the robot for each speed of 0.2 [m/sec] and 0.4 [m/sec], while the average of 0.2 [m/sec] was 1,043 [mm], the average of 0.4

[m/sec] was 1,246 [mm], depending on the speed, the robot and the experimental collaborator. A significant trend was seen in the distance evaluation (p <0.09).

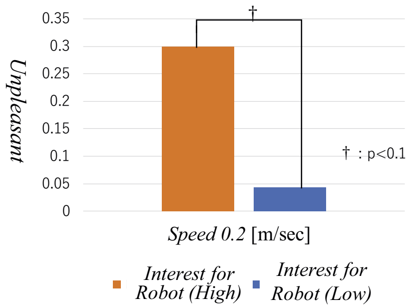


Figure 10. Personal space at robot approach speed 0.2[m/sec] and 0.4[m/sec]

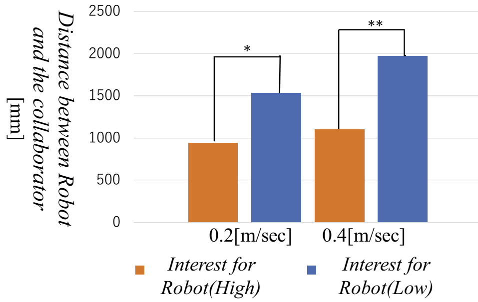


Figure 11. Personal space at robot approaching robot interest

With this result, it became clear that not only the distance but also the speed affects the response to the robot as it approaches the PS. In particular, the robot has the aspect of machine and object, therefore it is thought that there is a tendency to be perceived as dangerous, this would affect the psychological distance of subjective evaluation. Generally, a personal distance is to be observed also between animals and people, other than between humans. In the future, it is necessary to survey and compare the robot as a new target as well.

Figure 11 shows two different approaching speeds 0.2 and 0.4 [m/sec] and the difference of robot interest in subjective assessment questionnaire. As for the robot interest with questionnaire, we divided the group with high interest in the robot and the group with low interest to the robot by the subjective questionnaire calculated the average of each group and tested. As the result, the robot approaching speed 0.2 [m/sec], there was a significant difference in the psychological distance which is the subjective distance that is decided by the collaborators in the experiment, in any of the cases of 0.2 [m/sec] (p <.05), and 0.4 [m/sec] (p <.01). In any case, a robot interested person that is classified with the allowed a robot to approach closer, the distance of around one questionnaire, the meter observed on average can recognize the expression of the approaching opponent, and generally defined as the individual distance in PS to communicate (0.45 m - 1.20 m) with the people personally. On the other hand, those who are not interested in robots that are classified with the questionnaire chose to stop at a longer distance than those who are interested, both at high speed and at low speed. At 0.4 m / sec, the average distance is around 2 m, it is defined as the common social distance (1.20 m - 3.60 m) in PS as an unknown human communication space.

4.4. Additional Experiment: emotion analysis Result

We performed an additional experiment and analyzed the result with more statistical data. Figure 12 shows the result of the "calm" emotional state when the robot is inside / outside the PS.

In the Figure12, a significant tendency was seen in the value of "calm" emotions in and out of the PS. "Calm" is a classified in the comfortable state, which is a reaction of the autonomic nerve, and at the same time it is a value indicating a state of relaxation with a low degree of arousal level measured by brain waves. Ten people considering the counter balance of the experiment as a result of analyzing the results. From this, it is conceivable that it can be used as an index for autonomous control considering PS by analysis focusing on "calm" emotion and construction of prediction model.

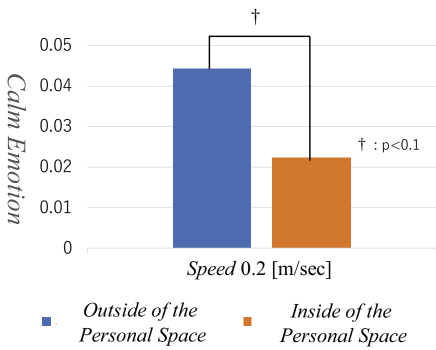


Figure 12. "Calm" emotion when the robot is inside / outside of the personal space

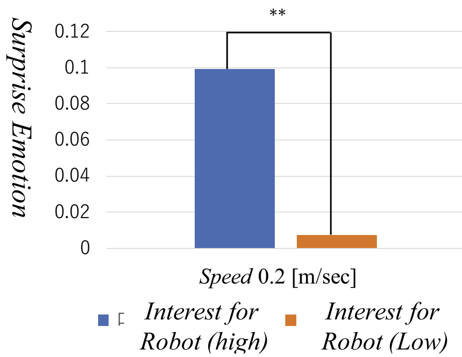


Figure 13. Robot against Robot Interest

Figure 13 shows the results of comparing the differences in the magnitude of emotions of "surprise" for 5 seconds before and after stopping the robot for each of the two groups with different robot interest levels by the questionnaire method. The result shows that the robot is 0.2 [m/sec]. There was a significant difference in the feeling of "surprise" when approaching the robot at 0.2 [m/sec]. ($p < .01$). Specifically, it was found that the group of people with less robot interest had a stronger emotion of "surprise". From those who are not interested in robots, they are not familiar with the autonomous robots, therefore the biological reaction is aroused in emotion of being "surprised". From this, it is conceivable that it can be used as a judgment index of the presence or absence of interest, whether or not a person is familiar with the robot, by analyzing people's "surprise" and constructing a prediction model.

5. Conclusion

In this study, we aimed to analyze the human emotional response when a robot moved across their PS boundary, based on biological information. The results of the experiment show a significant difference or a significant tendency in the difference in height of the robot interest degree and the speed of the robot's approach. The results show that it is effective to evaluate the experience of the robot at the PS boundary by emotion estimation using biological information. In the future, we aim to improve the user experience of the robot by maintaining the optimum distance deduced from the result obtained by the biometric information emotion estimation method.

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Toward a Real-Time and Physiologically Controlled Thermal Comfort Provision in Office Buildings

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Abstract
Thermal comfort is, by definition, a personal and subjective psychological sensation. Still, its provision in office buildings relies on underperforming and energy-hungry Heating Ventilation and Air Conditioning (HVAC) units that preclude people's personal preferences. This leads to people reporting a high discontent with the built environment. This study provides a preliminary evaluation of a physiologically controlled thermal comfort provision based on Pulse Rate Variability (PRV). The study is based on a premise that thermally uncomfortable environments affect temperature homeostasis in humans. This change in homeostasis is indirectly detected by e.g. the variability of the heart's beat-to-beat intervals. We experimented on a user sitting in two thermal environments (cold and neutral) to estimate PRV via a photoplethysmogram (PPG) signal recorded on his wrist. The result of the experiment shows that it is possible to predict the user's thermal state in real-time with an accuracy exceeding 90%. Hence, the paper constitutes a prima facie evidence of the possibility of designing real-time physiologically controlled thermal conditioning systems.

Keywords. thermal comfort, smart thermostats, heart rate variability, pulse rate variability, smart building, personal thermal comfort, humanized computing

1. Introduction

The provision of thermal comfort in buildings is mostly based on mechanical Heating Ventilation and Air Conditioning (HVAC) systems that, in a nutshell, hinge on controlled laboratory experiments and consider environmental parameters (e.g. air temperature, air velocity, mean radiant temperature and relative humidity) and personal factors (e.g. metabolic rate and clothing insulation) to predict a uniform thermal environment that, purportedly, is satisfactory to all occupants [1]. In practice, however, HVAC systems fails to live up to their expectations since people report a high thermal comfort dissatisfaction in buildings [2]. This dissatisfaction is expected because HVAC systems are based on mathematical models derived from experiments on a large group of people. On the contrary, by definition, thermal comfort is "a condition of mind that expresses satis-

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faction with the thermal environment and is assessed by subjective evaluation" [3], and is trigged by psychological and behavioral factors, and depends on people's norms and their expectations [4, 5]. As a result, it varies from one person to another [6]. It is, thus, a complex phenomenon that cannot be reduced to simple linear mathematical equations [7]. Moreover, HVAC units necessitate enormous energy in order to create its sine qua non thermal neutral conditions. Paradoxically, there is credible evidence that there exist no one-fits-all thermal comfort settings that would satisfy all occupants. Instead, there is a wide variation of satisfactory thermal comfort settings amongst people [8, 7], with e.g. acceptable temperature ranging between 18 °C and 28 °C in Japan [9], and, in extreme cases, can be even extended to between 10 °C and 35 °C [4]. Henceforth, achieving thermal neutrality is a costly and meretricious undertaking that is not necessarily the right way to provide thermal comfort.

Recent research, partly due to an increased awareness of the need for a sustainable energy consumption, propose to use personalized environmental conditioning systems [10, 8] as a compromise between thermal comfort and energy conservation. Personalized conditioning systems deliver the thermal comfort to the parts of the body where it is needed the most and allow occupants to extend their thermostat's dead-bands beyond ranges that would be otherwise prescribed by conventional thermal comfort models; therefore, they necessitate considerably lower energy without compromising people's thermal comfort [10]. Nevertheless, they have a lower adoption and acceptance rate presumably due to the required user interaction that can lead to rebounds and overshoots [10]. Another research trend is the use of occupancy-based intelligent thermal controllers [11, 12]. In essence, they adaptively dispense heating or cooling depending on the availability, or the lack thereof, of building occupants. However, while they provide a good energy saving [13], their performance is comparable to that already achievable by existing systems [14]. Additionally, like existing HVACs, they do not account for differences amongst people, their thermal preferences, their mental state and other psychometrics that influence thermal comfort. Recently, Barrios and Kleiminger [15] proposed an intelligent thermostat that infers thermal comfort from a combination of occupants' heart rates and their surrounding environment and they achieved a ± 0.5 point accuracy within the expected ASHRAE scale. Their infrastructure, however, requires periodic manual calibration from the users. The past few years have seen an increasing interest in the possibility of creating personalized thermal comfort systems that predict an individual's thermal needs based on the data collected in his surrounding. In an effort to provide a cohesive guidance to researchers in this emerging research area, Kim and her coauthors [16] recently proposed a personal comfort model that leverage the Internet of Things (IoT) and machine learning to learn and predict an individual's thermal comfort requirements and showed that the model is noticeably accurate compared to the widely used Predicted Mean Vote (PMV) model [17].

In our previous research we asserted that since, in humans, thermal regulation is controlled by involuntary mechanisms governed by the brain's hypothalamus [18], people's thermal comfort could be more rigorously estimated from the variation of their physiological signals. We showed that it was possible to predict, with a 93.7% accuracy, subjects' thermal comfort state using heart rate variability (HRV) [19] and we proposed a generic framework for a collective energy-efficient physiologically-controlled system that could be used in e.g. office environments [20]. This paper is a natural continuation of our previous works and presents a glimpse of the possibility of creating a real-time physiologically controlled thermal conditioning systems based on PRV.

2. Methods

2.1. Machine learning model

To predict thermal comfort, we conducted experiments on 17 male subjects doing light work (metabolic rate $\approx$1.0) in three thermal chambers whose settings conform to those of a cold, a neutral and a hot thermal sensation on a PMV index scale (Table 1). Each experiment lasted for about 30 minutes. For each environment, we recorded each subject's electrocardiogram (ECG). These ECG signals were used to extract inter-beat interval (IBI) signals that were subsequently used to compute HRV indices. In this study, we selected only time domain HRV indices that require a modest time complexity (Table 2). All HRV indices were computed as stated by the recommendations of the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology [21] on a window segment of 5 minutes long IBI signal. A new IBI sample is added to the segment (while the oldest one is removed) and new HRV indices are calculated. This process is repeated until the end of the entire IBI signal.

Table 1. Thermal chamber settings††

	cold	neutral	hot
activity level	1	1	1
clothing level	1	1	1
air temperature(°C)	18.0	24.0	30.0
radiant temperature(°C)	18.0	24.0	30.0
air speed (m/s)	0.3	0.3	0.3
humidity (%RH)	50.0	65.0	80.0
PMV index†	-1.79	-0.03	+1.87

†PMV adjusted for the cooling effect of an elevated air speed

†† Table adapted from an experiment in [19].

Unlike in our previous work [19], in which we evaluated a machine learning model for each user, in this study, the objective was to create a generic model that could be used to predict people's thermal comfort with little or no calibration. In order to achieve this, the extracted HRV indices of all subjects in all thermal environments were combined and shuffled. The resulting data samples were thereafter split into a training and testing set using a 10-fold cross validation, i.e. each of the 10 folds is used to train a random forest classifier on the remaining 9 folds. The resulting model is later used to predict the perceived thermal comfort status in real-time.

We evaluated the performance of the model by computing its precision, recall and F1-score and the support for each class. The precision expresses the proportion of classified true positives (TP) vis-à-vis that of the false negative (FP) in the whole dataset (Equation 7) while the recall expresses the proportion of samples that were misclassified as true, i.e. that are false negative (FN) in the dataset (Equation 8)

Table 2. Description of the selected HRV indices

HRV index	Short description	Equation
MEAN_RR	Mean of all RR intervals	
MEDIAN_RR	Median of all RR intervals	
SDRR	Standard deviation of all interval	
RMSSD	Square root of the mean of the sum of the squares of the difference between adjacent RR intervals	$\sqrt{\frac{1}{N-1}\sum_{i=1}^{N-1}(RR_{i+1}-RR_i)^2}$ (1)
SDSD	Standard deviation of all interval of differences between adjacent RR intervals	$\sigma(RR_{n+1}-RR_n)$ (2) †
SDRR_RMSSD	Ratio of SDRR over RMSSD	
HR	Heart Rate measured by the number of heart beats per minute	
pNN25	Percentage of adjacent RR intervals differing by more than 25 ms	$\frac{\sum_{i=1}^{N}\left(\lvert R_i-R_{i+1}\rvert>25ms\right)}{N-1}$ (3)
pNN50	Percentage of adjacent RR intervals differing by more than 50 ms	$\frac{\sum_{i=1}^{N}\left(\lvert R_i-R_{i+1}\rvert>50ms\right)}{N-1}$ (4)
SD1	Poincaré plot descriptor of the short-term heart rate variability	$\sqrt{variance\left(\frac{RR_i-RR_{i+1}}{\sqrt{2}}\right)}$ (5)
SD2	Poincaré plot descriptor of the long-term heart rate variability	$\sqrt{variance\left(\frac{RR_i+RR_{i+1}}{\sqrt{2}}\right)}$ (6)
KURT	Kurtosis of all RR intervals	ref. to note §
SKEW	Skewness of all RR intervals	ref. to note ⁎
MEAN_REL_RR	Mean of all relative RR intervals	ref. to note ‡
MEDIAN_REL_RR	Median of all relative RR intervals	ref. to note ‡
SDRR_REL_RR	Standard deviation of all relative RR interval	ref. to note ‡
RMSSD_REL_RR	Square root of the mean of the sum of the squares of the difference between adjacent relative RR intervals	ref. to eq. 1 and note ‡
SDSD_REL_RR	Standard deviation of all interval of differences between adjacent relative RR intervals	ref. to eq. 2 and note ‡
SDRR_RMSSD_REL_RR	Ratio of SDRR_REL over RMSSD_REL	
KURT_REL_RR	Kurtosis of all relative RR intervals	ref. to notes § and ‡
SKEW_REL_RR	Skewness of all relative RR intervals	ref. to notes ⁎ and ‡

† $\sigma(x)=\sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\bar{x})^2}$, N is the length of the signal

§ $KURTOSIS(x)=\frac{E\left(x-\bar{x}\right)^4}{\sigma(x)^4}$,
where $\bar{x}$ is the mean of x and E(k) the expected value of k

⁎ $SKEWNESS(x)=\frac{E\left(x-\bar{x}\right)^3}{\sigma(x)^3}$,
where $\bar{x}$ is the mean of x and E(k) the expected value of k

‡ $REL_{RR_i}=2\left(\frac{RR_i-RR_{i-1}}{RR_i+RR_{i-1}}\right),\quad i=2,\ldots,N$ [22]

$$precision = \frac{TP}{TP+FP} \tag{7}$$

$$recal = \frac{TP}{TP+FN} \tag{8}$$

The F1 score is a harmonic mean of the precision and the recall metrics (Equation 9)

$$F1-score = 2\frac{presion \times recall}{precision + recal} \tag{9}$$

2.2. *Real-time thermal comfort prediction experiment*

In this preliminary study, we evaluated one subject whose IBI signal was extracted via a photoplethysmography (PPG) signal recorded using an Empatica E4 wristband (Empatica, Milano, Italy). The blood volume pulse (BVP) signal is obtained by shining a combination of red and green lights on the skin of the wearer of the device. The skin absorbs most of the lights but some is reflected back. The ratio between the reflect and absorbed light depends on the changes in the blood flow due to the activity of the heart and is used to detect the heart beat pattern [23]. The Empatica E4 wristband's photoplethysmography utilizes a green light to detect the heart beat patterns and a red light to track down and reduce hand motion artifacts [24]. The extracted IBI signal is used to predict the thermal comfort of the user using a random forest machine learning model outlined in section 2.1. While this model was trained using IBI extracted from an ECG signal, the thermal comfort prediction is based on an IBI signal extracted from a photoplethysmography pulse rate. This is because the recording of an ECG signal would have required obtrusive chest-strapped ECG electrodes. However, the use of a PPG wristband is non-invasive and can be easily used in a typical office environment. It is important to note that the PPG signal and the ECG signal are not the same. However, PRV is highly correlated with HRV and could be used as its surrogate [25] especially when studying time domain HRV [26]. Nevertheless, PPG is not as precise as ECG. Furthermore, wrist-worn PPG devices are accurate only at rest and their performance decreases when there are excessive hand motions [27]. As a result, our experiment required the subject to sit still in a simulated office environment and refrain from sudden hand motions. In this preliminary study, we only tested two thermal environments: the cold and the neutral. Before the experiment, the user sat in an air conditioned room and was given a remote control to modify the room temperature until the user indicated that he felt cold or neutral depending on the environment under study. At this point, the user was given an Empatica E4 wristband that he wore on his left hand and requested to read some news on a computer. During the subsequent 30 minutes, the Empatica E4 wristband was used to record the subject's PPG signal which is sent to an Android application via Bluetooth wireless technology (Figure 1). An IBI signal is extracted from the received PPG signal and is fed to the machine learning model and the predicted environment is logged to a file for further analysis. In this experiment, we presumed that the user's initial thermal comfort sensation would stay the same during the duration of the experiment. This might be the case for a short period but may not be necessarily the case for a prolonged period.

Figure 1. Real-time thermal comfort prediction system —An Empatica E4 wristband is used to record a photoplethysmogram (PPG) signal. An inter-beat interval (IBI) signal is extracted from the PPG, sent to a smartphone, and used to calculate pulse rate variability indices (PRV). These indices are thereafter used to predict, in real-time, the comfort state of the wearer of the E4 device

3. Results and discussion

Thermal comfort is subjective and depends on, inter alia, the psychometrics and the biological makeup of the person. We asserted that it could be more rigorous to infer the person's thermal comfort from the variation of his biological signals that are normally altered when the person is thermally dis-comfortable. This study is limited to heart rate variability since we had previously shown it to change when the subjects were in thermally dis-comfortable environments [19]. The trained classifier achieved a very high classification performance and there was relatively very few misclassifications (Table 3). What's more, a 99% accuracy can be achieved using less than 5000 training samples (Figure 2). This suggests that people's thermal comfort can be deducted from a short segment of their IBI signal. It is also important to note that a few HRV features (MEADIAN RR, MEAN RR and HR) are more important in classifying thermal comfort (Figure 3).

Table 3. Model performance evaluation metrics

	precision	recall	F1-score	support
Cold	100	100	100	5054
Neutral	99.99	99.9	99.9	5103
Hot	100	99.96	99.98	5123
Average	99.99	99.99	99.99	15280

This might be helpful in cases where computing many HRV features is not computationally feasible.

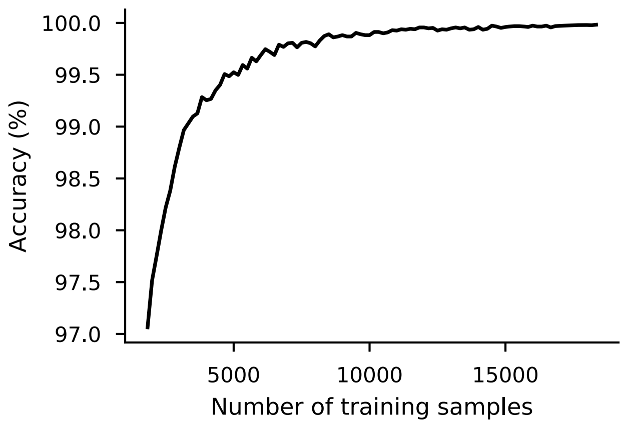

Figure 2. The prediction accuracy of the machine learning model achieve an acceptable performance even with a relatively small training samples

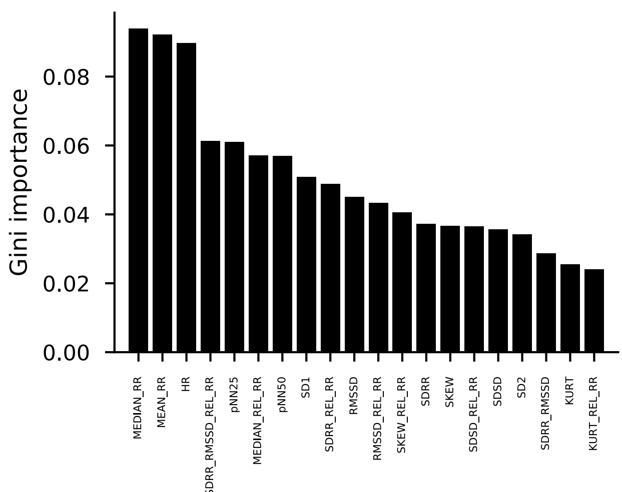

Figure 3. HRV feature importance based gini impurity index used for the calculation of splits during training shows that a few features (MEAN RR, MEADIAN RR and HR) are disproportionately more important for the thermal comfort prediction

Furthermore, since thermal comfort is a subjective sensation, in our experiment, we requested the user to manually vary the thermostat himself until he felt cold or neutral. By this approach, unlike arbitrary thermal comfort settings that are normally used without the individual's saying, the user can adjust the temperature to a level that is satisfactory to him. At the end of the experiment, we analyzed a log file containing the predicted comforts states, and it was found that the model could achieve a high accuracy (96.53% and 92.30% accuracy in the cold and neutral environment respectively). Moreover, the subject indicated he felt thermally comfortable at 27 °C. This is relatively higher than the normal temperature dictated by office HVAC units and is a good indicator that energy could be saved, for example in the summer, by elevating indoor temperatures depending on the thermal tolerance of its occupants. This experiment is however very limited in nature (only one user and in two thermal comfort environmental settings) and not conclusive. A more exhaustive experiment is required to prove the veracity of these findings.

4. Conclusion and future work

The prima facie results of this study highlight the possibility of designing thermal comfort provision systems that are based on the variation of people's physiological signal due to the change in the thermal environment. We showed that it is possible to predict thermal comfort based on the variability of the pulse rate. We surmise our proposed method provide the following advantages over existing methods:

- Higher thermal comfort prediction accuracy —existing thermal provision methods are capped at around 80% thermal satisfaction rate [28]. Our proposed approach might achieve a higher satisfaction rate since it provides a personalized thermal comfort based on how the person 'feels'.
- Reduction in energy consumption required for thermal comfort provision —since people have different thermal comfort expectations, it could be possible to swing the thermostat's deabands away from the traditional limits. This approach has the potential to significantly reduce the energy consummation [29] without affecting building occupants' thermal comfort.
- Such a physiologically controlled system could also be used as part of a responsive and healthy smart office to detect e.g office occupants' psychosocial stress [30] and for chronic diseases detection and prognosis [31].

At this stage, however, the results of this study are not conclusive. Further experiments are needed to assert the validity of this approach. Ideally, the study would be conducted on a large group of people, of all genders and age and be conducted in thermal settings similar to those of the ASHRAE PMV scale (hot, warm, slightly warm, neutral, slightly cool, cool and cold). There is also a need to compare a model extracted from an ECG signal with that extracted from a PPG signal and assess which one works well for thermal comfort prediction. In the future, we also plan to estimate the predicted comfort based on a majority vote of preceding predictions. This would reduce wrong predictions and improve the robustness of the system.

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Investigation of Dynamic Control of Learning Materials Based on Brain Waves

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Abstract. In conventional learning systems, the learning contents are created by somebody or a group of experts and provided to the students in a uniform way. Recent trend of computer-based learning materials can facilitate flexible configuration of learning materials. In this work, we propose OKAGE, a computer-based learning system in which the content of learning dynamically changes depending on the student's concentration level. We drive the concentration level using EEG. This paper describes the design and implementation of OKAGE and preliminary results of experiments.

Keywords. EEG, Alpha wave, E-learning

1. Introduction

Studying is becoming changing due to the use of computers, mobile phones, and the Internet. Computer-based learning or E-learning removes the restrictions about time and place for learning, which accelerates Massive Open Online Courses (MOOCs). Although digitization of learning materials is spreading, the learning contents are created by somebody or a group of experts and are provided to the students in a uniform way. Thus the possibility of digitization has not been fully explored.

In our previous work [1] we used a brain wave in e-learning and constructed a system that shows the degree of concentration in the lecture. Likewise, we think that the degree of concentration can be used to adaptation of the learning materials to each student.

Based on the above background, we propose OKAGE, a computer-based learning system in which the content of learning dynamically changes depending on the student's concentration level. In OKAGE, one learning material consists of several units and the transition of units dynamically changes by adapting to the degree of concentration calculated with the measured Electroencephalogram (EEG) [2] signals. Recently, EEG has been widely used to analyze emotion and human behavior [3,4]. In this paper we describe the design and implementation of OKAGE and preliminary results of experiments.

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2. Design of OKAGE

This section describes how we design OKAGE.

2.1. Design Overview

Design overview is shown in Figure 1. We assume that OKAGE is used in distribution services of lecture video, thus OKAGE adopts the client server system. While a learner watches a lecture video received from server PC, client PC obtains brain waves using EEG to calculate ratio of alpha waves. OKAGE switches the video to another video according to the ratio value in order to provide optimal lectures to the learner. We call this video transition.

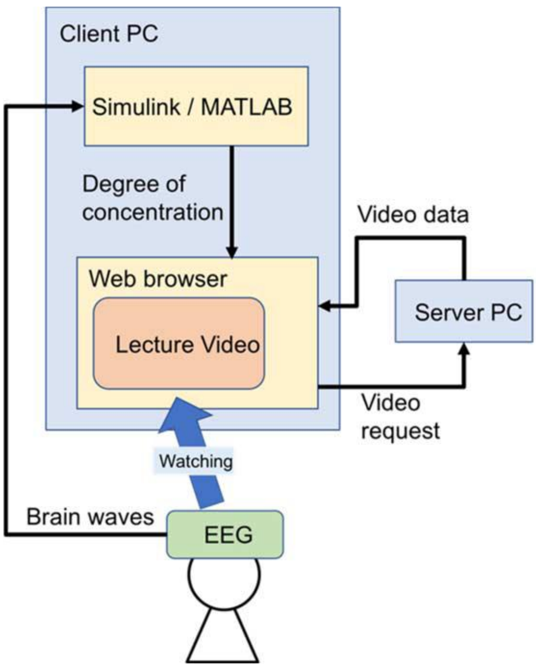

Figure 1. Design Overview.

2.2. The Ratio of Alpha Waves

There are several studies on the relationship between EEG signals and the attention level of human. Liu et al.[5] has explored alpha, beta, theta, and gamma and using many kinds of signals has proven to be effective for detecting the attention level of human. Although we use other signals as well in the future, let us use alpha wave first to see that using only alpha wave can sense the concentration level in a simple way. The software in the client PC converts a time domain signal from EEG into the frequency domain using Fast Fourier Transform (FFT) to calculate η. As frequently done, a high-pass filter is applied to the signal and we set the cut-off frequency to 50 Hz. The ratio of alpha waves is determined from the converted frequency domain. Calculation formulas are shown below in (1).

S : The sum of the absolute values of the frequency spectrograms of the alpha band
T : The sum of the absolute values of all the calculated frequency spectrograms

$$\eta = \frac{S}{T} \tag{1}$$

The calculated η is saved as text data, and the web browser in the client PC reads it as an index of video transition.

2.3. Video Transition

OKAGE switches the lecture video to the supplemental video that explained the lecture in detail in the case the lecturer cannot understand the lecture video. η explained in 2.2 is used as the index for video transition.

OKAGE calculates the average of η in one lecture video, and when the average exceeds the threshold value, make a transition to the supplemental video. Otherwise, OKAGE shifts the lecture video to the next lecture video. Figure 2 shows the flowchart.

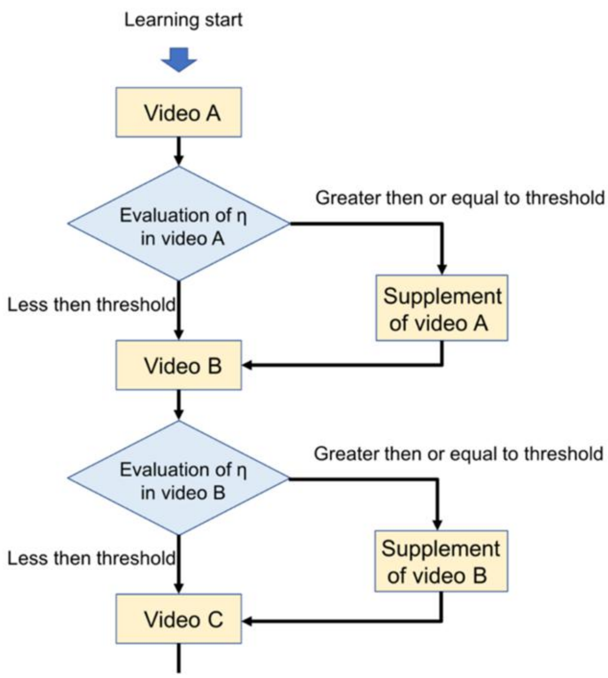

Figure 2. Flowchart

Using this video transition, we attempt to provide video lectures suitable for the state of the learner.

2.4. Lecture Video

We use three types of lecture video created at our research group: video taken by video cameras, slideshows with voice commentary, and video using animation using computer graphics. In this system, if we use animations using computer graphics or video taken by a video camera as lecture video, the boundary between video can be known to the learner because of video translation. In order to switch video naturally, we use slideshows with voice commentary as lecture video. Figure 3 is a part of the lecture slides. The length of lecture A, B, and C is 197 s, 192 s, and 125 s, respectively.

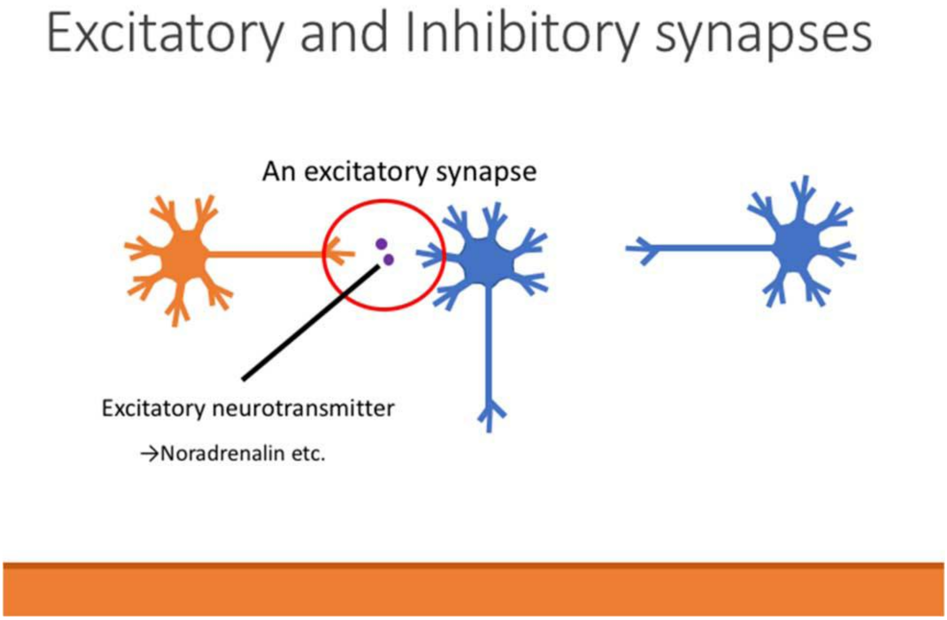

Figure 3. Lecture Slide

3. Measurement of the Degree of Concentration

We used g.Nautilus manufactured by g.tec as EEG in the system. The sampling frequency of g.Nautilus can be selected at 250 Hz and 500 Hz. Since the frequency of the brain waves is approximately 1 to 50 Hz, it was judged that it is sufficient to set the sampling frequency to 250 Hz.

International 10–20 system is used to acquire the brain wave of the subject. AFz is used for the ground, the right earlobe for the reference, and Oz, O1, O2 for the electrode.

4. Evaluation Experiments

In this experiment, we evaluated the usefulness of video transition in OKAGE.

4.1. Method

In this experiment, we evaluated the usefulness of video transition in OKAGE. The learning flow of the lecture video used in the experiment is shown in Figure 4. The learning path which the learner passes is in two ways. Let a pass in the order of A→A ' →B and a pass in the order of A→B represent pass X and pass Y, respectively.

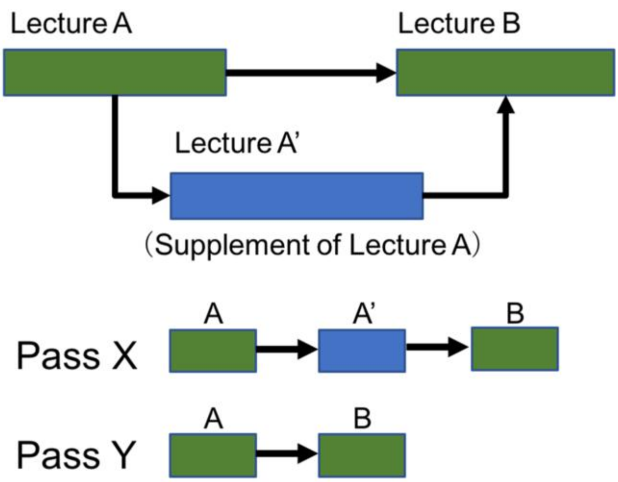

Figure 4. Learning Flow and Learning Path in the Experiment

Let G1 be the group of four learners who have prior knowledge of lecture movie A and G2 the group of four learners who did not give. We let each learner of each group view video of pass X and pass Y. Two of the four learners and the rest of them in each group watched the pass-X video the Pass-Y video, respectively. Brain wave data of the learner was acquired, and the average value of η in each lecture video was evaluated.

4.2. Results

Figure 5 and 6 show the transition of η of the learners who watched the lecture movie for G1 and G2 from the time at which they begin watching the video until 500 s since the start, respectively.

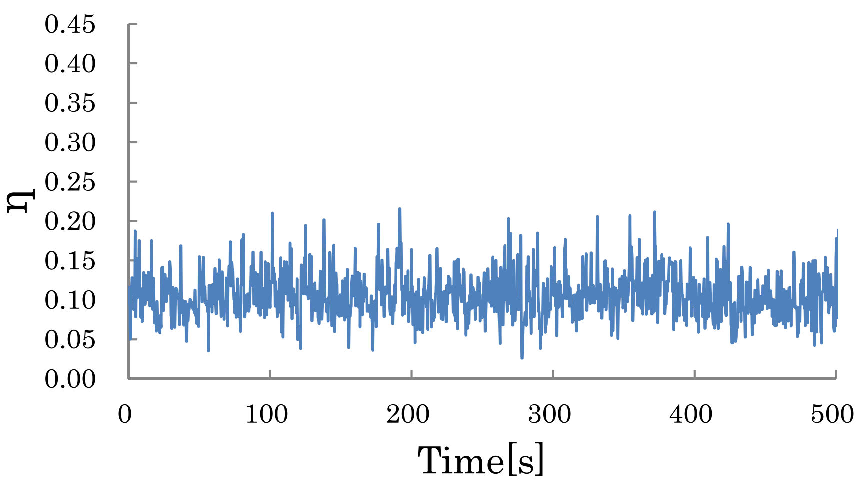

Figure 5. Transition of η of the Learner of G1

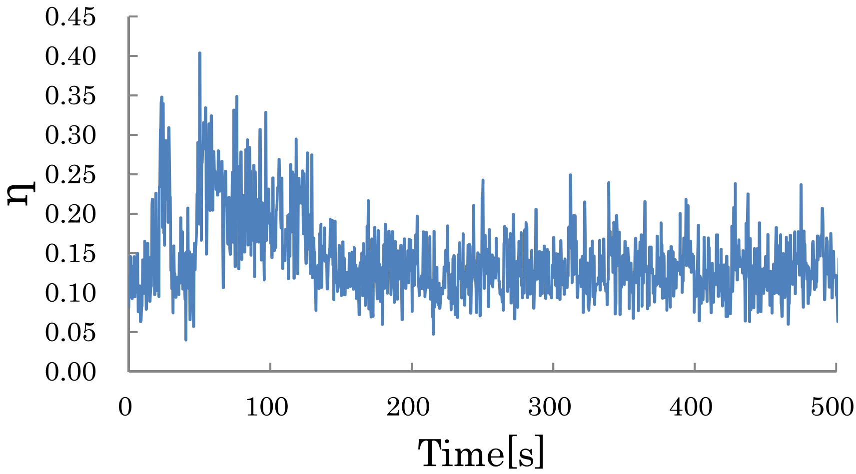

Figure 6. Transition of η of the Learner of G2

We calculated the average η of learners who were watching lecture video for each lecture movie. The average of the calculated values in each group is shown in Figure 7 and 8.

Table 1 shows the difference between η in lecture movie A and lecture movie B as Δη.

From this table, it can be seen that the difference of Δη between Pass X and Pass Y of G1 is 0.005. On the other hand, the difference in Δη between Pass X and Pass Y of G2 is 0.042.

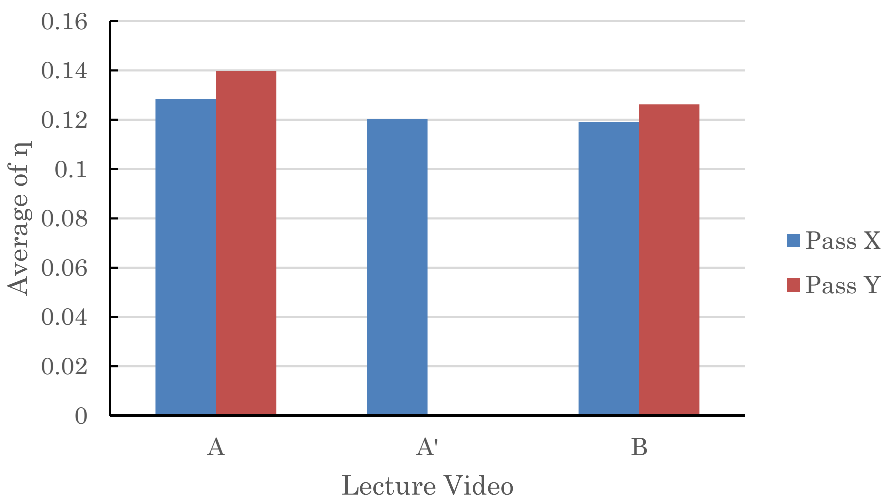

Figure 7. Average of η of G1 in each Lecture Video

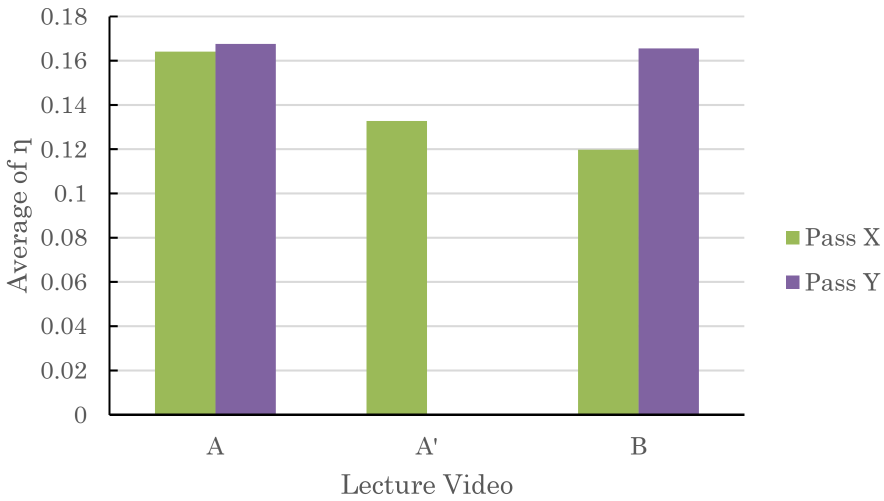

Figure 8. Average of η of G2 in each Lecture Video

Table 1. Difference between η in Lecture Video A and Lecture Video B

Group	Pass	Δ η
G1	X	0.009
	Y	0.014
G2	X	0.044
	Y	0.002

5. Discussions

Because G1 has a small difference in Δη between path X and pass Y, it can be considered that path Y having a short time can be performed in a concentrated state of the same quality as path X. On the other hand, because G2 has a large Δη in path X, supplemental video A' in path X is considered to be useful. From the above, it can be considered that it is appropriate to learn by classifying G1 and G2 into pass Y and pass X respectively.

The main focus of our work is dynamic control of learning materials. The trigger for transition is the concentration level of the learner. There is still a question of whether or not only alpha wave can determine the concentration level. This remains for our future work. In the experiment, we only compared groups with and without prior knowledge. This is also insufficient to verify the validity of dynamic control of learning materials. We will investigate the effect of dynamic materials with a large number of subjects.

6. Conclusions and Future Works

6.1. Conclusions

In this study, we have proposed and implemented a system that classifies learners' learning states using EEG and provides appropriate lecture video to each learner. We examined the usefulness of the system through experiments. However we could not prove accurately because there were few subjects. In addition, only a part of the design is implemented, and it is not yet possible to operate as a video distribution system considering individual differences. In order to make it possible, various challenges remain.

6.2. Future Works

Future works include improving accuracy of measurement of degree of concentration and considering degree of comprehension. In order to improve accuracy of measurement of degree of concentration, it is necessary to consider frequency bands other than alpha waves and acquire other biological information such as gaze and heartbeat. As a classification element, not only the degree of concentration but also the degree of comprehension needs to be considered, and we think that learning records and feedback by learners are necessary.

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Food Supply Chain Management System for Product History Using Blockchain

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Abstract. Food safety is being threatened by disguising the food production area. There is a need for a food supply chain system that can prove food safety and food brand. We examined the feasibility of a traceable food supply chain through experiments. We investigated the feasibility of a traceable food supply chain through experiments. We aimed to construct a system by which Blockchain technology can realize a highly reliable data management system even without a third party agency. We invent "Proof of Proof" (PoP) concept which is a security-enhanced Block chain technology concept based on the cooperation of multiple Blockchains. In this research, the data integrity of private type Blockchains was secured by mutual cooperation of plural Blockchains. By using our PoP, We developed a sufficiently fast Blockchain system that can prove food safety and food brand. In the future, we are convinced that it is possible to realize the next generation food supply chain that can prove food safety and food brand on an automated farm.

Keywords. Blockchain; food supply chain; traceability systems

1. Introduction

Food origin camouflage problems, food poisoning incidents, and fake food problems increased consumer anxiety and concern about food safety. Some efforts exist to visualize a part of production information in agricultural process by a specific organization, such as organic JAS; certification system of organic agricultural products in Japan [1], USDA; obligation to display the origin of agricultural products in the United States [2] and MRLs; setting of residual standards of agricultural chemicals in Europe [3]. In addition, it has been carried out the development of a system to visualize various agricultural production histories and communicate it to consumers [4]. However, it is limited to visualizing history information, and the reliability of data is not sufficiently guaranteed. Furthermore, in the future agriculture technology, it will be considered that a large amount of IoT smart sensing device will be introduced in order to manage all product history information. At that time, it will be important to ensure compatibility between reliability of sensing data and high-speed data processing [5].

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In this research, we focused on Blockchain technology that can realize highly reliable data management system without a third party organization. We developed product history management system to realize a food supply chain that consumers can trust.

Also, we conducted system development and performance verification assuming actual operation. Then, we operated the system and sold organic agricultural products registered production history information. Based on this result, we consider the possibility of social implementation of the food supply chain we mentioned above.
In this paper, we first explain the Blockchain usage policy of the production management system. Next, we explain the challenges in building the production management system and the ideas to overcome the problem. Then, we outline the Blockchain system implemented according to the previous idea and how to realize the reliability. Furthermore, we consider the verification results of performance evaluation of the constructed system. Finally, we investigate whether the constructed system has sufficient performance to social implementation, and describe future prospects.

2. Policy of production history management system

In this research, we had designed a system that managed production historical information such as farm work content and work volume in the crop agricultural production process. We used Blockchain technology for data management of this system. We explain the Blockchain utilization method and explain "Proof of Proof"(PoP) concept which is a security-enhanced Blockchain technology concept based on the cooperation of multiple Blockchains. By using our PoP, we realize high speed writing and securing data authenticity for the Blockchain by mutual cooperation of plural Blockchains.

2.1. Usage of Blockchain

Blockchain is a distributed ledger technology born as the core technology of bit coin which is a virtual currency. Features such as tamper difficulty of recorded data are drawing attention. Therefore, utilization is in progress for applications other than virtual currency. The Blockchain is defined as follows.

Blockchain is a ledger system with the following four requirements.

(1) P2P distributed system; share transaction data between P2P based distributed nodes.

(2) Block generation; a plurality of transaction data is grouped into one block and added to the chain.

(3) Append-only and Irreversible; each block in the chain is linked with a hash function and is added only new blocks. It is not possible to change past data partially in the chain.

(4) Consensus algorithm; when adding blocks to the chain, consensus procedures by participating nodes are required.

Blockchains are generally divided into public type and private type. With public Blockchain known as the Bitcoin, unspecified majority can join the P2P network. With private Blockchains, only single organizations or people within the company can join the Peer to Peer (P2P) network. Performance improvement such as high-speed processing and frequent version upgrade can be performed smoothly; because the identity of participants is confirmed and the administrator is limited. However, when the network scale is small, the reliability of data depends only on the administrator.

In order to realize high reliability, without a third party agency, it is necessary to manage data with public Blockchains. However, in actual operation, writing speed is also important.

In this research, we design Blockchains with high robustness, performance, and traceability for production history management (hereinafter this Blockchain is called "Broof") and operate it in a private type. However, the reliability of data cannot be guaranteed sufficiently with private Blockchains alone. Therefore, in this research, main data management is done in a private type Blockchain, and a mechanism for improving the reliability of data is done by linking with other public type Blockchains. In addition, the effectiveness is verified.

2.2. Compatibility of ensuring data authenticity and high speed writing

Although the production history management system in this research uses a Blockchain with a highly tamper-resistant data structure, the reliability of the data depends on the trust of the system administrator, since it uses a private type Blockchain.

Therefore, we devised a mechanism Proof of Proof (PoP) for guaranteeing the validity of data without relying on trust to the administrator. The outline is shown in **Figure 1**.

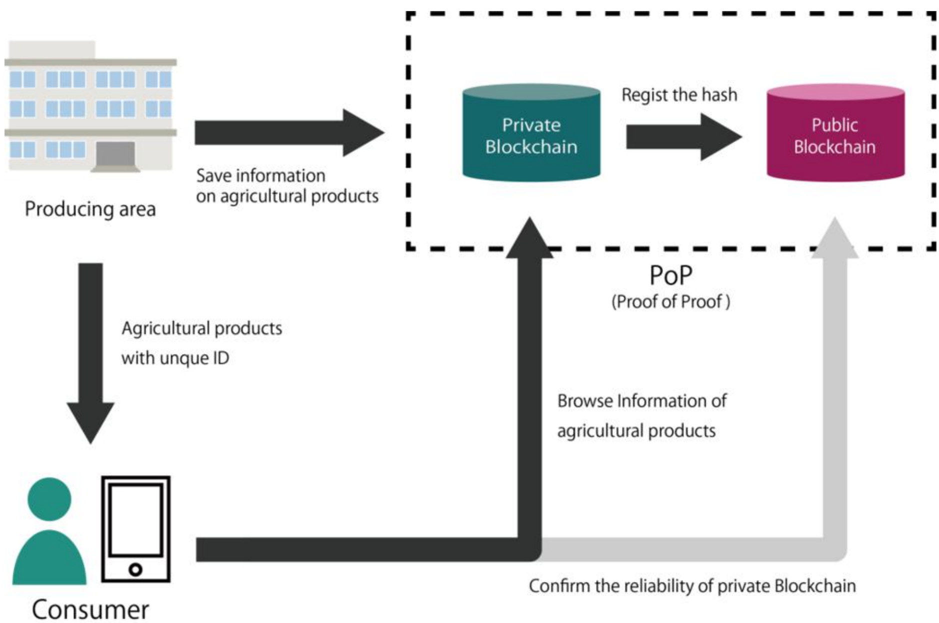

Figure 1. Overview of PoP.

PoP is a mechanism that guarantees the validity of data by combining different Blockchains. Many Blockchains include functions that autonomously suppress fraud under public monitoring by algorithms such as PoW (Proof of Work) and PoS (Proof of Stake).

While this function provides mathematical support to the validity of data, it has brought the need for an unspecified number of people to continue to use certain resources to prevent fraud. These weaknesses stem from the fact that the Blockchain contains the fraud suppression function. In PoP, the fraud suppression function is provided not on individual Blockchains but on a network of loosely coupled Blockchains. Blocks contain in individual Blockchains act as fingerprints of all data, at the time of block creation. Then by registering hashes in these blocks in each Blockchains enables to perform mutual monitoring. When data is altered in a Blockchain, the consistency with other Blockchains cannot be maintained since the data of the block as a fingerprint is also rewritten. In other words, by using PoP, data validity can be given to small Blockchains operated by a specific administrator.

3. System construction

We describe the implementation of the system constructed in this research. We had adopted UTXO (Unspent Transaction Output) approach to ensure and accurately record the history and relationship of data. Broof is in cooperation with KSI (Keyless Signature Infrastructure) to ensure data authenticity. We used IC cards to securely register production history information.

3.1. Data form considering traceability

Information transmitted to Broof such as production history data is treated as a transaction. Broof adopted the same UTXO type data management as Bitcoin [6].

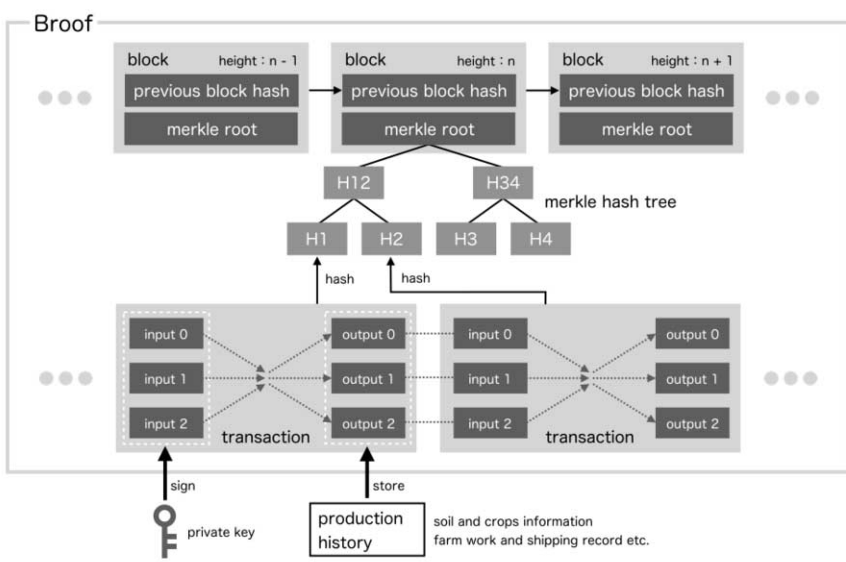

Figure 2. High traceability history management utilizing UTXO type transaction chain.

The structure of transaction is shown in **Figure 2**. The output of one transaction is used as input of another transaction. Once it used, it can no longer be used as input. Transaction inputs and outputs are linked like a chain, and the data structure is very high in traceability.

The product history information is embedded in the transaction together with the electronic signature of the registrant data. The transaction is verified for its validity by a process called "mining" performed by the Broof node, and the transaction group that passed this verification is grouped as a block. By capturing the transaction in the block, the transaction is determined as the data on the Blockchain. In addition, since all the blocks are connected in a chain using a hash function, it is extremely difficult to change and delete the past data included in the block.

3.2. Securing authenticity of data

In the system constructed in this research, PoP was realized by registering the hash value of the block on Broof in the Blockchain of Guardtime's Keyless Signature Infrastructure (KSI) [7].

KSI uses encryption keys when creating signatures, but does not use encryption keys to verify signatures. Therefore, KSI can be regarded as a Blockchain that connects data using a hash. KSI is a distributed system that provides a digital signature and timestamp based on a hierarchical hash tree composed of nodes joining the system in seconds and a calendar holding the root hash of the hash tree. This calendar is a publication database, the calendar hash values are periodically aggregated, published as a hash value called "publication code" on the Internet, and also published on the world distributed media. For example, the publication code is posted on the market version of the Financial Times, and the trust anchor becomes the credit basis (trust anchor) that is posted on such reliable media. In addition, all signatures can trace the hash tree and prove its validity by comparing it with the aforementioned "publication code".

By operating Broof in a private type, PoP is realized by processing data at high speed, linking hash of the data with a Blockchain with reliable credibility called KSI, and does not rely on trust to the administrator Thereby ensuring the validity of the data.

3.3. Safe registration of production history information

When registering the production history information, an IC card for system login was allocated to each farmer, and a secret key necessary for writing data to the Blockchain was made to correspond to the IC card. As a result, the digital signature by the secret key is given to the data such as the production history and the shipping information written by each farmer in the Blockchain, so the contents of the data and the registration source are proved, and at the same time a farmer prefers It is extremely difficult to write false data. Also, by keeping the secret key separately from Broof, we can prevent false data from being generated even by the operation manager of the Blockchain. In this way, by using a safe data registration method, a system that can register data such as soil inspection results by the Organic Agriculture Development Center and daily agricultural product growth records of each farmer over a certain period of time and can accumulate data without problems was constructed.

4. System Evaluation

4.1. Blockchain performance verification method

The constructed production history management system writes a hash into a public type Blockchain at regular intervals. This time was enough longer than the time of transaction processing. Since the processing performance is the processing performance itself of the private Blockchain Broof, it is sufficient to measure the processing performance of Broof. At this time, we constructed a Broof node like the one shown in **Figure 3** and created verification items for that.

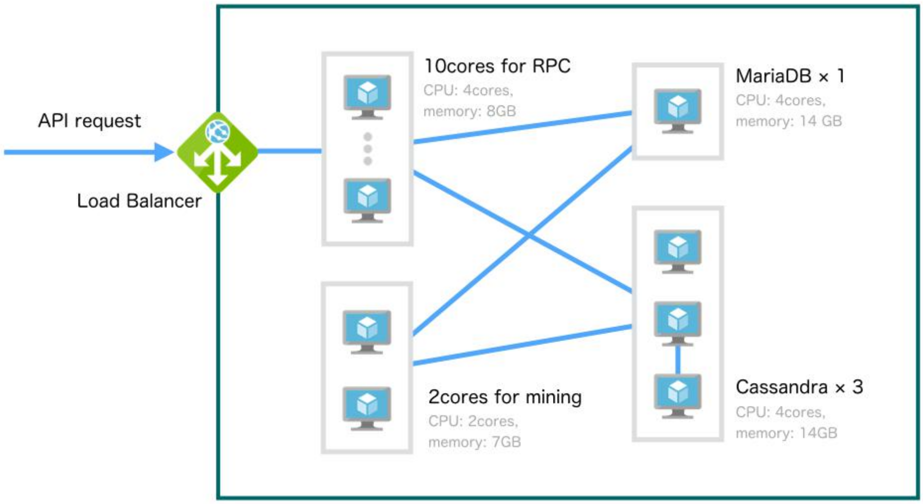

Figure 3. Node configuration of Broof (1 node).

We measured write speed and mining speed in the process of accumulating 5 million transactions. Both units are tps (transaction per second). The write speed represents how much transaction write requests could be handled in seconds, and the mining speed represents how much pace the transactions with writing requests were mined. Transactions are taken into the Blockchain by mining, and fixed as data. One measurement was set to 30 seconds, and the measurement was performed 33 times. The writing speed and the mining speed were averaged over 30 seconds. The mining difficulty adjustment is automatically performed so that the block generation speed is about 1 block per sec.

4.2. Performance verification result

The verification results are shown in **Figure 4**.

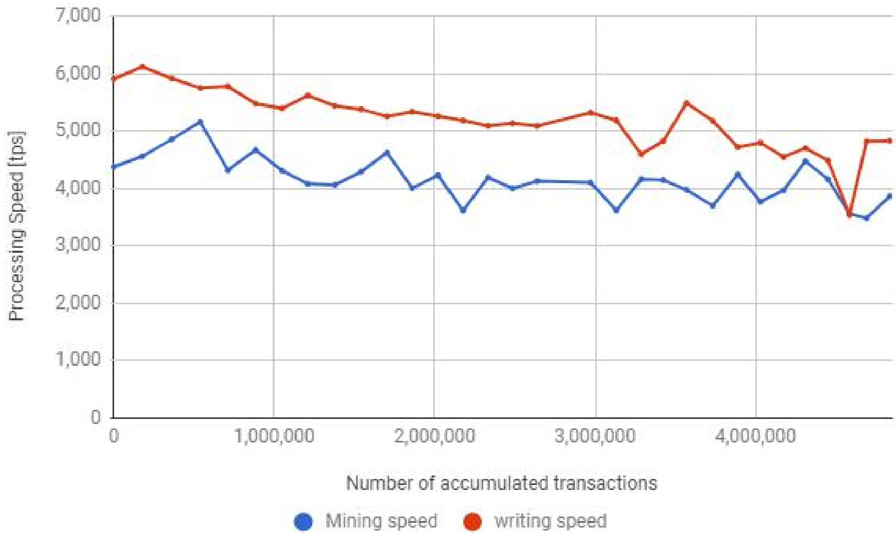

Figure 4. System performance verification result.

The mining (data definition) speed reached a maximum of 5,157 tps and an average of 4,147 tps.
Although the writing speed and the mining speed both deteriorate somewhat with the accumulation of data, it kept stably at 3,500 tps or more.in this verification.

5. Discussion

5.1. Reliability of product history information

We constructed a system with the PoP model that can guarantee the validity of product history information without relying on trust for administrators by compensating for the reliability of Blockchains operated in private type. This time the private Blockchain was only anchored in KSI, but if anchored to multiple public Blockchains, it can further improve the reliability of private Blockchain. In addition, if the data on the private Blockchain used in this study were transferred to the public Blockchain, it would be feasible to build a more reliable food supply chain by enlarging the network scale.

5.2. Data processing performance of the system

In 4.2 performance verification, the average processing speed of the system is 4, 000 tps. The processing speed of the Blockchain used in Bitcoin is about 7 tps. Although it is not possible to perform such a simple comparison with a large public network such as Bitcoin, it is certain that Broof's processing speed is very high compared to the existing Blockchains. In addition, the processing speed of the system exceeds the 1500 tps of the Zengin domestic exchange system, which was well-known as one of the most high-speed key systems in Japan.

Also, we evaluate the performance on the premise of popularizing this system throughout Japan. According to the Ministry of Agriculture and Forestry of Japan, the total weight of organic production, which JAS had authenticated was 42,386 tons in 2015 [9]. Each of Japan's 10 most-shipped vegetables had an average weight of about 385g [10][11]. The amount of most happened transactions is about 110 million a year, with an average of 3.5 transactions per second. Even if the timing of the data could not be evenly distributed, the speed of 4,000 tps is high enough to deal with the entire amount of Japanese organic JAS authenticated production.

In the benchmark result of section 4.2, we confirmed that the processing speed of the system deteriorated with the accumulation of data, which was a problem that could not be neglected when considering the long-term running operation. To resolve this problem, it was considered that distributing data to multiple Blockchains might help. Typically, a Blockchain requires all the transaction data to be saved to all nodes, so the total amount of data that the network can hold depends on the capacity size of one single node. Additionally, because data cannot be deleted, the total amount of data and the workload of the entire network will increase continuously. In contrast, if we use a multiple-Blockchain, for example, data can be distributed in a tree structure, which can avoid the degradation of processing speed as a result of data accumulation, but also guarantee data reliability while storing large amounts of data. We are also considering applying Plasma [12] which is being discussed to solve the problem of scalability of Blockchains. This is an idea to build a tree structure with multiple Blockchains and improve the throughput of the whole system.

5.3. Learning and development cost of Blockchain system development

For engineers, the cost of learning advanced technology such as Blockchain in order to use it in development is very high, in the process of considering the social implementation of the system, learning cost is a very important indicator. The Broof development library which is used in this study does not require any expertise to achieve simple Blockchain access, storage and retrieval functions. Therefore, the learning cost is very low. So the feasibility of Blockchain system development is improved. In addition, the production history information management system in this research just cost less than one month to complete. This is shorter than the 3 month development cycle using relational database.

Thanks to the highly traceable data structure, Blockchain is not only highly tamper-proof, but also has the asset management function of preventing double payments bug.

By using the features of the Blockchain, we reduced the time required for design, validation and the workload. This research shows that the learning cost and the development cost are very low, and it has a great contribution to the improvement of possibility to popular the system.

5.4. Operation example of this system

The production history data kept by the system during the production phase is allowed to be read by consumers. As an object of organic farm products in Aya town, Miyazaki

Prefecture, we use this system to verify the possibility of consumers who can confirm the history of the organic production and purchase it. We used the system at Roppongi Ark Hills market, with functions running well and successfully selling organic produce from Aya town. Each product is packaged with NFC-tagged QR codes, and customers can verify the production history of the product on the package by simply brushing the smartphone (or reading the QR code). The appearance is shown in **Figure 5**.

Figure 5. Smartphone interface viewing production history for customers.

6. Conclusion

In this research, we have developed a Blockchain system that manages product history information, including farm work content and work volume in the vegetable production process. We devised Proof of Proof is a security-enhanced Blockchain technology concept based on the cooperation of multiple Blockchains and we implemented by combing a private type Blockchain and a public type Blockchain. We achieved high speed transaction processing and ensuring data authenticity at the same time. As a result, it was possible to construct a system that secured authenticity and processing 4,000 tps fast. Also, when actually selling vegetables in Aya town to Roppongi, the system worked without any problem and we got enough performance. Also, the performance was sufficient speed for shipment quantity of organic JAS in Japan. We were able to demonstrate the possibility of social realization of the food supply chain by this system.

In the future, by utilizing IoT smart sensing device and realizing the farm automation, by directly writing the information transmitted automatically in the Blockchain, the human error is eliminated and the next-generation system with improved data reliability supply chain implementation is also considered possible.

In the future agricultural technology, IoT smart sensor devices will be used in large quantities. We consider three points are important, the reliability of data, distribution of data, and communication of data.
We believe the reliability of data becomes very important, especially when sensing data is used in various scenes, especially when it is used as learning data of AI. First of all, the reliability of data is high in the Blockchain is a data store which cannot be tampered effectively. In addition, a device incorporating a node or a wallet directly connects to the block chain, and by recording the data together with the electronic signature by the secret key held by the device, it is possible to prove to the device which generates the data.
And we consider that the impact on the distribution of smart sensing data, such as data sales, is great. As mentioned earlier, by having the private key of the device, it becomes possible to prove that it is the main data generation, and at the same time, benefit born by trading the data is to be had as a token on the Blockchain. In other words, the device can do economic activities autonomously as people do. We believe that this will promote the distribution and utilization of data.
In the future where large numbers of devices are connected to the network, there is a high possibility that the amount of traffic that cannot be handled is concentrated on the server in a simple client / server type network. Therefore, in order to support such a future network, we believe that a decentralized network capable of P2P (M2M) communication that does not pass through the server is necessary. Block chains are advantageous over other solutions in that they have advantages as a distributed network, but also have advantages in data reliability and distribution as described above.

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A Gamified Participatory Sensing for Tourism: The Effect to a Sightseeing

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Abstract. We have been working on a real-time tourism guidance system to improve the tourist's satisfaction in sightseeing. In this system, participatory sensing is leveraged to collect real-time sightseeing contents or data. The amount and quality of data collected in participatory sensing depend on the user's contribution. Therefore, gamification is generally utilized as an incentive mechanism. Few existing studies addressed the appropriateness of the gamification design or target tourists. In this paper, we design a gamification mechanism consisting of two types of sensing tasks and three types of rewarding methods and implement the mechanism in our participatory sensing platform called ParmoSense. We conducted a sightseeing experiment supposing three different user types. As a result, we confirmed that some type of tourists (participants) can collect sightseeing information while enjoying sightseeing through behavior change.

Keywords. Gamification, Participatory Sensing, Sightseeing, Behavior Change

1. Introduction

In Japan, the number of inbound tourists has increased by three times in the last 5 years. A further increase of inbound tourists is expected in upcoming years, especially around Tokyo Olympics in 2020. To help inbound tourists enjoy sightseeing comfortably, richer tourist information must be provided. Hence, we have been working on a real-time tourism guidance system to improve the tourist's satisfaction in sightseeing by means of participatory tourism information collection and curation of the collected infotmation [1]. This system provides tourism content to tourists taking into consideration not only user preference but also the dynamic information including time-limited events and congestion degree information on sightseeing spots, in addition to the static information which can be obtained from conventional guidebooks and websites. To collect detailed and dynamic information of sightseeing spots, a participatory sensing [2] can be used for generating and updating tourist information, thereby obtaining up-to-date tourist information at low cost. However, the amount and quality of collected information are contributor-dependent in participatory sensing. So, the motivation of users who

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participate in sensing tasks is important to continuously and stably collect information. As a method for motivating users, *Gamification*, which uses game design techniques and mechanisms is often used. So far, many participatory sensing systems have incorporated gamification, and the usefulness of gamification has been shown through evaluation on the difference of quality and quantity of data depending on the presence or absence of it [3,4,5]. However, there are few concrete studies that address the appropriateness of the gamification design or target tourists. To realize a sustainable participatory sensing system in the tourism domain, a detailed gamification design should be discussed.

In this study, we aim to investigate the difference of contribution in participatory sensing affected by gamification design and attributes of users. We designed several gamification mechanisms which have a different type of sensing tasks and different rewarding methods, and implement them into ParmoSense [6], an integrated participatory sensing platform we developed. The designed gamification mechanisms consist of two types of sensing tasks: a task of walking around a certain area (Area Mission) and a task of taking a picture in a checkpoint (Check-in Mission) and three types of rewarding methods: static, weighted and dynamically weighted reward points for each task. Moreover, we obtain user's attributes through questionnaire and classify the users into three groups based on the motivation of participating in tasks (game, reward and sightseeing oriented). To confirm effects of the designed gamification mechanisms, we conducted a real-world experiment in Kyoto, Japan with 33 participants. Participants used a smartphone application for sensing during sightseeing. After the experiment, we collected questionnaire and analyzed the questionnaire data. As a result, we obtained the following insights on effects of gamification:

- The gamification significantly increases user's fun, even during sightseeing.
- Reward-oriented users tend to be affected by gamification, and easily change behavior during sightseeing.
- Users tend to give priority to Check-in missions compared to Area missions.
- Check-in missions are useful for collecting information of the specific place, but Area missions are better in creating comprehensive tourist information while maintaining sightseeing satisfaction of participants.

2. Related work

Since a participatory sensing approach relies on voluntary participation of public people, motivating users is essential to get continuous contributions. There are two types of methods to motivate users: 1) monetary incentive and 2) non-monetary incentive. The monetary incentive is effective for attracting users, but there is a limit of the total budget for rewards. The non-monetary incentive gives *experience*, e.g., fun, usefulness, as compensation for participant's contribution [7,8,9]. For example, *gamification* is one of the non-monetary incentive methods. This method incorporates game element into existing systems and enhances user's behavior [3]. Niels et al. [5] proposed the crowdsourcing application, called GeoOulu, with the gamification mechanism. They confirmed that participants of the application are encouraged significantly by using gamification methods such as animation of UI and leaderboard. Also, gamification contributes to the improvement of data quality as well. Ueyama et al. [4] proposed the participatory sensing system adopting both monetary incentive and gamification mechanism. They showed that the gamification contributes to not only motivating participants but also suppression of monetary reward raises. Medusa [10] incorporates a different type of experience using gamification effectively. Medusa adopts the concept of reverse incentive (obligation/responsibility of executing tasks) as compensatory privilege of performing the task in order to retain participants. This method prevents participants from quitting the system in the middle of sensing tasks.

However, existing studies have not concretely discussed how gamification mechanism can motivate users and suppress monetary rewards. In this paper, we elucidate the extent of effectiveness in each gamification mechanism of the participatory sensing system through a case study.

3. Gamification Design

We investigate whether there are differences in contribution depending on the gamification type and the user's oriented type in information collection by participatory sensing for tourism. We designed the gamification with different tasks and different point acquisition conditions, and implemented them on our user-participatory sensing platform (ParmoSense). Our designed gamification has the following six types: two tasks, "Area Mission" that requests walking around a specific area and "Check-in Mission" that requests taking a photo at a specific place; three point acquisition conditions, Constant rewarding, Weighted rewarding, and Dynamic-weighted rewarding. We also set three types of motivations for participation as user's oriented type, Game oriented type, Reward oriented type, and Sightseeing oriented type. In the following sub-sections, the details of *ParmoSense*, mission design, rewarding method and user types are described.

3.1. ParmoSense

Our smartphone application for participatory sensing is called *ParmoSense* and it consists of six screens shown in Fig. 1 (1)–(6). The details of the screens are described below.

(1) This is the main screen of the application that indicates sensing tasks with pins or polygons as missions. User's ranking and points are displayed on the upper right corner of the screen.
(2) This screen is displayed when the user taps a mission pin in the map. It shows a detail of the check-in mission. Check-in is allowed only when the user is within a certain distance from the pinned place.
(3) This screen is displayed when the user taps the mission button in the bottom of the screen. In this screen, the details of missions in the map are shown in a list form.
(4) This screen is displayed when the user taps the check-in button in (2) to take and upload a photo or taps the camera button in the bottom of the screen for free posting.
(5) This screen is displayed after taking a photo in (4). The user can input texts on information or impressions of the photo (spot).
(6) This screen is displayed when the user taps the timeline button on the bottom left corner of the screen. It shows the photos and comments posted by other users.

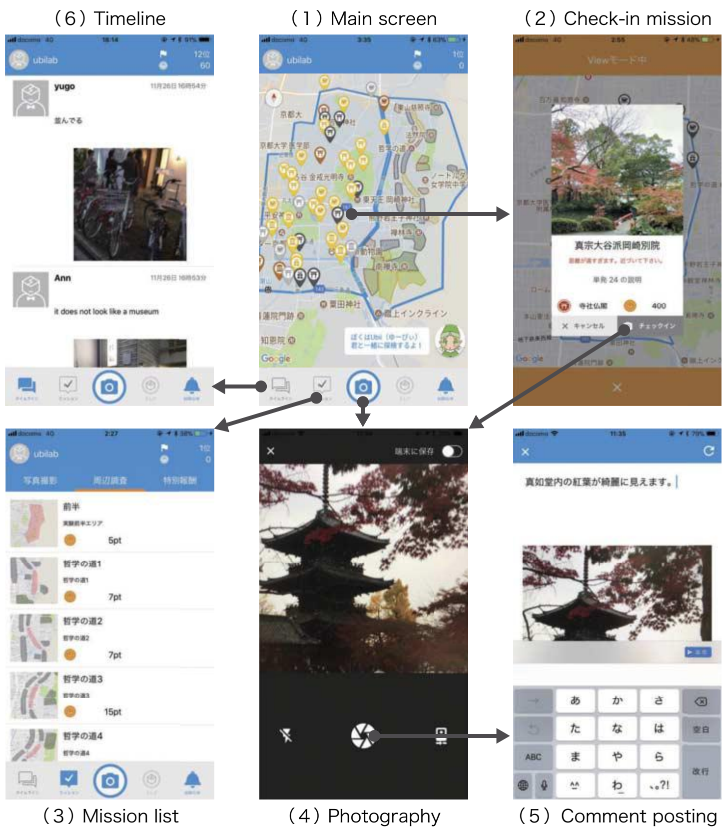


Figure 1. (1) Map-based main screen. (2) Check-in mission screen. (3) Mission list screen. (4) Photography screen. (5) Comment posting screen (6) Timeline screen

The timestamp, GPS information, acceleration, gyroscope, geomagnetism and illuminance values of the smartphone are collected at the sampling rate of 10 Hz while this application is running (even in background). These data are transmitted to the server every 5 seconds. These sensor data are collected at the moment when the user takes a photo and is sent to the server with the taken photo independently of the periodic sensor data.

3.2. *Mission design*

We designed two kinds of mission: “Area Mission” and “Check-in Mission” as sensing tasks. Additionally, “Free posting” was also designed so that the users can freely post photos on places they find interesting and share them with other tourists.

Area Mission
Area mission is displayed as polygons in a specific sightseeing area on the map, as shown in Fig. 2. By walking around this area and collecting sensor values, points are given to the user at fixed time intervals. A gold area, a silver area, and a bronze area are set according to the points to be given.

Figure 2. Area Mission

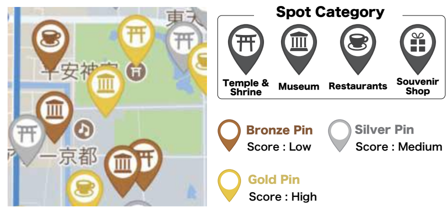


Figure 3. Check-in Mission

Check-in Mission

Check-in mission is displayed with a pin in a specific sightseeing spot on the map, as shown in Fig. 3. It is possible to check in when the user is within a certain distance from the pinned place. By posting photos and comment on the spot, check-in is completed and points are given. Temples/shrines, museums, restaurants, and souvenir shops which are commonly mentioned as category of sightseeing spots are set as types of pins. The colors of the pins are set according to the points, similar to the area mission.

In addition to the above missions, "Free posting" is also introduced. In this mission, users can take photos freely at places where they are interested and post the photos with comments. Posted contents are shared by all users on the timeline.

3.3. Rewarding method

Three kinds of rewarding method are designed as shown below.

Constant rewarding

Constant points are obtained depending on the type of mission (Area Mission, Check-in Mission).

Weighted rewarding

Points are changed according to spots. The points are determined by the demand level of information about the spot. In the experiments described in section 4, the number of hits that were hit when searching the web for each sightseeing spot name are assumed as the demand level of information, and the points were determined accordingly.

Dynamic-weighted rewarding

In addition to the weighted points, the amount of information collected by participatory sensing is reflected as weights at fixed time intervals. For the sake of simplicity, we set the weight in advance and change it every 30 minutes accordingly in the experiment.

3.4. User's oriented type

We determined the user type of each participant based on the response to the following question while participating in a stamp-rally that gives point-based reward, what do you think the most important in the following? – Enjoy stamp-rally (Game oriented), Aim to get more reward (Reward oriented), Enjoy sightseeing (Sightseeing oriented).

4. Sightseeing Experiment

We conducted experimental sightseeing using the developed application to investigate the effect of our designed gamification and difference of user's oriented types. In the following sub-sections, we explain the detail of recruiting, grouping and procedure in our experiment.

4.1. Recruitment and Grouping

We recruited 33 participants (21 lab members and 12 others) in total. There were 25 male and 8 female participates. Most of the participants were in their 20s (one 30s and one 40s). The number of Japanese and non-Japanese are 29 and 4 respectively. Among them, 17 participants are classified to Sightseeing type, 7 participants to Game type, and remaining 9 participants to Reward type.

The participants are assigned to the three groups taking into account the age, sex, nationality, and the oriented type. The size of each group is 11. Different reward methods are applied to the groups: constant rewarding for Group A, weighted rewarding for Group B, and dynamic-weighted rewarding for Group C.

4.2. Experimental Procedure

The experiment was conducted in Kyoto in November 2017. In this experiment, we asked the participants to do sightseeing in an area of Kyoto city while earning points by clearing the mission. After the experiment, we collected questionnaire from the participants. To clarify the effect due to the difference in mission type, we requested participants to engage in area mission and check-in mission separately in the first and second half of the experiment respectively. The experiment time was set to 4.5 hours in total which consists of 2.5 hours course and 2 hours course planned with reference to the sightseeing model course. Ahead of the experiment, we asked participants to install our developed application on their smartphone. After that, we fully explained the usage of the application and the contents of each mission for each group.

First half experiment (Area Mission)

In the first half of the experiment, area missions were assigned to the participants. The course started from the Keage station to Ginkakuji temple. The participants were asked to do sightseeing freely using our application. The points are given to each participant based on the following rules:

(A) Get 10 points every 10 seconds within the experiment area of the first half of the experiment.
(B) Get 15, 10, 7 points every 10 seconds in case of the special areas such as gold area, silver area, and bronze area, respectively.
(C) The special areas are updated every 30 minutes.

The number of special areas set in this experiment is 33 (11 areas for gold, silver, and bronze, respectively) in total. Also, 30 points are given for free posting.

Table 1. Questionnaire items after experiment

Item No.	Questionnaire Detail
Q1	Did you enjoy sightseeing by using our application?
Q2	How many times did the mission change your destination or the route of travel?
Q3	Which did you prioritize, sightseeing or mission in first half of the experiment?
Q4	Which did you prioritize, sightseeing or mission in second half of the experiment?

Second half experiment (Check-in mission)

In the latter half of the experiment, check-in missions were assigned to the participants. The course started from Ginkakuji temple to Higashiyama station. The participants were asked to do sightseeing freely using our application. The points are given to each participant based on the following rules.

(A) Get 400 points at any check-in spots
(B) Get 730 $\sim$ 620 points, 370 $\sim$ 310 points or 180 $\sim$ 150 points in case of checking in at the gold pin, silver pin and bronze pin, respectively.
(C) The special check-in spots with colored pins are updated every 30 minutes.

In this experiment, we set 45 special spots; 23 spots for temples and shrines, 7 spots for museums, 4 spots for souvenir shops, and 11 spots for cafes. Also, the highest point of all the group is set to be constant. Similarly to the first half, we decided to give 30 points for one text posting.

Questionnaire

We asked five questions after the experiment for clarifying the influence of gamification and user's oriented type. Table 1 shows the questions which ask:

- Fun of sightseeing. (Q1)
- Influence of missions to a sightseeing. (Q2)
- The difference of priority against a sightseeing and missions. (Q3, Q4)

All of these questions were asked to answer by 5 grades evaluation.
In Q1, 1 means "not pleasant at all" and 5 means "a lot of fun." In addition, we asked the participants to describe the reason why they felt so. In Q2, 1 means "0 times," 2 means "1 $\sim$ 3 times," 3 means "4 $\sim$ 6 times," 4 means "7 $\sim$ 10 times," 5 means "more than 10 times." In Q3, Q4, 1 means that a participant strongly gave a priority to a sightseeing rather than missions. 5 means the opposite.
Finally, impression and feedback against the experiment were collected by free description.

5. Results & Discussion

In order to clarify the fun level of sightseeing based on gamification and user's oriented type and the influence of gamification on sightseeing, the results of each questionnaire item are analyzed by a group and by user's oriented type.

5.1. Result

5.1.1. fun

Regarding the fun of sightseeing in Q1, the total average score was 4 or more. In addition, as a result of one-way analysis of variance (one-way ANOVA) for each group and each user's oriented type, there was no significant difference ($p > 0.05$). That is, the participants enjoyed sightseeing, and it was confirmed that there are no difference depending on the type of gamification and user's oriented type. In the free description for Q1, the following opinion was obtained as a positive opinion: "Because in order to complete the mission, I could go to places where I could not normally go." or "There was a game element that enabled competition with other users."

5.1.2. behavior change

For the number of behavior changes by gamification in Q2, the mode was 2 (1 to 3 times) and the average was 2.88. As a result of one-way ANOVA by a group, there was no significant difference ($p > 0.05$). Meanwhile, as a result of one-way ANOVA by user's oriented type, a significant difference was confirmed ($p < 0.001$). The average scores of the game oriented type, the reward oriented type, and the sightseeing oriented type were 2.57, 4.11, and 2.35, respectively, and it was confirmed that the reward oriented type users changed their behavior in comparison to others. In other words, it was found that the reward oriented type users change the destination and the movement route according to the mission.

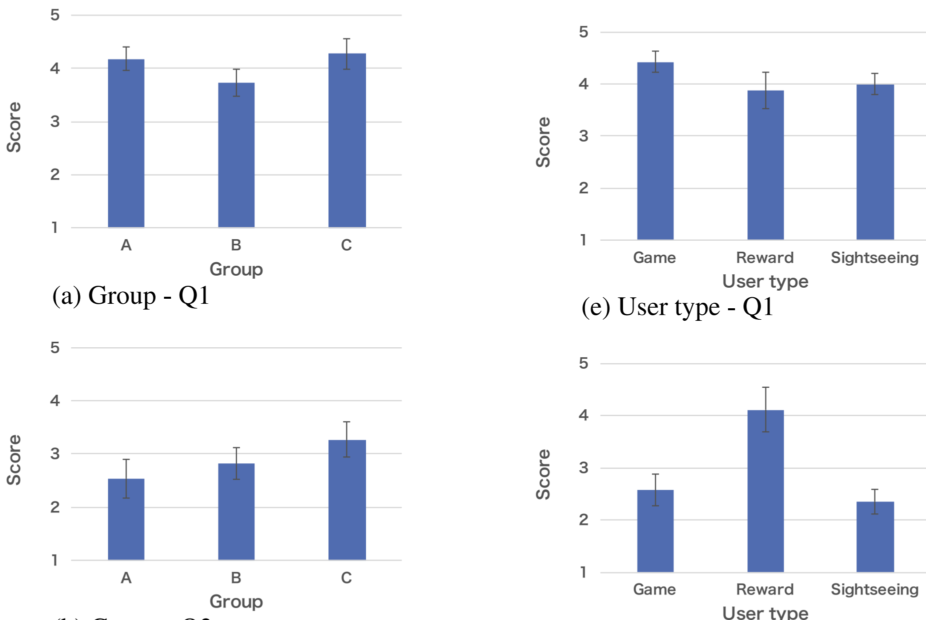
5.1.3. mission VS sightseeing

The average scores of answers on priorities of sightseeing and mission, in the first half experiment (Area Mission) and the second half experiment (Checkin Mission) of Q3 and Q4 were 2.39 in the first half and 3.82 in the second half. The main effects were confirmed only in the first half and the second half ($p < 0.001$), as a result of the two-way ANOVA in the first half and the second half of the experiment and gamification type or user's oriented type. Neither interaction was confirmed ($p > 0.05$). From these results, it was found that regardless of group and user type,the participants prioritize missions more than sightseeing in check-in missions than area missions. In addition, the following opinions were obtained in the free description for the experiment: "I was able to enjoy sightseeing in the first half, but I could not enjoy sightseeing in the second half," "I could not afford to do sightseeing because I was desperate for collecting points," "I was distracted by the app."

5.2. Gamification suitable for sightseeing

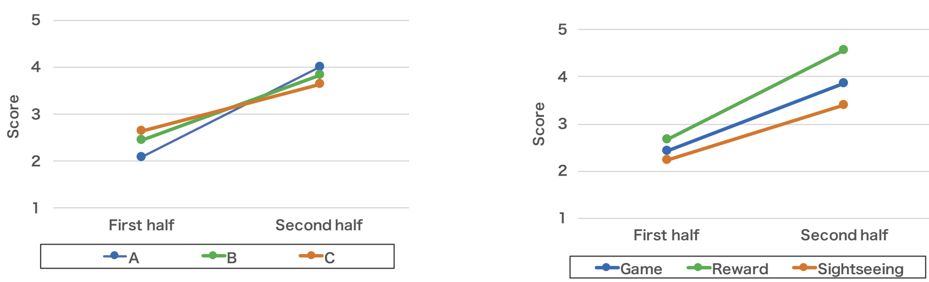
It was confirmed that sightseeing can be enjoyed even if gamification was introduced during sightseeing from the result of Q1. Additionally, we found that introducing gamification during sightseeing can lead to behavior change from Q2. As a result, we confirmed that it is possible for tourists to enjoy sightseeing and, experience behavior change while participating in collection of sightseeing information.

Here, an important point is the mission adopted as gamification. From the results of Q3 and Q4, it was found that the check-in mission has priority over the area mission. In



(a) Group - Q1
(e) User type - Q1
(b) Group - Q2
(f) User type - Q2

Figure 4. Results of one-way ANOVA



(a) Group - Q3,Q4
(b) User type - Q3,Q4

Figure 5. Results of two-way ANOVA

addition, with a free description, multiple opinions were obtained that, during check-in mission, users could not concentrate on sightseeing. The check-in mission is an effective way to collect specific information, but focuses on clearing the mission beyond enjoying sightseeing. Therefore, considering a sightseeing satisfaction of the user, the check-in mission is considered to be unsuitable. For these reasons, we consider that the area mission should be adopted as gamification in sightseeing situation. In order to encourage a behavior change, we think that more effective gamification is necessary for reward oriented type users.

6. Conclusion

In this paper, targeting participatory sightseeing information collection, we proposed several gamification types with different types of sensing tasks and different rewarding methods. We also implemented the types in a smartphone application. We conducted a real-world experiment in Kyoto, Japan with 33 participants. Participants used the smartphone application for sensing during sightseeing. Through analysis of the questionnaire data, it was confirmed that sensing tasks can be requested to some type of tourists who can collect sightseeing information while enjoying sightseeing through behavior change. We also confirmed that the check-in mission is an effective way to collect specific information, but it may urge tourists to clear the mission rather than enjoy sightseeing.

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Validation of Usability of Bridges in Urban Districts by Multi-Agent Simulation Techniques

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Abstract. A multi-agent simulation model of urban traffic behavior using Origin-Destination (OD) data and its application to validation of usability of bridges in urban districts are proposed. In this model, inhabitants' behaviors of travel are expressed by a series of decisions of inhabitant agents. They select a series of transportation methods and their routes by optimizing their own utility functions. There are too many candidates in their decisions to calculate in practical time, thus some assumptions and mathematical optimization techniques are applied to reduce calculation time, where route search algorithms of agents are divided into two parts of common and individual. This simulation technique is applied to evaluate the usability of bridges. The evaluation results can be utilized by the administrators of them who judge whether removal of them from the urban district causes inconvenient situations or not. This paper shows some numerical assessment results for a real urban district in Japan by comparing the different OD patterns.

Keywords. multi-agent simulation, urban traffic simulation, optimization.

1. Introduction

In Japan, the bridges built over 30 years ago are fast increasing in urban districts and require any treatments as soon as possible. They are facing the alternative of getting any treatments or being removed. Local governments as administrators of them need to select the bridges for removal from the viewpoints both of the treatment costs and their usability. However it is difficult to evaluate the usability of such traffic infrastructure facilities in urban districts due to the variety of usability derived from the inhabitants around them. In this paper, we try to evaluate the usability of the bridges by comparing the travel behaviors of inhabitants with and without them in computer simulations. This simulation model has an advantage that it could be used to evaluate and optimize the traffic system of the city beforehand.

We have proposed a multi-agent simulation model of urban traffic behavior using Origin-Destination (OD) data, where each agent corresponds to an inhabitant lived around the candidate bridge and the movement of each agent is represented as a transition from zone to zone in a grid-wise area, and we have examined the validity of our simulation model[1,2]. In this paper, the simulation model is improved so as to express the passing the bridge explicitly. Then we propose the assessment method for the bridge usability.

The agents' decision of their trips are modeled to express traffic behavior of a city. A trip is a series of movement from an origin point to a destination point on a road network. For example, a sequence of using bicycle from one's home to the nearest station, using railway to the nearest station of one's destination and walking to the destination is a trip. Decision of a trip includes the use of means of mobility as well as the route. The means of mobility is a transportation method such as walk, railway, a private car, a bus, etc, and it abbreviated to MoM in the rest of this paper. The decision making of route selection in the multi-agent model is described as a discrete choice model. There are several models of discrete choice, for example, if-then rules, utility functions and Elimination-By-Aspects (EBA)[3]. Since both route and MoM need to be decided in the model, if-then rule and EBA are thought to be too complicated to describe. Therefore, the method of using utility functions is adopted to describe agents' decisions. The proposed model can express traffic equilibrium by introducing the utility function in the multi-agents decision making. However, combination of routes is too large to calculate when the model is constructed as practical size. So numerical optimization modeling methods are applied to reduce combination size and solve it efficiently.

First, this paper shows the multi-agent simulation model of urban traffic in Section 2. The decision making method of the model is described in detail in Section 3. Then, a simulation example about the bridge evaluation is shown in Section 4.

2. Multi-Agent Simulation Model of Urban Traffic

2.1. Outline of the Model

Primary factors of daily movement which are performed by people in a city are where they live, where they work, and, where they go shopping. Additionally, their travels are influenced by traffic infrastructure and available MoM (Mean of Mobility). Therefore, we consider a city structure, MoM, and, inhabitants as elements of the urban traffic, and, they are assumed as follows.

2.1.1. City Structure

The city consists of a set of nodes which represent cross-points of roads and railways. An OD of an agent is given by an origin node and an destination node, and a trip of the agent is represented as series of ways which traces nodes one by one. In our simulation model, we introduce an assumption that OD information of each agent is given beforehand. Each way has capacity of the road and existence of railway station, etc. Ways are prepared forward direction and opposite direction respectively.

2.1.2. MoM

Walk, bicycle, private car, train, bus, etc. are considered as MoM. Each MoM has parameters of cost and degree of tiresomeness.

2.1.3. Inhabitant

Inhabitants are modeled as agents. The agents travel according to their OD information. Each agent has properties such as age, possession of a driving license or not and senses of cost and tiresomeness, etc., and decides its trip minimizing the own utility function. In other words, each agent makes a decision of route and MoM. Their properties differ, particularly in senses. Hence, they will make different decisions as a result even if they are in a same situation.

2.2. Elements of the Model

Elements of the simulation model of urban traffic are prepared. In the followings, elements which are indicated by '–', '∗' and ∘ are constants, decision variables and dependent variables, respectively.

- Scale
  - number of nodes: N
  - number of ways: W
  - number of agents: I
  - population of a agent: p^{I}
  - number of types of MoM: J
  - number of times of algorithm 1: F
- Node: N_n $(n \in \{1, \ldots, N\})$
  - station number (0: no station): $s_{jn} \in \{0, 1, 2, \ldots\}$
  - corresponding way: $w_{n_1 n_2}$
- Way: $\mathrm{W}_w(w \in \{1, \ldots, W\})$
  - capacity of road: l_w
  - existence of route of MoM j: $a_{jw} \in \{0, 1\}$
  - Distance: r_w [m]
  - ∘ expanded distance: v_w [m]
  - ∘ traffic volume of road: u_w
- Agent: $\mathrm{P}_i(i \in \{1, \ldots, I\})$
  - available MoM: $a_{ij} \in \{0, 1\}$
  - sense for cost: w_i^{C} $(0 \leq w_i^{\mathrm{C}} \leq 1)$
  - sense for tiresomeness: w_i^{T} $(0 \leq w_i^{\mathrm{T}} \leq 1)$
    $(w_i^{\mathrm{C}} + w_i^{\mathrm{T}} = 1)$
  - origin node: $z_{in}^{\mathrm{O}} \in \{0, 1\}$
  - destination node: $z_{in}^{\mathrm{D}} \in \{0, 1\}$
  - ∗ use of way: $y_{ijw} \in \{0, 1\}$
- MoM: $\mathrm{M}_j(j \in \{1, \ldots, J\})$
  - use/non-use of road: $u_j^{\mathrm{R}} \in \{0, 1\}$
  - use/non-use of station: $u_j^{\mathrm{S}} \in \{0, 1\}$
  - possibility of change from j_1 to j_2: $t_{j_1 j_2} \in \{0, 1\}$
  - possibility of multiple times use: $m_j \in \{0, 1\}$
  - cost as distance rate: c_j^{A} [Yen/m]
  - initial cost: c_j^{B} [Yen]

– fare between stations: $c^{\mathrm{F}}_{js_1,s_2}$ [Yen]
– tiresomeness as distance rate: t^{A}_j
– initial tiresomeness: t^{B}_j

3. Decision Making of the Agent

3.1. Basic Principle

Simulation using the agent-based model is performed where the inhabitant agents decide their trips under their OD information. In detail, each agent P_i decides y_{ijw} to optimize their evaluation function according to their senses w^{C}_i and w^{T}_i.

Agents' decisions consist of route selection and selection of MoMs. From viewpoint of computational complexity, route selection has much larger combination than selection of MoMs. Therefore, it is important that computational load of route selection is reduced in order to calculate in practical time. Consequently, a part of route selection algorithm is constructed in common with all agents to reduce computational time. For the purpose, we introduce these two assumptions:

1. Expanded distances do not differ with agents and
2. Expanded distances do not differ with MoM in case of using same route.

The expanded distance is a distance being added influence of traffic volume to express increase of time as pseudo increase of distance. In other words, the expanded distance is a distance reflecting a traffic congestion. From the assumption 1, route search is not necessary to be performed by each agent in case of no change of MoM. All agents can jointly use the the minimum route between all the points which were searched beforehand in the road network. In case of that plural MoMs are used, for example, a agent goes from home to the nearest station by bicycle, then changes to train and goes to the other station, and finally walks to destination, it is necessary to calculate decision of all combinations. However, even in such a case, the minimum route as mentioned above can be used as minimum routes of each MoM. Thus, combination size necessary to be searched is reduced substantially. The assumption 2 makes it possible that plural MoMs which move on roadway, jointly use results of minimum route search. It also reduces computational time.

3.2. Decision Making Method of an Agent

Each agent has senses of cost w^{C}_i and that of tiresomeness w^{T}_i, and they differ depending on the agent. The agents decides their route and mean of mobility according to their senses. The process of the decision making is divided into common part (algorithm 1) and individual part (algorithm 2) as follows:

1. The shortest paths between all pairs of points are searched at every MoM by Dijkstra's algorithm with priority queue.
2. Each agent minimizes values of routes by selecting appropriate MoM and paths.

Details of the algorithms are described below.

3.2.1. Algorithm 1

Ways have parameters of distance, however, it is expanded to express existence of the paths and traffic volume (traffic jam). The expanded distance is set according to the road capacity and the traffic volume using BPR function which is proposed by Bureau of Public Roads of U.S. in 1964 [4]. BPR function is described as $t = t_0(1 + \alpha(\frac{u}{l})^\beta)$. Here, u is traffic volume, l is traffic capacity, and, t is the time required. We consider a assumption that there is a proportional relation between the time required and expanded distance; therefore, BPR function is remodeled into the function which derive the expanded distance from the actual distance r as $v = r(1+\alpha(\frac{u}{l})^\beta)$. We use standard parameters $\alpha = 0.48$ and $\beta = 2.82$ proposed by Japan Society of Civil Engineers [4]. Consequently, expanded distance v_w is described as

$$v_w = \begin{cases} r_w(1 + 0.48(\frac{u_w}{l_w})^{2.82}) & \text{if } l_w > 0 \\ \infty & \text{if } l_w = 0. \end{cases} \tag{1}$$

Actually, ∞ is a sufficient large number.

The minimum routes of every combination of two nodes are derived from v_w given as described above by using Dijkstra's algorithm with priority queue. If the MoM does not use roadway such as train, there is no traffic jam; therefore, actual distance is used. Moreover, such MoM can use only ways where track exists; thus, size of candidates to be searched is limited and the computational load is smaller than that of using roadway.

3.2.2. Algorithm 2

The decision of the agent P_i is made by finding optimized trip R_i^* minimizing

$$f_i^* = \min_{R \in \mathcal{R}_i} f_i(R), \tag{2}$$

$$f_i(R) = w_i^{\mathrm{C}} C_R + w_i^{\mathrm{T}} T_R, \tag{3}$$

where C_R is cost of trip R, T_R is tiresomeness of trip R, and, w_i^{C} and w_i^{T} are senses for cost and tiresomeness of an agent. Here, we assume that cost C_R and tiresomeness T_R are basically expressed by liner function of the expanded distance:

$$C_R = \sum_{\ell=1}^{L_R} \left(c_{j_{R\ell}}^{\mathrm{A}} v_{R\ell} + c_{j_{R\ell}}^{\mathrm{B}} \right) \tag{4}$$

$$T_R = \sum_{\ell=1}^{L_R} \left(t_{j_{R\ell}}^{\mathrm{A}} v_{R\ell} + t_{j_{R\ell}}^{\mathrm{B}} \right) \tag{5}$$

where L_R is number of steps of changing MoM, $j_{R\ell}$ is the ℓth MoM in trip R and $v_{R\ell}$ is an expanded distance of ℓth MoM in trip R. Provided that the MoM is a public transportation, a fare of the corresponding interval is applied instead of the expanded distance. In this case, $c_{j_{R\ell}}^{\mathrm{A}} v_{R\ell} + c_{j_{R\ell}}^{\mathrm{B}}$ in Eq. (4) is replaced with $c_{j_{R\ell} s_{1R\ell}, s_{2R\ell}}^{\mathrm{F}}$:

$$C_R = \sum_{\substack{\ell=1 \\ (u^{\mathrm{S}}_{j_{R\ell}}=0)}}^{L_R} \left(c^{\mathrm{A}}_{j_{R\ell}} v_{R\ell} + c^{\mathrm{B}}_{j_{R\ell}} \right) + \sum_{\substack{\ell=1 \\ (u^{\mathrm{S}}_{j_{R\ell}}=1)}}^{L_R} c^{\mathrm{F}}_{j_{R\ell} s_{1R\ell}, s_{2R\ell}}, \tag{6}$$

where $s_{1R\ell}$ and $s_{2R\ell}$ are the origin station and the destination station respectively. Each agent decide the optimum route for itself which minimize the evaluation value $f_i(R)$ by solving the combinatorial optimization problem.

The combinatorial optimization problem has high complexity; thus a branch and bound method is constructed and applied. First, the cases of single MoM ($L_R = 1$) are searched. Routes of the OD of all MoM is already calculated at algorithm 1; therefore only MoM j have to be searched. The best solution obtained by the search include the trip where the agent uses the private car from origin to destination. This trip is a strong candidate of the optimal trip in many cases. Thus the best solution can be used as a strong upper bound in bounding operation. After that, search is continued in depth-first policy. MoM has parameters $t_{j_1 j_2}$ and m_j, the former is possibility of change from j_1 to j_2 and the other is possibility of multiple times use m_j. These parameters prevent L_R increasing infinitely as well as eliminate unfeasible combination of MoM. As mentioned above, a number of branches are well suppressed and high-quality upper bound is acquirable in early stages of search; thus, computational time is remarkably reduced.

Let M_ℓ be ℓth part of trip R, the route search problem of trip R is divided into sub-problems M_ℓ:

$$R = (M_1, M_2, \ldots, M_{L_{\max}}), \tag{7}$$

$$f_i(R) = \sum_{\ell=1}^{L_{\max}} f_i(M_\ell), \tag{8}$$

where $L_{\max}$ is the maximum value of L_R. The optimum solution is searched utilizing the structure from $\ell = 1$ by branch and bound method.

3.3. Procedure of Simulation

Fig. 1 is a flowchart which shows outline of the simulation. First, algorithm 1 is executed, then algorithm 2 of each agent is performed in order. Provided that agent number i is divisible by F which is frequency of algorithm 1, algorithm 1 is re-executed to reflect newest traffic volume to the expanded distance. We should set F appropriately to include traffic volume sufficiently and reduce search load as much as possible.

The procedure shown in Fig. 1 derives traffic equilibrium named as Wardrop's principle[5]. Wardrop's principle describes criteria of route selection when there are alternative routes between origin and destination. The core concept of the principle is equilibrium of users. In the equilibrium, travel times in all routes used are equal and less than those of a single vehicle on any unused route, and no one can not reduce their travel times by changing their routes. It is difficult to calculate the user equilibrium of a large and complicated network, and therefore, a method is taken in which OD was divided into pieces and they are allocated to the shortest route one by one.

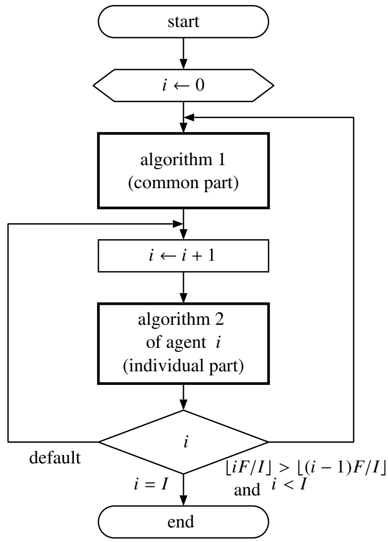

Figure 1. Flowchart of simulation model.

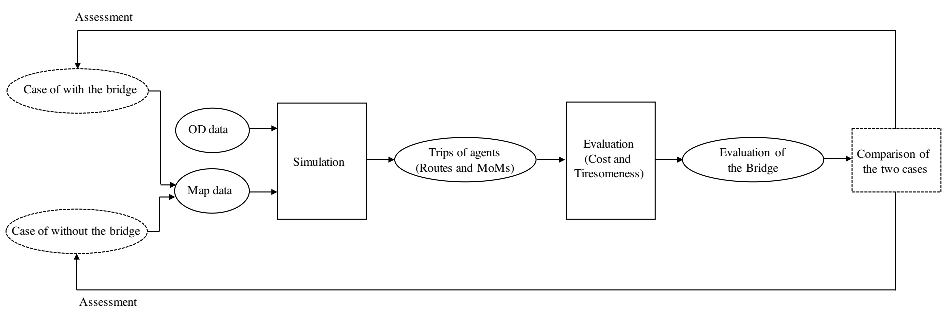

Figure 2. Evaluation procedure of the bridges.

Wardrop principle has an assumption that all users have impartial values of route, because the principle is described by the whole traffic flow. Preferences of users and availabilities of routes are not considered in the assumption. However, actual users have various ages and sexes, and they have different senses of values. Moreover, it is easy to imagine that users whose properties are same have different senses and choices. Therefore, it is important to consider various kinds of senses of users to estimate traffic flow more actually. Thus, in this research, a simulation model of urban traffic using multi-agent framework is constructed where senses of users are explicitly considered.

3.4. Procedure of Bridge Assessment

The overall procedure of the bridge assessment is shown in Fig. 2. OD and Map data are inputted into the multi-agent simulator, and it calculate the routes and MoMs of all agents. The total evaluation value:

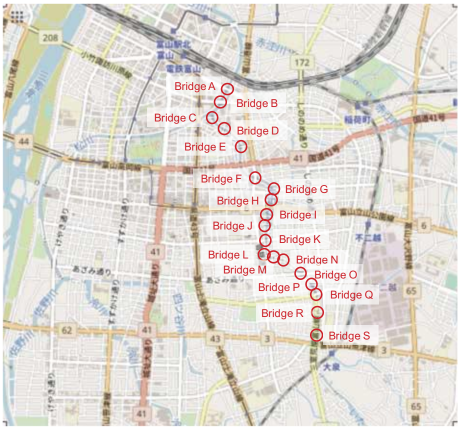

Figure 3. The simulation area (Central Toyama city, Japan).

Figure 4. The road/rail-road network of the target area. Pink and violet points are crossing points on the road and the later denote that the node has one or more stations. Gray lines between two nodes represents roads and colored ways denote railways.

$$U = \sum_{i=1}^{I} f_i^* \tag{9}$$

is calculated, which reflects the total usability of the inhabitants around the simulation area. We can compare the two cases with presence and absence of the candidate bridge by comparing values of U corresponding to the area with and without it.

4. Result of Bridges assessment

4.1. Experimental settings

We modeled the area of central Toyama city, Japan which has 19 bridges to be investigated. The target bridges are relatively small ones which connects not-broad roads. Fig.3 shows the simulation area and the candidate bridges. The road/rail-road network corresponding to the simulation area is constructed by referring to OpenStreetMap (OSM). OpenStreetMap (OSM) is one of the global geographical services whose users can read and edit freely [6]. OSM covers important traffic networks sufficiently and the data can be used on an open database license. Fig. 4 shows the constructed network from OSM. Fig. 4 includes 2789 nodes.

We use a scenario where the inhabitants lived in the simulation area go to their office or school in the usual morning. The origin point of each agent is set to its home. The home address of inhabitants are acquired from e-Stat Japan[7]. Next, the population is divided according to age composition and working population by industry of Toyama city, and their destination areas are assigned suitably in order to set their destination nodes. Agent number I and iteration number F are set to 1500 and 5, respectively.

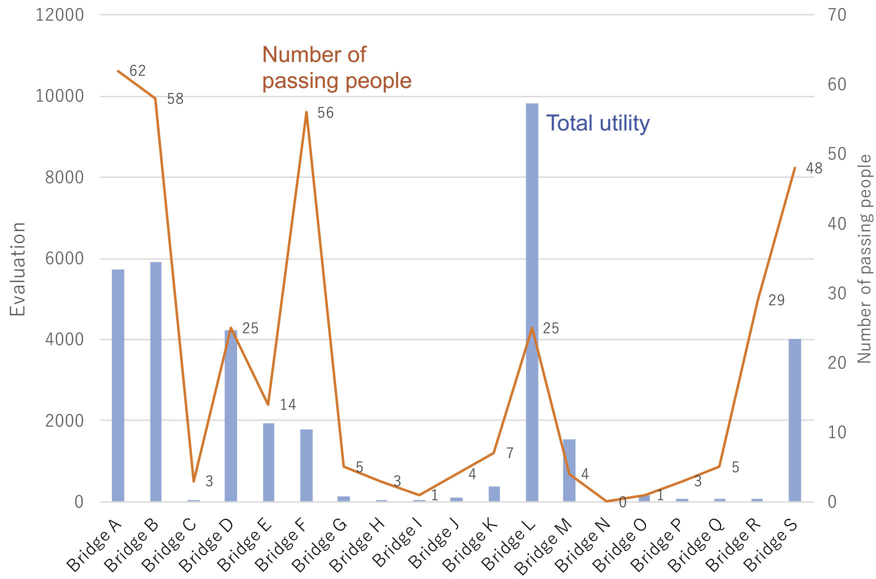

Figure 5. Result of changes in the utility values.

4.2. *Simulation results*

We compare the two simulation results with both presence and absence of the candidate bridge. Fig. 5 shows the changes in the total utility values U between the two simulation results. The horizontal axis lists the case of each candidate bridge, and the vertical axis shows the utility values of the results with absence of the bridge subtracted by that with presence of it. Positive values in vertical axis indicate worsening of utilities by removing the bridges. Fig. 5 also show the numbers of passing people for each bridge in the case of presence of it. Moreover, the utility values break down into the tiresomeness and the travel costs in Eq. 6.

From Figs. 5 and 6, we can observe the followings:

(a) Bridges A, B, D, L and S provide high level of usability for the inhabitants.
(b) Among these high-level bridges, Bridge L provides the highest usability for relatively small number of the inhabitants. By removing Bridge L, both the tiresomeness and the travel costs are increasing.
(c) On the other hand, absence of Bridge S causes increasing of the tiresomeness, whereas it causes decreasing of the travel costs.
(d) Bridges C, G, H, I, J, K, N, O, P, Q and R provides the low level of usability for the inhabitants.
(e) Among these low-level bridges, Bridge R is utilized by relatively large number of the inhabitants.

We can conclude that Bridge L needs to be maintained whereas the bridge R can be removed, because alternative route can be provided easily with small costs. Some behavioral transformations are observed in selecting MoMs in our simulation results. These can be found in the changes in travel costs in Fig. 6. It is possible to introduce a new public transport policy by referring to our simulation results while removing the bridges.

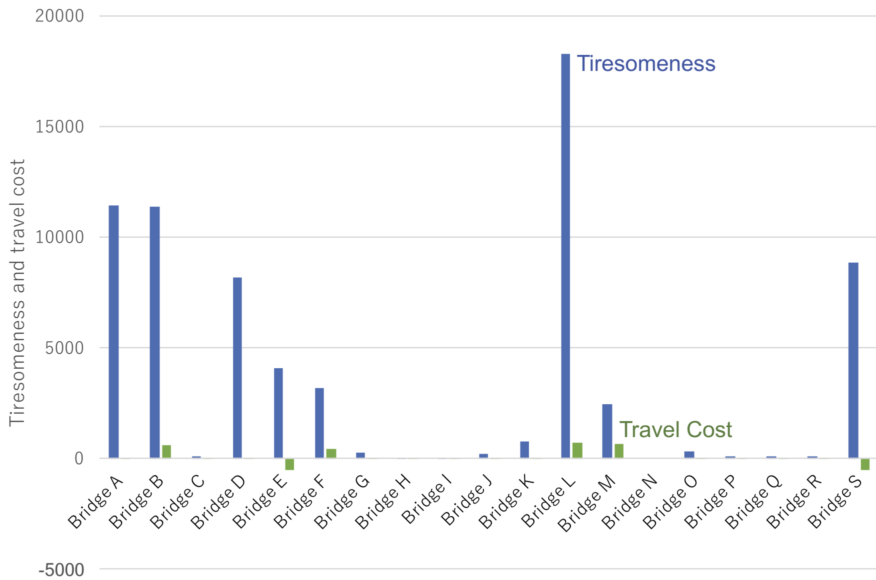

Figure 6. Result of changes in the tiresomeness and the travel costs.

5. Conclusion

A multi-agent simulation model of urban traffic behavior and its application to validation of usability of bridges in urban districts are discussed. This simulation technique is applied to evaluate the usability of bridges. The evaluation results can be utilized by the administrators of them who judge whether removal of them from the urban district causes inconvenient situations or not.

In order to conduct actual assessments of the traffic infrastructure, not only the sufficient number of OD patterns but also the real OD data have to be prepared for simulation. Sensor network technologies are rapidly evolving and are thought to be able to provide high-accuracy OD data for our simulation method.

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Twitter Stream Event Detection for Critical Situation Management

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Abstract. Social media and social networks are nowadays frequented by many millions of people providing a huge amount of various kinds of information. Processing of data coming from social platforms has attracted attention during last years due to the widespread availability of data and the ease to access to them. These data can be extracted and analysed to detect relevant information in different application contexts. Among social networks, Twitter is one of the most popular and fastest-growing blogging service able to provide relevant information for situation awareness and decision making support. This paper presents a novel approach for detecting events analysing real-time data incoming from the Twitter stream exploiting: tweets semantic analysis, rule based classification, and time-space detection models. The proposed approach has been implemented and applied in the detection of hazardous natural events and related consequences. Results of the application of the implemented software tool to a real scenario are reported.

Keywords. Twitter; event detection; crowdsensing; social network; situation awareness

1. Introduction

Processing of data, retrieved from social networks and physical sensors deployed on the field, allows identification and detection of dangerous events in a specific application domain. Such online approach enables the recognition of a critical situation when it happens. The mechanism that aims to timely recognize events, characterizing the critical situation, is usually called Real-time Situational Awareness (RTSA, [1]). RTSA is the process in charge of recognizing the critical situation as soon as possible in order to be able to take a decision for facing it properly.

In RTSA, social networks can be integrated with physical sensors as to extend specific information with people alerts, sentiments, intentions and reactions that can be traced back to specific events improving event detection capability. By means of the possibility to easily link persons, facts and places through a large quantity of online geo-referenced data, social networks users are the real producers of current information about social phenomena as “smart sensors” providing qualitative, and sometimes quantitative, information.

Among social networks, Twitter [2] has recently received much attention for its particular characteristics such as communication immediacy, ease of use, and easy access to the user data stream. Twitter is one of the fastest-growing microblogging [3] that allows users to exchange small digital content such as short texts, links, images, or videos. Messages on Twitter (tweets) report from people daily-life stories, to the latest local and worldwide news [4]. It has also become an important analytical tool for crime prediction [5] and monitoring of terrorist activities.

This paper proposes an innovative approach for event detection from Twitter stream, introducing the Twitter Event Detector (TED) tool, implemented in the context of the EU project STORM [6]. The TED is able to detect event occurrences caused by climatic changes and anthropogenic factors that may damage Cultural Heritage.

In Section II a brief summary of related works is provided referencing technologies for social networks event detection. Section III clarifies concepts of event processing and crowdsensing technologies. Section IV defines the technique of event detection from Twitter stream. Implementation details are given in Section V contextualizing the TED in the STORM platform logical architecture. Section VI describes the application of the TED in the case study of the Baths of Diocletian (BoD) heritage site together with results of the experimental campaign. Finally, in Section VII conclusions are drawn.

2. Related Works

In the last years, techniques and methods for processing social networks data deriving specific information in several domains have been widely studied. Many of them have been designed for the marketing domain exploiting the sentiment analysis [7] that analyses user opinions in order to extract emotions about products and services, or even political figures [8]. In particular, a large volume of public data can be analysed in order to produce information related to trends [9], community dynamics [10] and information propagation [11]. Social networks can be also used for detecting natural disasters (e.g. earthquakes, storms, fires, etc) and related consequences (e.g. transportation system failures, lifeline failures, structural failures, etc).

Regarding Twitter, in [12] a survey of techniques for detecting events from the stream is presented. In this paper authors provide a selection of more representative techniques of event detection, classifying them according to the event type, detection task, and detection method. In [13], a system for the Twitter-based event detection is proposed focusing on the ranking of events importance and on the prediction of the tweet location from its author's network. A demonstration of earthquakes detection using the Twitter stream is given in [14]. In particular, in this work authors propose a method able to process the Twitter stream detecting events basing on the real time analysis of the tweet frequency.

3. Crowdsensing for Event Detection

This section clarifies the basic concepts used throughout the paper. The terms *event* and *situation* are defined in the context of event processing and situation awareness. Afterwards fundamentals of crowdsensing technology in social networks are given.

3.1. Events and Critical Situation

As defined in [18], an *event* is "*an occurrence within a particular system or domain; it is something that has happened, or is contemplated as having happened in that domain*". This definition places the event concept into two different contexts: i) the real world in which events happen and ii) the field of computerized event processing, where the word “*event*” is used to mean a programming entity that represents the event occurrence. With the term *situation* [19], we intend “*one or more event occurrences that might require a reaction*”. The critical situation aggregates a set of specific events that require appropriate reactions like securing and first aid.

3.2. Crowdsensing on Social Networks

Crowdsensing is a technique that uses people and their mobile devices to collect data. It can take advantage of human perception and intelligence to acquire better knowledge about the surrounding environment (i.e. people act as a “smart sensors”) [15]. This approach has both advantages, related to the intrinsic “sensory perception” of individuals - which is the organization, identification, and interpretation of sensory information to represent and understand the surrounding environment and communicate that information in a comprehensible way – and disadvantages, which, of course, are mainly related to the subjective nature of the interpretation process of sensory information.

Crowdsensing has become a leading paradigm for large-scale sensing, which leverages heterogeneous crowdsourced data from two data sources (participatory sensing and participatory social media) [16], evolving the participatory sensing vision proposed by Burke [17]. Indeed, with the rapid raise and diffusion of social media (e.g. Facebook, Twitter, Youtube, etc), end-users are no longer mere content consumers but “prosumers” that provide information on social media, more (i.e. Twitter) or less (i.e. Facebook) intentionally. Depending on the awareness of participants to the sensing task, crowdsensing can be classified into two types [16]: *explicit crowdsensing*, where users voluntarily participate in contributing information; *implicit crowdsensing*, where data is sensed and collected without user’s explicit intention.

Social Media Crowdsensing (SMC) is based on crowdsensing mechanisms that aim to acquire and collect data from all potentially relevant sources, where public users’ activity on social network (i.e. posts with “public” privacy settings) are monitored in order to gather explicit or implicit data to gain situational awareness. Thus, to fully leverage the power of crowd participation, crowdsensing needs the fusion of human and machine intelligence (i.e. analysis and validation process) in order to aggregate sensing and data understanding [16].

4. Detecting Events from the Twitter Stream

Event detection from Twitter cannot be performed analysing the content of a single tweet, but a mechanism of real-time analysis of the Twitter stream should be applied in order to select relevant information meeting precise requirements. The proposed process of event detection is made up by four steps: i) extraction of domain tweets; ii) classification of domain tweets; iii) tweets frequency evaluation; iv) localisation of events. In the following, details on these steps are given.

4.1. Tweets Extraction

The Twitter stream can be accessed using the Twitter Streaming API [20] that extracts tweets applying a set of keywords defined by the user and provides tweets containing at least one of the specified keywords. Keywords depend on the application domain and they should be accurately selected according to their relevance in the particular context. In this approach, keyness [21] [22] provides an indicator of the keyword relevance as a content descriptor and it is evaluated basing on the chi-square function related to the frequency of the keyword in a set of *n* documents:

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i} \quad (1)$$

Here, the keyness is evaluated using two documents: i) the *reference corpus* and ii) the *target corpus*. The *reference corpus* is a very large collection of texts, written in natural language, in which a vast number of different topics are discussed; it is representative of a common natural language. The *target corpus* is a set of texts belonging to a specific topic and it is representative of what and how people write about a specific topic. Assuming w_k the word of which the keyness has to be evaluated, the following definitions are given: T_{Ref} is the total number of words in the *reference corpus* and T_{Targ} in the target corpus, T is the total number of words in all (both) documents, F_{Ref} is the expected frequency of w_k in the reference document, F_{Targ} is the expected frequency of w_k in the target document, W frequency of w_k in all (both) documents. Keyness is derived from (1) considering two terms of the sum: the contribute coming from the *reference corpus* and that coming from the *target corpus*. Applying the symbols defined, the analytic expression for the keyness is obtained:

$$K(w_k) = \frac{\left(F_{Ref} - \frac{T_{Ref}}{T}.W\right)^2}{\frac{T_{Ref}}{T}.W} + \frac{\left(F_{Targ} - \frac{T_{Targ}}{T}.W\right)^2}{\frac{T_{Targ}}{T}.W} \quad (2)$$

This formula permits to identify the keywords for setting up the extraction through the Twitter API.

4.2. Classification of the Tweets

Classification of domain tweets is performed through a set of rules applied to the tweets checking the existence of words combinations associated with a precise event type. Each rule is expressed as a logic function, whose terms are represented by words (or words' stems in some cases) and operators are represented by the Boolean operators *not* (*!*), *and* (*&&*), *or* (||). At the end of the classification process, each tweet is associated with the corresponding event.

4.3. The Frequency Based Detection Method

Events detection relies on the examination of the stream behaviour during the event occurrences. This approach is able to detect events from the Twitter stream regardless of the intensity of the reaction caused in the crowd, exploiting models adaptable to the tweets frequency.

The process of tweeting can be modelled as a homogeneous Poisson process [14] that is a simple and widely used stochastic process for modelling the times at which arrivals enter a system [23]. It is used in scenarios where the occurrences of certain arrivals happen at a certain rate, but completely at random. It is characterised by the exponential Probability Density Function (PDF) $f(t, \lambda)$.We can consider the interarrival times (*t1, t2, ... tn*), where *ti* is the elapsed time between arrival *i* and arrival *i+1*. The 1st arrival occurs after time *t* if there are no arrivals in the interval [0, t], hence, the probability that a tweet arrives is given by the following probability distribution: $F(t,\lambda) = 1 - e^{-\lambda t}$. The difference between the "*normal*" case and the "*alarm*" case is in the growth of the value of λ that is the tweet frequency. The value of λ in the case of event occurrence λ_e has been evaluated experimentally analysing the classified tweet frequency traced using data logs. For what is described above, the probability that a tweet arrival is relative to an event occurrence is: $P_e(t,\lambda_e) = 1 - e^{-\lambda_e t}$. Supposing to have n tweets related to the same event, for each tweet it should be verified if its relative arrival time is enough close to the ideal trend model given by the exponential distribution. Considering the posting of a tweet is independent from the others and $t_0 \dots t_n$ the arrival times of the tweets with the same event classification, the probability that all the *n* tweets are related to the same event is given as:

$$P_n(t,\lambda_e) = \prod_{i=1}^{n}(1 - e^{-\lambda_e t_i}) \qquad (3)$$

The above formula evaluates the probability that a selected set of *n* contiguous tweets represents an event. The detection algorithm evaluates $P_n(t, \lambda_e)$ each time a new tweet is received applying the formula to the latest *n* tweets received. If the evaluated probability exceeds a specific threshold, established experimentally, the event is detected. The latest *n* tweets matching with the detection criterion are aggregated in a tweet burst.

4.4. Localisation of the Events

An event (e.g. earthquake, intensive rainfall, storms, tornado, etc) can affect a wide geographical area provoking several consequences (e.g. fires, structural failures, lifeline failures, landslides, tsunamis, flooding, etc). Then a single burst can contain information regarding events happened in different locations and it needs to be analysed in order to identify the locations referred.

In order to localise the tweets two main criteria are followed: i) GPS localisation and ii) location rules based analysis. The GPS localisation checks the distance between the GPS point of the tweet (gathered by the mobile device) and the site position. The tweets located near the site are selected from the burst. However, only about 2% of the tweets are GPS located by users and for this reason, also the second criterion should be used in combination with the first in order to locate the event. The second criterion is based on rules checking the presence of location keywords (e.g. city and street names, monuments names, artworks names, site name, etc), formulated similarly to those used for the tweets classification.

The event is localised in a particular place if in the burst at least one tweet is localised according one of the two criteria.

5. Implementation

The methodology described in the previous section has been implemented in the TED in the context of the EU project STORM [6] briefly described in the following.

5.1. The STORM Project

STORM is a project co-funded by the Horizon 2020 programme, aligned with the EU Communication "*Towards an integrated approach to cultural heritage for Europe*". STORM aims at undertaking the challenge of researching new ways to mitigate the impacts of harsh climate events upon cultural heritage sites. Its main goal is to improve the resilience of cultural heritage against climate changes and natural disasters through eco-innovative, cost-effective and collaborative technologies.

STORM provides sustainable methods: to perform a proper analysis of materials properties, environmental conditions and cultural assets to be assessed; to implement a situational picture based on the data/information collected from the field through sensors, tools and crowdsensing mobile apps; to define a framework supporting knowledge-sharing among stakeholders. Five different pilot sites, representing different profiles in terms of threats and risks, include some of the most relevant European cultural heritage assets in Italy, Greece, United Kingdom, Portugal and Turkey.

5.2. The STORM Platform Architectural Design

The STORM architectural design is inspired by a Layered Architecture principle. As a result, the STORM platform architectural design is made up by six architectural logic levels, namely, *Source, Data*, *Information*, *Event*, *Service* and *Application Layer*, according to the type of input received from and the output provided to the next layers.

The layers interact with each other in order to enrich data extracted from the lowest layer, adding information up to the higher level. Through a more detailed view, it's possible to show the interactions between layers and their included modules, namely, the *STORM Interoperability Architecture*, shown in Figure 1. The *STORM Interoperability Architecture* is modelled according to a data-driven approach where aspects of the data interoperability among each architectural layer are considered, exploiting a set of standard APIs.

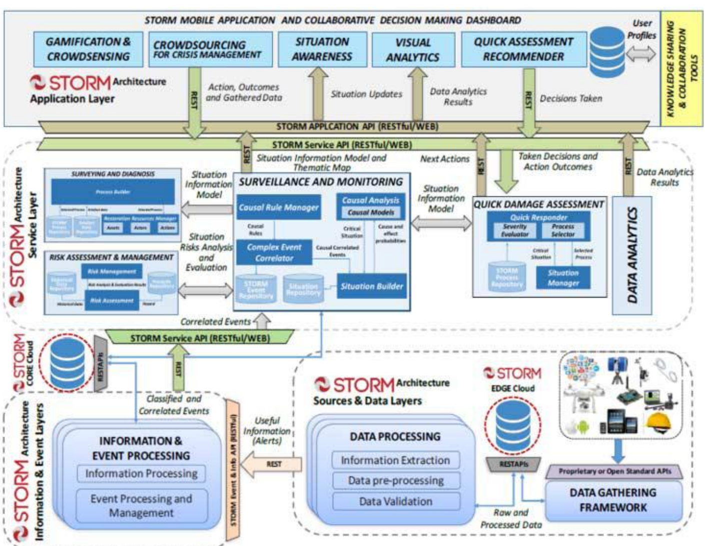

Figure 1: STORM Interoperability Architecture

At the *Data Layer*, the modules are responsible for carrying out the extraction of data from the *Source Layer*, which is made up by physical sensors and human sensors for supporting the implicit and explicit crowdsensing applications. In the *Data Layer*, the modules pre-process and validate the collected raw data. They also provide in output a set of useful information for threat identification that are the input of the modules at the upper level through the STORM (RESTful) APIs. Upon the *Data Layer,* the *Information Layer* is responsible to correlate useful information to produce simple events that are aggregated in groups in the *Event Layer.* Groups of events are provided at the *Service Layer,* where the *Surveillance and Monitoring* module builds the critical situation. Once the critical situation is identified, the *Quick Damage Assessment* module and the *Surveying and Diagnosis* module manage respectively the sudden-onset or slow-onset disasters considering related risk information provided by the *Risk Assessment and Management* module. During the processes execution, professionals and volunteers interact through the crowdsourcing mobile applications and the dashboard provided by the *Application Layer*, monitoring the situation and receiving indications on required tasks.

5.3. Twitter Event Detector Architectural Design

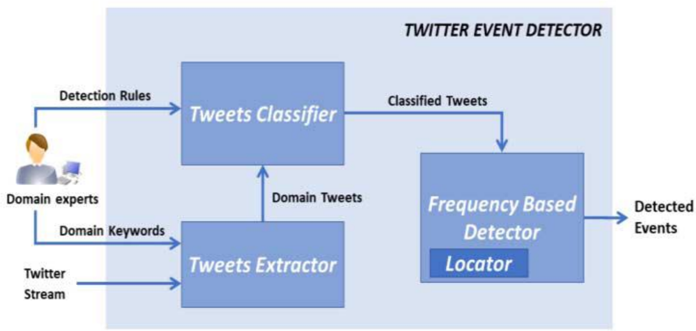

Figure 2: Logical architecture of the Twitter Events Detector

The TED, situated at the *Source* and *Data Layers* of the STORM Platform, is made up by three components as depicted in Figure 2.

The *Tweets Extractor* component is responsible of gathering the tweets from the Twitter stream through the Twitter API. This component receives in input the Domain Keywords, identified by the Domain Experts and produces as output the Domain Tweets.

The *Tweets Classifier* classifies the Domain Tweets according to the events classification. It receives in input the Domain Tweets gathered by the *Tweets Extractor* and the Detection Rules formulated by the Domain Experts. Once the tweets are classified, they are analysed by the *Frequency Based Detector*.

The *Frequency Based Detector* implements the detection algorithm and when it finds a burst, the *Locator* subcomponent localizes the event. Events detected by the TED are provided to the *Information Layer* of the STORM logical architecture to be correlated with other information coming from physical sensors. The TED has been developed entirely in Java language and it is currently in testing phase, active 24 hours per day.

6. Experimental Campaign

An experimental campaign has been performed on the TED in order to verify efficiency and effectiveness in event detection. The TED has been tested in the context of the BoD [24] heritage site in Rome.

6.1. The Case Study

The above methodology has been customized for the BoD site selecting keywords and developing rules ad-hoc for detecting events that may afflict the site. The following list of events has been identified for the BoD by the experts: i) fires and explosion/urban conflagration, ii) lifeline failure (e.g. blackout, lack of gas or water), iii) structural failure, iv) telecommunication system failure, v) terrorism, vi) thunderstorm, vii) system transportation failure, viii) vandalism.

Keywords have been selected using as target corpus a huge set of Italian tweets related to these events, obtained through a search engine. Italian corpora have been used because, for the Italian heritage site, this choice permits to extract more tweets than using other languages.

In Table 1 some examples of rules are shown. In order to provide an easy comprehension, rules have been translated in English from Italian.

Table 1: Examples of rules for the tweets classification

Event Class	Classification Rule
Fires and explosion/urban conflagration	(fire && fireman ! friendly) || (fire && victim ! friendly) || (fire && house ! friendly) || (fire && auto ! friendly) || (fire && road ! friendly) || (fireman && fire! Friendly) || (blaze && victim) || (blaze && damage) || (blaze && casa) || (blaze && house) || (blaze && car) || (blaze && road) || (flame && victim) || (flame && damage) || (flame && house) || (flame && house) || (flame && car) || (destruct && flame) || (news && fire) || (news && blaze) || (emergency && fire) || (emergency && flame) || (emergency && blaze) $NOT =chef, heart, government, soul, mosquito, desertification, weapon
Structural failure	(bridge && collaps) || (bridge && cave) || (road && collaps) || (road && cave) || (house && collaps) || (house && cave) || (wall && collaps) || (wall && crack) || (wall && cave) || (building && collaps) || (building && crack) ||(church && collaps) ||(church && crack) || (museum && collaps) || (tower && collaps) || (tower && crack) || (structure && crack) || (structure && collaps) $NOT =soccer, basket, volley
Thunderstorm	(thunder && storm) || (lightning && storm) || (lightning && fire) || (lightning && flame) || (flash && storm) || (thunder && flash) || (lightning && fall) || (thunder && lightning) || (lightning && rain) || (thunderbolt && rain) || (thunderbolt && storm) || (thunder && rain) || (flash && rain) || (flash && rumble)
Vandalism	(vandal && acid) || (vandal && dirty || (vandal && spoil) || (vandal && cultural) || (vandal && heritage) || (vandal && historic) || (vandal && art) || (vandal && break) || || (vandal && spray) || (vandal && damage) || (vandal && destroy) || (vandal && soil) ||(vandal && write) || (vandal && draw) || (vandal && scratch) || (vandal && etched) || (vandal && painting) || (vandal && work) || (vandal && act) || (vandal && graffiti) || (vandal && writer) || vandal && ruin) || (vandal && wall)

6.2. The Experimental Campaign Results

Tweets extracted from September 5th until October 9th 2017 have been saved and different rule sets have been applied to stored data with a post-processing method. In particular, five different rule sets have been applied in five experiments as follows: i) preliminary detection and location rules were used for the first experiment; ii) conditions for avoiding several false positives have been added; iii) detection rule have been extended; iv) location rules related to the site have been added; v) location rules have been improved with places near the site.

As Figure 3 shows, sequential improvements of keywords have affected the number of the detected bursts reducing the false positives and improving the detection.

In terms of detected events related to the BoD, Figure 4 highlights that the best result is achieved with the experiment v). In this experiment, 93 events regarding the BoD, with only 3 false positives, have been produced including information related to the following hazards: system transportation failure, lifeline failure, structural failure, vandalism and terrorism.

Most of them have been detected during the intensive rainfall that hit Rome on September 9th. A terrorism alert has been located in Rome train station (near the BoD) on September 5th when a person terrified passersby with a knife. Some episode of vandalism has been located in the downtown Rome.

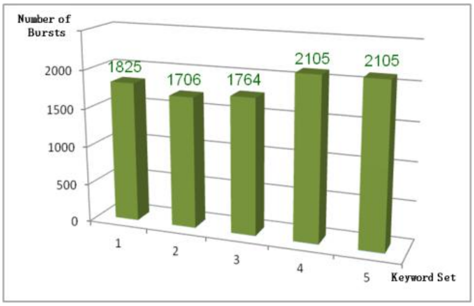

Figure 3: Number of Bursts per keyword Set

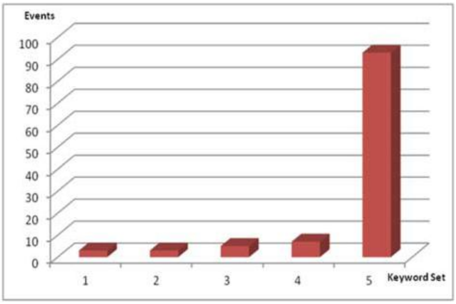

Figure 4: Events detected for the BoD per keyword set

7. Conclusion and Future Work

The TED will be integrated in the STORM Platform for Cultural Heritage safeguard. This will offer the possibility to test several aspects of the tool such as: reliability, availability, portability and usability.

Furthermore, the social network crowdsensing technology is applicable in different domains: critical infrastructure protection, public safety and security. The need of enhancing the existent RTSA systems leads to propose the integration of the TED in these systems for producing additional information during a disaster, such as: the status of areas or infrastructures, severity of damages, sites accessibility, locations of injured persons and so on.

Acknowledgments

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Effect of Sounds Generated from Repetitive Auditory Stimuli on Brain Functions

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Abstract: Despite the implementation of various countermeasures, environmental noise is still causing a wide range of problems in our modern daily life. The present study focused on the acoustic properties of environmental noise besides its volume and investigated the effect of repetitive auditory stimuli with different tones on living organisms through bioinstrumentation. The repetitive auditory stimuli used comprised a sine wave, white noise, and pink noise. After measuring the brain waves and reaction time of subjects exposed to auditory stimuli, we analyzed the input intensities in the primary sensory area, deep brain activities, and information processing rates. Compared with the other auditory stimuli used, the pink noise had strong input intensities in the primary sensory area and elicited fast reactions to the stimuli while suppressing deep brain activities. While sensory gating is known to occur in response to consecutive auditory stimuli consisting of the same tone, this study has suggested that differences in particular auditory stimuli can decrease sensory gating effects and, by extension, suppress deep brain activities.

1. Introduction

In daily situations, people interpret information from environmental stimuli around them to ensure safety, achieve various life objectives, and thereby gain a foothold for leading a comfortable life. Properly receiving and processing such environmental stimuli allows people to engage in social activities in an unhindered and efficient manner. Conversely, an input of unnecessary or excessive stimuli can obstruct comfortable life experiences.

Environmental noise is one of such environmental stimuli people are exposed to in their daily life. Conventional evaluation methods are mostly based on either psychological criteria such as “noisiness” and “discomfort” or epidemiological criteria such as health hazards and prevalence rates until now [1]~[6]. Accordingly, sounds that are not loud enough to cause any epidemiological problems and sounds that are not noisy or uncomfortable have largely been disregarded. Moreover, only a handful of studies have discussed how environmental noise affects living organisms. Therefore, it is still uncertain what acoustic properties cause adverse physical effects that have been identified in previous epidemiological investigations.

In recent years, studies have been conducted to evaluate sound quality based on the peak value coefficient of variation in respiratory frequency data [7]. Other studies have involved quantifying stresses by measuring changes in activity in the sympathetic

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nervous system based on amylase levels in saliva extracted from subjects exposed to noise [8]. These studies have explored the impact of auditory stimuli on living organisms. However, all have investigated sounds that are conventionally defined as noises, with none assessing the impact of sounds that do not elicit the feelings of noisiness or discomfort.

In a previous study, the authors witnessed temporal changes in *in vivo* reactions to repetitive auditory stimuli. When subjects were exposed to 1000 Hz sine waves repetitively at constant intervals, the oscillation of the P50 event-related potential (ERP) attenuated over time [9]. This result suggests that repetitive exposure to the same tone gradually suppresses an input into the primary auditory cortex. However, since only one tone was used for stimulation, it was possible that the suppressive effect of repetitive auditory stimuli was exclusively attributed to the acoustic properties of the sine wave. In studies that investigated about the characteristics of tone, there are many studies for the musical sound. However, these studies using the sound stimulation except the musical sound, there are few studies that investigated the influence on living body with brain waves as an index [10][11].

The present study aimed to determine the impact of different tones in environmental noise on living organisms. By observing changes in brain waves while subjects were exposed to auditory stimuli, we assessed differences in the impact from one tone to another and examined the effects of each tone. The experiment used three model sounds with different acoustic properties and involved measuring ERP components, power spectra value (alpha-2 wave), and reaction times in response to the auditory stimuli. On the basis of these data, we evaluated the input into the brain and the effects on the whole brain activity.

2. Methods

2.1. Subjects

The subjects were 20 healthy adults (15 men and 5 women) aged between 20 and 22 years old. The present study was approved by the Ethical Review Board of the Open University of Japan. Informed consent was obtained from all participants after the intent of the study was explained to them both in writing and orally. The participants were also assured that they would remain anonymous and would be able to withdraw from the study at any point.

2.2. Stimulation and presentation

The subjects were exposed to each auditory stimulus for a total of 80 times over a period of 2 minutes and 40 seconds. Three types of auditory stimulus were used: 1000 Hz sine wave, white noise, and pink noise (hereinafter abbreviated as Sine, White, and Pink, respectively). The length of stimulation was 500 milliseconds, and the inter-stimulus interval was randomly selected from 1.5 to 2.5 seconds. The audio file was a WAVE formatted file with a sampling rate of 44.1 kHz and a bit rate of 16 bit. The utterance of auditory stimuli was controlled with Superlab 5.0 software (Cedrus).

The auditory stimuli were presented from encapsulated earphones (hf5 Etymotic Research) plugged into an audio interface (UA-55, Roland) connected to a laptop computer via a USB cable. The presented sound intensity was unified at 70 db for all stimulus conditions. Figure 1 below shows schematic diagram of the equipment setup used in the experiment.

Figure 2 indicates the timing of auditory stimuli presented in the experiment. The black sections signify the utterance of sound, each representing 500 milliseconds duration of auditory stimulus. Meanwhile, the white parts represent silent periods lasting for random duration from 1.5 to 2.5 seconds.

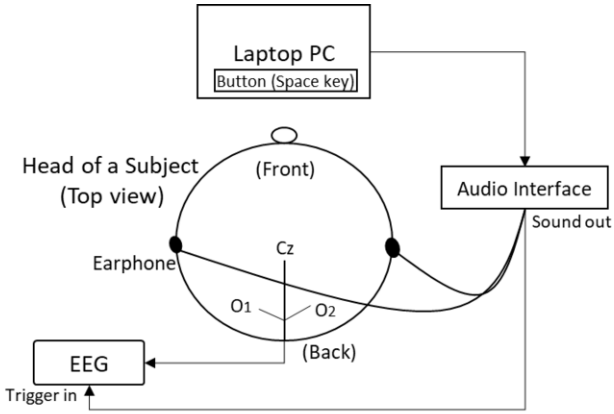

Figure 1. Experiment setup

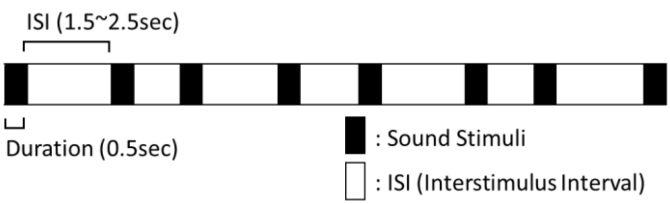

Figure 2. Inter-stimulus intervals

2.2.1. Brain waves

A Nexus 10 system (Mind Media) was used to measure brain waves. In accordance with the international 10-20 system, silver–silver chloride electrodes were placed on the top of the head (C_z) and two occipital sites (O_1 and O_2), and reference electrodes were placed on the earlobes. After amplified by the built-in amplifier of the electroencephalograph, brain waves were saved as digital data with a sampling frequency of 256 Hz in the laptop computer, and 1 to 30 Hz of band-pass filters were applied using brain wave analysis software (Biotrace, Mindmedia).

For the measurement of ERPs, audio signals were output from the audio interface in a parallel manner to synchronize the time of sound output and the time of brain wave acquisition. Through the analogue input terminal of the electroencephalograph, trigger signals were fed into the brain wave analysis software. With the time of trigger input set as 0 milliseconds, ERPs were calculated from the arithmetic mean of the brain wave data at the C_z site until 1000 milliseconds based on the number of stimulus exposure.

The present study used P50 as the index of input intensity into the primary sensory cortex. From the positive peak waveform of the acquired ERPs between 30 and 90 milliseconds, the maximum potential value was extrapolated for each subject and condition. The power spectra value of the alpha-2 wave component (hereinafter called alpha-2 power) was used as the index for deep brain activity. For each subject and condition, 10 to 13 Hz band-pass filters were applied to the overall bandwidth of spontaneous brainwaves in the occipital region. For each stimulus condition, the mean of the alpha-2 power was obtained from three periods: 1 minute prior to the auditory experiment, 2 minutes and 40 seconds from the start to finish of the auditory experiment, and 1 minute after the auditory experiment. The means of all the subjects were further averaged to evaluate changes in the alpha-2 power before, during, and after the auditory experiment.

2.2.2. Reaction time

To measure reaction time to sound stimuli, the subjects were asked to press the space key of the laptop when they hear a sound. Superlab 5.0 software (Cedrus) was used to record the time elapsed between the utterance of stimuli and the pressing of the key. All instances of key-pressing reactions to stimuli were recorded, with reaction times of 400 milliseconds or longer excluded as abnormal reactions. The remaining values were averaged for each experiment, and the reaction time (hereinafter abbreviated as RT) was calculated for each subject and stimulus condition.

3. Results

3.1. P50

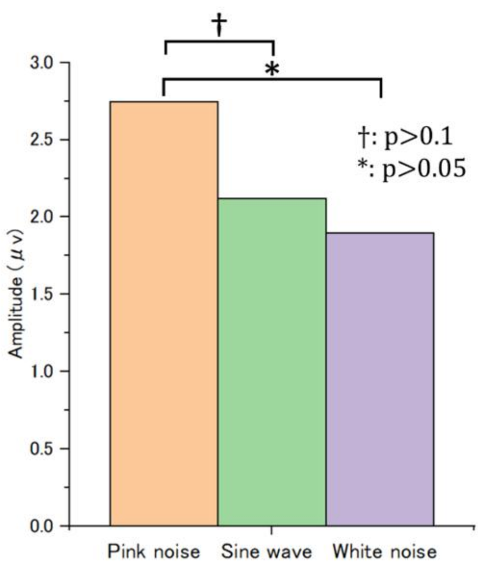

Figure 3. Overall mean peak P50 values for different stimuli

Figure 3 shows the mean peak P50 values of the ERP components from all subjects by stimulus type. The parentheses signify significant differences between the linked conditions (* p > 0.05, † p > 0.1).

The results indicate that the mean peak P50 oscillation value was largest in Pink, followed by Sine and then White. The Pink condition was significantly larger than the White condition (p < 0.05) and slightly significantly larger than the Sine condition (p < 0.1). No significant difference was observed between the Sine and White conditions.

3.2. Alpha2 Power

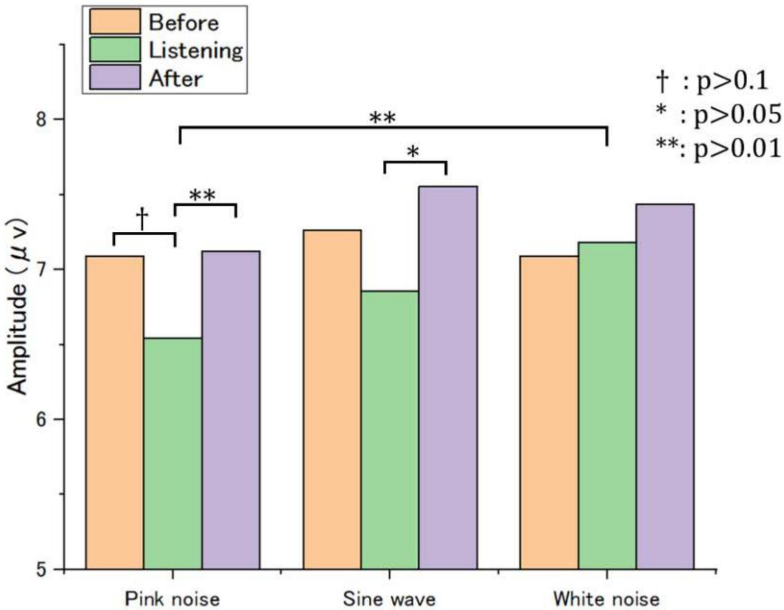

Figure 4. Means of alpha-2 power (voltage values) by stimulus type

Shown below are the alpha-2 power means before, during, and after the auditory experiment. Figure 4 shows the means of alpha-2 power in all subjects before, durian, and after the auditory experiment by stimulus type.

The mean alpha-2 power after the experiment was significantly larger than that during the experiment in the Pink and Sine conditions. During the auditory experiment, the mean alpha-2 power was significantly larger in the Pink condition compared with the White condition (p<0.01). Additionally, the mean values in the Pink condition were slightly significantly smaller before and during the auditory experiment (P < 0.1).

3.3. Reaction Time

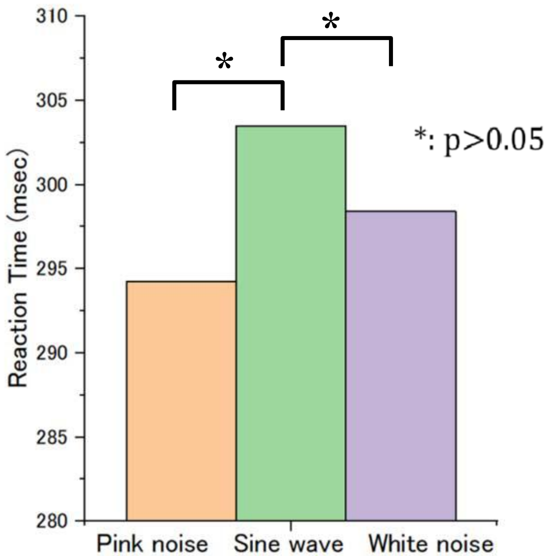

Figure 5. Mean reaction time by stimulus type

The RT results are shown here. Figure 5 shows the mean RT of all subjects by stimulus type. The parentheses between the graphs indicate significant differences (*: $p > 0.05$). According to these results, the mean RT was fastest in Pink, followed by White and then Sine, and significant differences were observed between the Pink and Sine conditions and White and Sine conditions.

4. Discussion

When exposed to repetitive auditory stimuli, the subjects exhibited the largest mean peak P50 event-related potential value with the Pink stimulus, followed by Sine and then White. Significant differences in the peak values were observed between the Pink exposure and the White exposure ($p < 0.05$), and slightly significant differences were observed between the Pink exposure and the Sine exposure (Figure 3). Peak P50 values reflect the intensity of auditory stimulus input into the primary sensory cortex and can be used as an index of sensory gating. Sensory gating is a filtering mechanism for extraneous sensory stimuli, serving to inhibit input of unnecessary stimuli into the sensory cortex [12][13]. In the present study, the largest P50 peak value was measured during the Pink exposure, and the P50 peak values during the Sine and White exposures were significantly lower. This suggests that pink noise is less likely to induce sensory gating than the other tones. Over approximately 2 minutes and 40 seconds of auditory exposure in this study, repetitive pink noise stimuli were less likely to inhibit input intensities into the primary auditory cortex.

The results show that the mean RT was fastest during the Pink exposure, and the RT during the Sine exposure was significantly slower than those during the Pink and White exposures (Figure 5). The length of time before a reaction is elicited is considered to correspond with the length of the nerve path responsible for that information processing [14][15]. Therefore, of the three different tones used in this study, the pink noise induced the shortest RT and thus may entail the least amount of information processing in the nervous system. Conversely, the sine wave may involve a long information processing pathway. Consequently, consecutive pink noise stimuli are less likely to suppress input intensities into the primary auditory cortex, and as such, pink noise may be processed rabidly in the cognitive processing mechanism of the brain.

Meanwhile, the mean alpha-2 power of brain waves before, during, and after the auditory experiment slightly significantly decreased during the Pink exposure compared with before the exposure. The values after the Pink and Sine exposures significantly increased compared with before the exposures (Figure 4). The alpha-2 power of brain waves is an index reflecting the activity of the deep brain [16]. The alpha-2 power during the Pink exposure significantly decreased compared with before and after the exposure, thus suggesting that consecutive pink noise stimuli may suppress the activity of the deep brain. This may be because consecutive stimuli of pink noise, which is less susceptible to sensory gating, are subjected to rapid cognitive processing as auditory information in the brain. This makes it difficult for the brain to function in a multimodal manner, thus resulting in the suppressed brain activity. In contrast, the consecutive stimuli of the sine wave and white noise did not reduce the alpha-2 power of brain waves. This implies that the process of sensory gating is regulated in the hypothalamus.

5. Summary

The present study focused on the acoustic properties of environmental noise besides its volume and investigated the impact of repetitive auditory stimuli with different tones on living organisms. While the subjects were exposed to three different tones (pink noise, white noise, and 1000 Hz sine wave), we measured brain waves and RT in response to the stimuli to examine the information processing in the brain by sound type.

The experiment revealed that the mean peak P50 values and RT speeds differed depending on the sound type. The different auditory stimuli had different input intensities into the brain, thus suggesting that the nerve pathways involved in information processing from input to output may be different in length. The mean alpha-2 power values indicate that some types of sound may suppress deep brain function during exposure.

The pink noise was less likely to suppress P50 and tended to elicit shorter RT. This result suggests that pink noise is easily input into the primary auditory cortex even when heard repeatedly. Moreover, pink noise may involve a shorter nerve pathway in cerebral information processing. Meanwhile, the intensities of the alpha-2 power, which reflects the deep brain activity, decreased during the Pink exposure. Therefore, pink noise, which is less susceptible to sensory gating, is subjected to intense cognitive processing as auditory information in the brain. This makes it difficult for the brain to function in a multimodal manner, thus resulting in the suppressed brain activity.

We investigated the influence of repetitive sound with on the living body by using 3 model sounds. In daily life, there are numerous occasions of exposure to various sounds.

These environmental sounds are considered to affect the brain function of the listeners. It is suggested that such effects can be controlled by tones in repetitive sound. It is thought that this can be applied to assess the quality of noise in daily life.

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Managing Multi-User Smart Environments Through BLE Based System

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Abstract. Smart and intelligent environment systems will be increasingly important in everyday life. Designing and developing them requires to face some research problems. A properly management of different types of sensors is very challenging but necessary in this area. A new wave of smart devices and systems brings customizable benefits for different users. Example of this are smart-phones, smart-bands, smart-watches, smart homes or smart cars. A successful combination of them bring interesting everyday life benefits.

One of the most important problems that needs to be solved in a practical way is the so called "multi-users problem ". Addressing it is fundamental for moving forward into a successful adoption in everyday life of the smart technologies mentioned before. Associating users and services in a spaces in which there are many possible combination of them, is a core task.

This work proposes a novel system based on interactions between Android smart-phones and Bluetooth Low Energy (BLE) technology beacons to deal with the challenges of a multi-user smart environment. We process data collected in a smart environment populated by many users. In particular we associate data collected and beacons. This processing generates database log traces containing measurements related to single user activities, helping in better matching services with users.

Keywords. Iot, BLE Beacon, habit mining, multiuser,intelligent environments

Introduction

Nowadays technological development in fields as information and communication is experiencing a very fast growth. Such high efficiency and performance levels were hardly predictable even few decades ago. This has brought two implications: more powerful tools have been designed, devices optimization allows a significant reduction in their dimensions and costs. This rapidly has allowed a widespread adoption of these micro-systems, involving also original everyday life aspects. This makes some areas of IT evolving as pervasive and ubiquitous. Sensors, actuators, smart appliances are all leading actors in the Internet of Things (IoT) paradigm application. Its deployment and implementation finds most interesting application into common spaces, as homes, offices or industries. They, enriched with sensors and appliances introduced above, can be turned into Smart (or Intelligent) Spaces: the universAAL [1] specification reports the smart space as "an environment centered on its human users in which a set of embedded networked artefacts, both hardware and software, collectively realize the paradigm of ambient intelligence".

This work introduces a novel system based on interactions between Bluetooth Low Energy (BLE) technology tools (BLE Beacons [2]) and smartphones. They are combined for managing data coming from a multiuser environment, allowing us to obtain many single-user traces in a multi-user populated domestic environment. Each trace is related to each user actions. These individualizations of actions support a better association between services and users.

The next sections are structured as follows: after an overview about relevant works, we explain a strategy to extract single-users traces from a multi-users smart environment, reporting also an explicative example. After that, implementation architecture and examples are described as well as the experiments conducted and their results.

Related Works

Intelligent Environments [3] have many appreciable potential benefits, but some problems are still open and need to be faced. Some of these problems are the difference and heterogeneity of sensors types, the amount of data generated by all the IoT devices connected and the presence of many users inside the environment. Particularly this last point is currently bottleneck to apply this paradigm into everyday life spaces. Carrying out contemporary different activities in many parts of the house by many people implies the generation of a dataset hardly exploitable by state of the art techniques designed for smart houses.

Researchers proposed different techniques to address this problem. In many cases the model complexity or the practical effort require makes these solution quite unpractical. In [4] the authors manage multi-user environments using a very dense hardware setting. They assumes users wearing many body sensors, but this has a huge impact under the practical aspect. Another strategy adopted in the past consists in deploying video-camera systems. This solution is adopted for instance in [5]. The limitation of this approach is correlated mainly to privacy issues and to the impossibility of install them in every space. More recent works adopted solutions linked to adding preprocessing logical layers on already existing activity recognition algorithm to improve their performance. For instance Roy in [6] uses spatiotemporal constraints to improve machine learning algorithms. However this is an approach strictly linked to two other specific systems, that does not allow the identification of users preferences. BLE proximity beacons have been exploited to localization purposes also by Faragher[2] and Rida [7]. In his work Palumbo [8] performs indoor smartphone localization exploiting their signals.

Proposed System

In this section an overview and a description of the system is provided. A first important step consists in describing the hypothesis and assumptions considered. Smart spaces techniques can involve a very wide range of different environment typologies. However this work is strictly focused on domestic environments. There are many other applica-

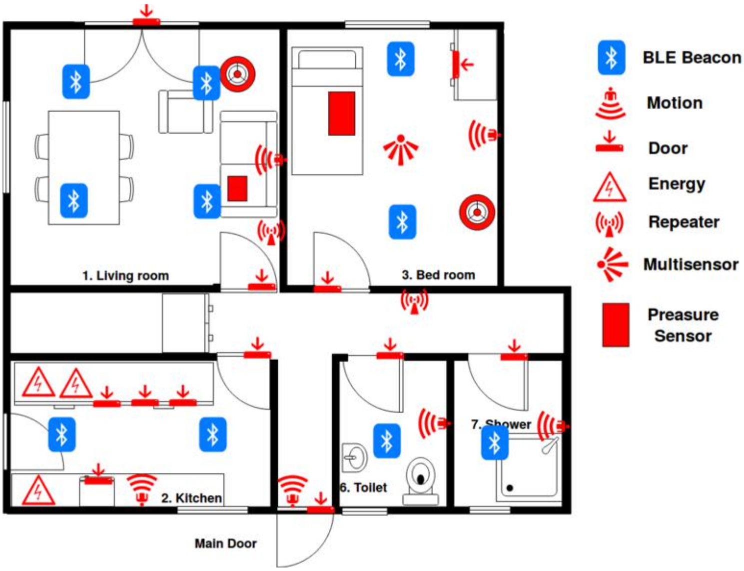


Figure 1. Smart Home Map

tions that can obtain great benefits from intelligent environments paradigm, as for instance, private or public offices, and also this work can be extended to cover these scenarios, but by now our designing proposals, algorithms and test are related to private domestic environments, the so called smart house.

Environment model

Considered scenarios will be always multi-users. In the literature this feature is subject to many conceptions. In this work a space in which many individuals act independently both in different parts of the house and in the same areas is represented through the term "multi-users". The inhabitants (users) set is $H = \{H_1, \ldots, H_P\}$ with $|H| = P \in \mathbb{N}, P > 1$.

The environment model we refers to in this paper is shown in Figure 1. It is the smart home section of the Smart Spaces Lab at Middlesex University in London. It is containing the classical rooms of a common house: living room, bed room, kitchen toilet and shower. Each room is equipped with all the typical appliances and furnitures that can be found in common houses. Moreover each room is enriched with a set of heterogeneous sensors: motion Passive Infra Red based, doors contact, energy monitoring and multisensor device including temperature, humidity level and light intensity. This sensors set can be formalized as: $S = \{S_1 \ldots S_m\}$ with $|S| = m$ total number of installed sensors. Each sensor is associated to a state. We indicate the state of a sensor $S_i, 1 \leq i \leq m$ using the notation $S_i[t]$ where t is a temporal indication. Moreover the set of the possible states is $S_i[t] \in \{0, 1\}$. This means that the state activation is considered as a boolean value (not activated/activated).

The users, acting inside the environment, cause sensors activations records. They are collected by the smart home system, paired with activation time stamp ts and stored into a list, $A = [\langle ts_w, A_w \rangle], w \in \mathbb{N}$. When assigned to a user H_i, they are going to compose data traces $T_{H_i} = \{A_1^{H_i}, A_2^{H_i}, \ldots, A_{L_{T_{H_i}}}^{H_i}\}$ with $|T_{H_i}| = L_{T_{H_i}} \in \mathbb{N}, 1 \leq i \leq P$. Notice that $L_{T_{H_i}}$ is different for each user, since it depends on the user's activities. Hence, since multi-users assumptions, more than one trace will be produced. The set of data traces will be $T = \{T_{H_1}, T_{H_2}, \ldots, T_{H_P}\}$ with $|T| = P, P \in \mathbb{N}$. This last formula implies $|T| = |H|$, so, we are imposing a trace for each user. This is not automatically obtained just recording activation data, but it is the final goal of this work. By now the dataset produced by this kind of environment would be a confused interleaving of different $T_{H_i}, 1 \leq i \leq P$, without the possibility of reconstructing the different traces.

The reader can notice that the figure shows another sensor type not included in the list. Bluetooth Low Energy (BLE) beacons, especially in this work, are modeled as particular sensors. In fact they do not produce directly a record, but their presence is exploited to create distinguished traces assigning properly each record. Due to these characteristic, it is opportune defining differently the beacon set B as $B = \{B_1, \ldots B_n\}$ with B finite set and $|B| = n$ number of beacons in the system. When a user H_i enters into a proximity beacon domain B_{id}, the system creates an association between H_i and B_{id}. An association is expressed as a coupled value $\langle ts, B_{id}\rangle$ where ts the time stamp indicating when the association happens and B_{id} is the beacon involved. For each user, the multi user management system generates an association list $\Lambda^{H_i} = [\langle ts, B_{id}\rangle, \ldots], 1 \leq id \leq n$ and ts is a progressive number. The set of all the association lists is $\Lambda = \Lambda^{H_i}$ *for each* $i : 1 \leq i \leq P$

It is interesting to point out how they are distributed into the environment. In fact, differently from the sensors S_i, deployed in according to their utility (i.e. pressure sensors on chairs and bed, energy consumption meter on outlets and so on), the beacons are equally distributed into the rooms. The amount of installed beacon, is the minimum necessary to cover each room. In this work we assume they are uniformly distributed in space, so each of them covers comparable areas. In other words, the house surface is divided into domains $D = \{D_{B_1}, \ldots, D_{B_n}\} = \{D_1, \ldots D_n\}, |D| = n$. Each corresponds to a beacon. Vice versa each beacon has his own domain: it can be indicated $B_i \leftrightarrow D_i$ with $1 \leq i \leq n$.

Since the domains represents in practical terms spatial disjoint areas, the sensors can be associated to one and only one domain $D_i, 1 \leq i \leq n$. So the sensor set S can be subdivided into subsets $S = S^{D_1} \cup S^{D_2} \cup \ldots \cup S^{D_n}$ s.t. $S^i \cap S^j = \emptyset, 1 \leq i \leq R, 1 \leq j \leq R, i \neq j$.

However there are some cases in which the sensor, due to their technical functionality, cover more than just one domain. As example think about PIR sensors: they usually are utilized to cover whole rooms, in the example shown in Figure 1 they would be detected in more than one domain in rooms 1, 2 and 3. To model this eventuality the notation used is the following: if the activation area of a sensor S_k covers a set of domains $\delta_{S_k} = \{\delta_1 \ldots \delta_f\} \subseteq D, f \in \mathbb{N}, f \leq n$, the projection of S_k on δ_{S_k} is defined as $\pi = S_k^{\delta_1}, \ldots, S_k^{\delta_f}, |\pi| = f$. The state of a sensor S_k is computed using the formula

$$S_k[t] = S_k^{\delta_1}[t] || \ldots || S_k^{\delta_f}[t] \tag{1}$$

In other words, this is the boolean operation OR, it means that to activate S_k it is enough to activate one of its projections.

Assumptions

The definitions introduced above, describe the model used to represent the environment. Since we want to provide a matching between each activation A and the user that caused it with his activity, we need to consider space inhabitants as sensor provided. But adding very complex devices to people strongly limits the user experience system level. For this reason in this work we make the following hypothesis:

- to each user in H correspond one and only one smart-phone device registered on the system capable to communicate with beacons through low energy bluetooth signals
- users bring the smart-phone always with themselves while performing activities into the home

These hypothesis are very reasonable since the smart-phone is an increasingly common device in our everyday life. They have a crucial role in the system: they scan the area near them checking if there is any beacon nearby. If there is one, it communicates this information to a server that stores the data. If there is more than one beacon, the smart-phone chooses the nearest one. The information exchange is performed only when the nearest beacon is different from the last sent.

The beacon proximity is computed evaluating RSSI (Receive Signal Strength indicator) of the beacons BLE [7]. Periodically each smartphone H_i scans BLE devices and detects the nearest one choosing maximum RSSI. It is the most reasonable measure indicating the distance between a signal sender and a signal receiver, since it indicates the strength or the received signal. It is particularly significant if the beacons domain is homogeneous, all have the same specifications and the same transmission power. When the nearest beacon changes, H_i sends information to the system. They are stored into Λ^{H_i}.

Traces extraction algorithm

The elements described by now can provide all the ingredients necessary to compute single user activations traces. What we know is the evolution of the beacons associations of each user and the global activations dataset. The methodology for merging the data is described in the Algorithm 1.

Summarizing, the algorithm assigns to a given user all the sensor activations that happens into the domain of the beacon associated to him/her at that time. The algorithm can partially assign to different traces T^{H_i} and T^{H_j} the same activations, and this potentially can generate traces suffering of some kind of noise. This can happen when:

- it is dealing with cross-domain sensors
- two (or more) different users are performing actions very nearly and they are associated to the same beacon.

In the first case it occurs due to cross-domain sensors peculiarity: the activation of the sensor in a domain, implies the activation of all the projection sensors into the other domain interested by the sensor.

The second point, instead is given by the system design. It is probable that if two users are very near each other, they are performing or the same activity together or two activities in the same area. So having the activations duplicated into their traces does not add noise but instead improves their quality.

Algorithm 1 Algorithm devised for single user activations traces extraction from multi-user data log and beacon association set

Input: H users set
Input: Λ set of association lists
Input: A activations list
Output: T single user traces set
for all $H_i \in H$ **do**
  $\Lambda^{H_i} \leftarrow \Lambda.get(H_i)$
  $\alpha \leftarrow \Lambda^{H_i}[0], \alpha = \langle ts, B_{id} \rangle$
  for all j s.t. $1 \leq j < |\Lambda^{H_i}|$ **do**
    $\beta \leftarrow \Lambda^{H_i}[j]$
    $\delta \leftarrow \alpha.B_{id}$
    for all $A_w \in A$ s.t. $\alpha.ts \leq A_w.ts < \beta.ts$ **do**
      if $A_w.sensor \in S^{D_\delta}$ **then**
        $T_{H_i}.add(A_w)$
      end if
    end for
    $\alpha \leftarrow \beta$
  end for
  $T.add(T^{H_i})$
end for

Example

To explain how the algorithm works, we can refer to a scenario example. The Table 1 contains a graphical representation of the system state during the action execution for two different users $H = \{H_1, H_2\}$. The left table contains data related to H_1, the right one to H_2. Each table contain the sensor activations and the beacon associations grouped by beacon domains. The notation for the sensor activation is S_{ij} and indicates the activation of the j-th sensor of the i-th domain. In case of cross-domain sensors, $S_{ij}^{\delta_i}$ indicates the projection of the same sensor in different domains. The columns labeled with $t_1 \ldots t_\infty$ represent the state evolution in time. If there is an activation (or a beacon association) from domain D_i of the sensor S_{ij} in time t_k, then the corresponding cell has 1, empty cell means 0 (no activation).

To project the example to the map in Figure 1, we can consider B_1 the beacon in the north-east of the living room and B_3 the south-east one. The sensors $S_{13}^{\delta_1}$ and $S_{33}^{\delta_3}$ are projections of the PIR sensor S_{1333} (it influences both the domains). Notice that $S_1 333$ is not reported into the table, since its value can be inferred using Formula 1. The As indicated in the table S_{11} is the window sensor, S_{12} is the lamp sensor, S_{31} is the door sensor and S_{32} is the sofa sensor.

The behavior of H_1 is: t_1 open windows, t_2 and t_3 turn off the lamp, t_4 open the door, t_5 close the door.

The behavior of H_2 is: t_1 and t_2 enter room and stay on the sofa, t_3 close the window, t_4 turn on the light and t_5 stay on the sofa.

The PIR sensor value $S_{1333}[t] = S_{13}^{\delta_1}[t] || S_{33}^{\delta_3}[t], \mathit{for\ each}\ t : t_1 \leq t \leq t_5$

Table 1. Tabular representation of activities progress combining Beacon Domain Areas, Beacon and Sensors for two different users. For facilitating interpretation W = window, L = lamp, D = door, S = sofa

Domain Area	Sensor	t_1	t_2	t_3	t_4	t_5
D_1	B_1	1	1	1		
	S_{11} (W)	1				
	S_{12} (L)		1	1		
	$S_{13}^{\delta_1}$(PIR)	1	1	1		
D_2	B_2					
	S_{21}					
	S_{22}					
D_3	B_3				1	1
	S_{31}(D)					1
	S_{32}(S)					
	$S_{33}^{\delta_3}$(PIR)				1	1
⋮	⋮	⋮	⋮	⋮	⋮	⋮
D_n	B_n					
	S_{n1}					
	S_{nm}					

Domain Area	Sensor	t_1	t_2	t_3	t_4	t_5
D_1	B_1			1	1	
	S_{11}(W)			1		
	S_{12}(L)				1	
	$S_{13}^{\delta_1}$(PIR)			1	1	
D_2	B_2					
	S_{21}					
	S_{22}					
D_3	B_3	1	1			1
	S_{31} (D)					
	S_{32} (S)	1	1			1
	$S_{33}^{\delta_3}$(PIR)	1	1			1
⋮	⋮	⋮	⋮	⋮	⋮	⋮
D_n	B_n					
	S_{n1}					
	S_{nm}					

The list A produced would be: $A = [\ \langle t_1 : S_{11}\rangle, \langle t_1 : S_{1333}\rangle, \langle t_1 : S_{32}\rangle, \langle t_2 : S_{1333}\rangle\ \langle t_2 : S_{12}\rangle, \langle t_2 : S_{32}\rangle, \langle t_3 : S_{1333}\rangle, \langle t_3 : S_{12}\rangle, \langle t_3 : S_{11}\rangle, \langle t_4 : S_{1333}\rangle, \langle t_4 : S_{31}\rangle, \langle t_4 : S_{11}\rangle, \langle t_5 : S_{1333}\rangle, \langle t_5 : S_{31}\rangle, \langle t_5 : S_{32}\rangle\ ]$, representing a portion of sensor database log.

Moreover the multi-users management system would produce also two beacons association lists: $\Lambda^{H_1} = [\langle t_1, B_1\rangle, \langle t_4, B_3\rangle]$ and $\Lambda^{H_2} = [\langle t_1, B_3\rangle, \langle t_3, B_1\rangle, \langle t_5, B_3\rangle]$. Applying Algorithm 1 to H, A and Λ, the result set $T = \{T_{H_1}, T_{H_2}\}$ will be:

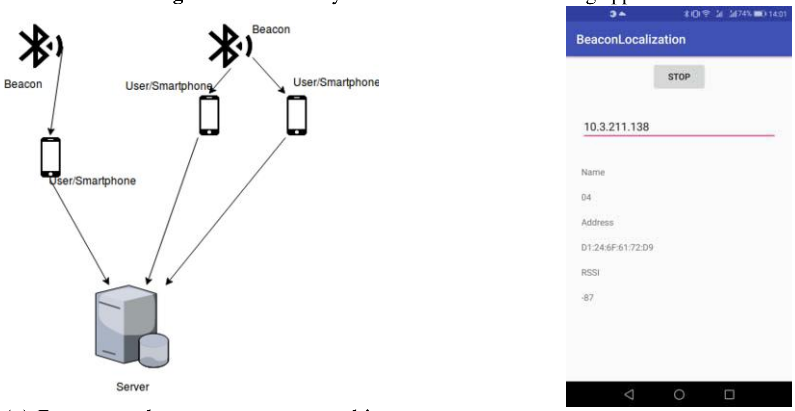
- $T_{H_1} = \{\ \langle t_1 : S_{11}\rangle, \langle t_1 : S_{1333}\rangle, \langle t_2 : S_{1333}\rangle\ \langle t_2 : S_{12}\rangle, \langle t_3 : S_{1333}\rangle, \langle t_3 : S_{12}\rangle, \langle t_3 : S_{11}\rangle, \langle t_4 : S_{1333}\rangle, \langle t_5 : S_{1333}\rangle, \langle t_4 : S_{31}\rangle, \langle t_5 : S_{31}\rangle, \langle t_1 : S_{32}\rangle\ \}$
- $T_{H_2} = \{\ \langle t_1 : S_{1333}\rangle, \langle t_1 : S_{32}\rangle, \langle t_2 : S_{1333}\rangle, \langle t_2 : S_{32}\rangle, \langle t_3 : S_{1333}\rangle, \langle t_3 : S_{12}\rangle, \langle t_3 : S_{11}\rangle, \langle t_4 : S_{1333}\rangle, \langle t_4 : S_{32}\rangle, \langle t_5 : S_{1333}\rangle, \langle t_5 : S_{31}\rangle, \langle t_1 : S_{11}\rangle\ \}$

Implementation and experiments

The system described in the previous section has been implemented into the smart house model illustrated in Figure 1. The Figure 2a shows the beacons subsystem architecture. All the devices catch the BLE signals and communicate to the server where the strongest one came from. A screnshot of the application performing that is shown in Figure 2b. The top IP field contains the address of the server, "Name" field is the beacon number of the nearest beacon while the "Address" field contains its the MAC address. "RSSI" shows the value of the RSSI signal computed for the nearest beacon.

The BLE beacons have a different behavior respect to the other sensors: indeed while the former have a simpler structure and just emit a signal indicating their presence, the latter after sensing the environment send actively the information to a central server. Due to this different characteristics, beacons are managed by another subsystem. Its structure is illustrated in Figure 2a. The beacons are installed in each room uniformly distributed accordingly to the surface they need to cover. They just send their signals, that are caught

Figure 2. Beacons system architecture and running application screenshot



(a) Beacons subsystem structure architecture

(b) Running beacons application screenshot.

by the smartphones. They run a custom application developed to understand which is the nearest beacon. Each time the nearest beacon is identified, the information is sent to the server. The beacons utilized in this work are very simple. They are fully standalone Bluetooth Smart proximity beacon using iBeacon and AltBeacon technology. Their consumptions are very low, they can last until 9 months with their most energy consumption configuration (high advertising rate).

As explained before, each smartphone represents a users. In our experiments the smartphones utilized are all Android smartphones. The application developed can run on Android version ≥ 5.0 because they are BLE optimized. Three devices have been tested, a Samsung Galaxy S4, Android version 5.0, a Nexus 7 tablet, Android version 6.0 and a Honor 8, Android version 7.0.

The server collect the smartphones measurements and stores the beacon history into different files. To distinguish the smartphones it considers their IP address as unique key. This works only for static address configuration. In fact if the goal is to store user data to utilize them along different sessions and analyze his behavior, a dynamic IP addresses configuration is not good because there is no warranty about the IP assignment in two different sessions.

To evaluate the results, the following procedure has been followed: first two experimenters perform activities into the smart house illustrated in Figure 1. Manually analyzing the log, a ground truth trace for each user is computed. Than the Algorithm 1 is applied and the results for each user are compared with the ground truth. The metric to evaluate them is the Jaccard similarity index between the traces obtained and the correspondent ground truth. Given $\bar{T}^{H_i}$ the ground truth trace, the Jaccard similarity is computed $J_{H_i} = \frac{\bar{T}^{H_i} \cap T^{H_i}}{T^{H_i} \cup T^{H_i}}$.

Two are the scenarios tested:

- two users H_1, H_2 perform activities at the same time in different parts of the house. The first user keeps tidy the living room, then he moves in the kitchen and there he prepares a tea. The second user moves from the kitchen to the bedroom and there he makes the bed. Both users never act in the same room at the same time.

Table 2. Experimental results, Jaccard similarity value between the ground truth traces and the computed traces.

	H_1	H_2
Scenario 1	87.4%	86.6%
Scenario 2	77.1%	75.5%

- two users H_1, H_2 perform activities at the same time. They are partially performed also in the same room. H_1 prepares a tea in the kitchen. In the meanwhile H_2 enters in the kitchen to wash hands, then move quickly to living room and then sits on the bed in the bedroom.

The results obtained in the experiments is shown in Table 2.

Conclusions and future works

The goal of this work is to provide a feasible solution to the multi-users intelligent environments problem. The main idea is to be able to distinguish between different users, for building the data traces of the sensor activations correlated to their activities. Naturally, the optimal result would be to obtain a log related to a given user containing only the correct measurements.

This paper describes a first implementation of the proposed system: its effectiveness and precision depend on a lot of factors, that can have an impact more or less important. Most of them are related to beacons. They impacts mainly for three factors:

- **Technology:** the proximity BLE technology is evolving. There exists new protocols and formats, for instance Eddystone. They can provide more data and metadata useful for improving precision.
- **Installation:** the beacons position is very important, since if the beacons are too far each other, some sensors could be uncovered and the granularity could be too coarse. On the contrary if they are too near each other, the coverage areas are going to overlap and it becomes difficult for the smartphone (but also for an human) to understand which is the nearest proximity beacon. In our experiments, the minimum distance between two beacons in the same room is $1,5$ meters. The maximum is strongly dependent by sensors installation density, in our scenario is $3,5$ meters.
- **Exploitation:** by now the nearest beacon information is mined just looking at the maximum RSSI value given by all the reached beacons. So each beacon is analyzed independently from the others. Other more complex algorithms that involves triangulation techniques between many beacons can bring more precision in localizing the users and, consequently, in separating the user traces.

The technological limits are the main responsible of the errors occurred: the recognizing of beacon change can be slower of the sensor triggering. In that case the measurement correlated can be lost (decreasing the precision). The simple RSSI measurement can also bring a wrong nearest computation for short time, causing measurements losses or wrong associations. Moreover there could be interferences from beacons installed in neighbour rooms: this is a rare event since the BLE signal is quite weak and walls and obstacles make it also weaker, so interferences in other rooms from farer beacons are not probable. However if they could happen, the effects on the performances are similar to the ones described above.

For readability and brevity, we just presented a scenario example. However the possible inhabitant activities combinations are very variegated. There could be actions in which activities involve completely different sensors or other in which all the users act in a very small area. In the latter case, probably users are associated to the same beacon, implying overlapped traces.

Next steps will involve in exploiting the traces obtained with this technique. They can be useful in many applications as for instance providing a clean database for training and testing other state of the art activity recognition or habit mining techniques. It would be interesting also to check the dirty measurements impact in applying these techniques, comparing the results between a single user database application and multi user multi traces obtained with this technique.

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Preference-Aware Video Summarization for Virtual Tour Experience

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Abstract. Recently, there are increasing demands for tour recommendations using videos because more tourists search and watch tourism videos when planning a sightseeing tour. However, searching desired videos are very hard (even not possible) or require significant labor. In addition, since each searched video is on a fixed route, it is necessary to search other route videos when it does not match the user's desire. In this paper, we propose a system for curating a tour video adjusted to the intention or preference of each individual user from consumer generated media (CGM) including videos, photos and comments posted on each sightseeing spot/route through Social Networking Service. This system creates a tour route based on user's preference and a summarized video along the route. For creation of a summarized video, we propose a video summarization algorithm that maximizes viewing satisfaction within a specified playback time. Users can plan favorite a tour easily by watching this summarized video. In order to evaluate effectiveness of our method, we compared watching a summarized video with searching by Internet. As a result, we found that watching a summarized video can help a user imagine a tour easily, improve sightseeing and increase his/her satisfaction.

Keywords. sightseeing, recommendation system, video summarization, consumer generated media, curation

1. Introduction

The number of inbound visitors is increasing in Japan toward Tokyo Olympics held in 2020. It prompts the demand of sightseeing contents based on the latest information technology. Guidebooks and official websites are the most common media of sightseeing information for tourists. In addition to such an official and static information, Consumer Generated Media (CGM) posted on SNS like Instagram or YouTube have been attracting more attention because of its freshness and a sense of reality. CGM includes photos and videos taken by tourists. These contents may not be accurate but will reflect the real situation of tour spots. Sometimes, they have newer information than guidebooks and website and include tourists' opinions on sightseeing spots.

The video contents of CGM are helpful for a tourist to plan a tour route because a video has richer information than text. Actually, the investigation of Google shows that more than 40% tourists watch videos about tourism to select sightseeing spots in planning tour routes [9]. However, it is hard to find the suitable video contents for each sightseeing spot among distributed CGM contents. Also, it is even harder to select videos that meet a demand and a preference of each tourist because tourists' requirements are different from each other.

There are some existing studies on automatically creating tour routes taking into account tourists' preferences, aiming to help tour planning. Kurata et al. have proposed a method to create the tour route automatically considering tourist's interests extracted with an analytic hierarchy process [4]. Hidaka et al. have proposed a method to calculate the order of recommendation among tour spots and create a proper tour route following the order [2]. According to the results of these existing studies, it would be useful if the tour video considering both the route and tourist's preference is provided to each tourist.

In this paper, we propose a tour video curation system that selects and summarizes various CGM photos and videos along the tour route determined based on the tourist's preference. We aim to create a tourism video that achieves both conciseness and high satisfaction because the shorter video is more useful for quick tour planning as long as the included information is not spoiled. Our method first calculates the preference-aware tour route based on the existing method proposed in [2]. Each sightseeing spot included in this route has different preference value according to the tourist's interest. In our method, the video of the spot having the lower preference value is selected for shortening the playback time. The reason why we do not cut whole videos of lower preference value spots is to give a virtual experience that the tourist walks along the actual sightseeing route. Finally, our method can generate a preference-aware digest tour video keeping the high satisfaction.

We conducted an experiment to evaluate the effectiveness of our system. In the experiment, we asked the subjects to watch the preference-aware tour video generated by our method. Then, we asked the question about the easiness, the amount of information, and satisfaction compared with the case searching this information from the Internet. As a result, we confirmed that the preference-aware tour video generated from CGMs are helpful to imagine the tour route compared with the Internet-based information retrieval. Also, we confirmed that the generated digest videos keep high user's satisfaction. We also found that the digest experience along the sightseeing route improves tourist's motivation.

2. Related work

2.1. Sightseeing route recommendation

Generally methods of planning sightseeing routes are reading guidebooks or looking web site. However, these methods are difficult to plan a sightseeing route each along user's preference because these can not reflect user's preference dynamically. Based on this fact, there are studies of recommending sightseeing routes along their preference. Maruyama at el. suggested "P-Tour" that recommends sightseeing routes considering tour time[8]. Kurata at el. proposed "CT-Planner" that can create interesting tour routes dynamically for users using GUI[5]. These recommended sightseeing routes meet requirements, but users are not able to imagine the tour experience because these routes are shown only on the maps.

2.2. CGM curation

Amount of information we can search has increased dramatically thanks to the shared web contents. It is difficult for users to search desired information quickly since new information is continuously uploaded on the web. As a solution for this problem, there are many applications curating web contents such as "SmartNews"[1]. Curation can effectively share only valuable information.

CGM like reviews or photos on SNS are valuable information for tourists. There are studies of developing sightseeing support systems that curate tourism information on web. Lim proposed a system, called TourRecInt, whose goal is to recommend tours based on user interest[7]. This system combined knowledge from Flickr's geo-tagged photos and Wikipedia, and exploited user's visit history. Kurushima at el. created a photographer behavior model from geo-tag in Flickr photos, and they used this model to recommend sightseeing routes[3]. Similarly, Sun at el. extracted landmarks from geo-tagged photos, and recommend them to users[10].

2.3. Tourism video summarizations

In order to extract important scenes from long time video, the technology of summarizing videos is essential. The research fields of video summarization are diverse such as television programs, sports videos and cooking videos, etc. Fujisawa at el. proposed the system which can compile a sport video in real time[1]. In addition, Laganiere at el. extracted important scenes from features changes to summarize videos[6]. However, tourism videos taken by tourists do not include featured scene switching or sounds unlike television programs or sport videos. So, Zhang at el. proposed a summarization method along path from tourism videos[11].

3. Tourism Video Curation System

Our proposed system, named the tourism video curation system, creates tour routes taking into account user's interests and summarized videos along the routes using CGM data. Users can experience virtual tour through watching the summarized videos, and they can plan/adjust the whole tour route easily. Fig. 1 shows the overview of our system. Our system consists of 4 steps.

1. **Data collection**
2. **Tour route creation**
3. **Summarized video creation**
4. **Summarized video watching**

First, in the data collection, the system collects information such as tour purpose and spots of interest to create a tour route. Second, in the tour route creation, the system extracts user's preference based on input information and creates a tour route for users. Third, in the summarized video creation, the system creates summarized videos along the tour route created in the second step. Finally, in the summarized video viewing, users can decide a favorite tour route by repeating watching the summarized videos and adjusting the tour route.

[1] https://www.smartnews.com/ja/

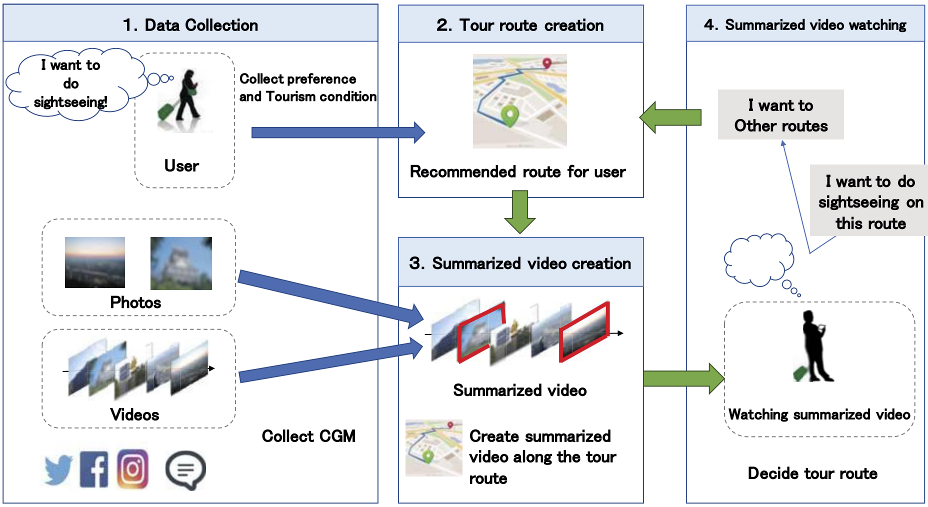

Figure 1. System overview

3.1. Data collecting

3.1.1. Collecting user's information

First, the system collects personal information of a user such as age, gender and interests. Additionally, it collects the start and the destination locations and the length of sightseeing time. In [2], the authors proposed to collect this kind of information by using smartphone applications with which users input the required information manually. Our system follows this method to collect user's preference.

3.1.2. Collecting CGM

The system needs tour videos and photos of sightseeing spots to create summarized videos. We collect these videos and photos through SNS or participatory sensing. The collected photos for each spot are used to create the slideshow video for the spot. The data collection is conducted automatically after the tour route creation. So, the data only along the tour route are collected.

3.2. Tour route creation

In this step, the tour route is created based on user's information. Sightseeing spots are selected automatically including the start and destination points. Hidaka at el. [2] proposed a method to represent features of sightseeing spots and user's interests by feature vectors and obtain user's interest ranking of spots by calculating inner product of these two vectors. They recommended sightseeing spots according to the ranking.

Our system uses this method to create a tour route by connecting spots of high ranking with the shortest path.

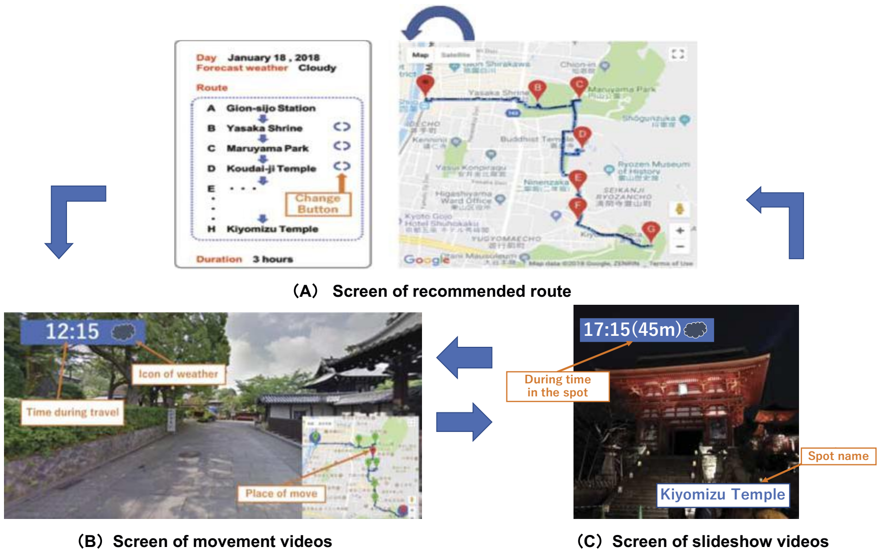

Figure 2. User interface when watching a summarized video

3.3. Summarized videos creation

In this step, the system creates a summarized video to allow user to grasp movement between spots in the recommended route. The method of creating a summarized video is most important in this paper, so it is explained in detail in Section 4.

3.4. Summarized video watching

In this step, users watch a summarized video. Fig.2 shows a user interface when watching a summarized video.

First, user checks the recommended tour route in screen (A). Screen (A) shows information about the day, weather forecast, the tour route and duration of tour with maps. Second, in screen (B), user can view a movement video between spots. The upper left of screen (B) displays elapsed time in the movement and an icon showing weather. The lower right of screen (B) displays a map image that helps user know which route to follow in the area. Screen (C) is shown when arriving at a sightseeing spot, where slideshow video of the spot is played back. The lower right of screen (C) displays name of the spot and the upper left of screen (C) displays elapsed time in the movement, the icon of weather and estimated time that is necessary to enjoy the spot. Screen (A) is shown when all video playback is finished. Users can change the route if there are no favorite spots included in the route by pressing change button in screen (A). After this, a recommended tour route is recreated. Users can create a favorite tour route by following these steps repeatedly.

4. Tour video summarization problem and solution

In this section, we define the tourism video summarization problem and give our solution.

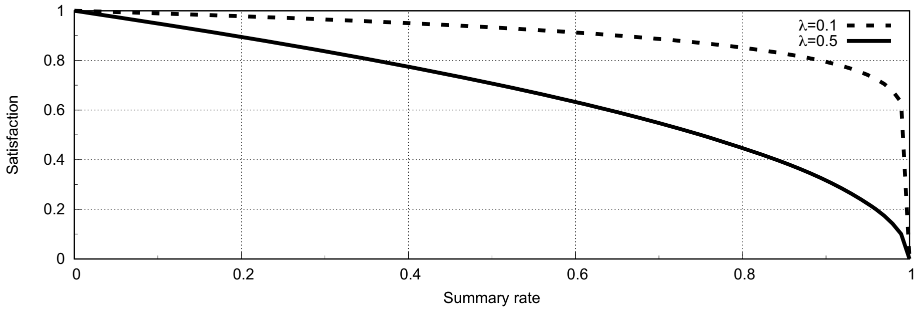

Figure 3. Example of satisfaction function

4.1. Tourism video summarization problem

Route video and playback time constraint

A recommended tour route is denoted by $r = \langle s_1, s_2, ..., s_N \rangle$. Here, s_i $(1 \leq N)$ denotes i-th visiting sightseeing spot and N denotes the number of spots in the route. The slideshow video for spot s_i is denoted by v_{s_i}. v_{s_i} is created from multiple photos for spot s_i collected as CGM. $v_{s_i \rightarrow s_{i+1}}$ denotes the video showing movement between a spot s_i and the next spot s_{i+1}. We assume that all videos for the spots and the movements between spots in r are given in advance.

The summarized video denoted by v_r has the following constraint aiming to allow users to view the video in a short time.

$$|v_r| \leq T \tag{1}$$

Here, $|v_r|$ is a playback time of v_r, and T is a constant value given by user. 30 seconds to 2 minutes are supposed as T so that users view the video repeatedly to plan the best tour route.

Summarization rate and satisfaction function

The summarization rate of v is denoted by $\theta_v (0 < \theta < 1)$. When summarizing the video v with summarization rate θ, playback time of the resulting video (denoted by v^*) becomes $(1-\theta) \cdot |v|$.

Users' satisfaction level when viewing v^* is denoted by $Sat(v, \theta)$. Generally, satisfaction level decreases as a summarization rate becomes high. Moreover, user's satisfaction level gradually decreases when summarization rate is in low range, while the level sharply decreases when summarization rate is in high range. Thus, $Sat(v, \theta)$ can be represented as follows.

$$Sat(v, \theta) \stackrel{def}{=} (1-\theta)^{\lambda} \tag{2}$$

In the above equation, λ is a constant $(0 < \lambda < 1)$ and larger λ leads to quicker decrease of satisfaction level. Fig.3 shows examples of the satisfaction function when λ is 0.5 and 0.1.

Each user has different λ for each spot. Let λ_s denote the λ value for spot s. λ_s can be determined from user's preference. We assume that λ for all movements between spots has a constant value λ_0.

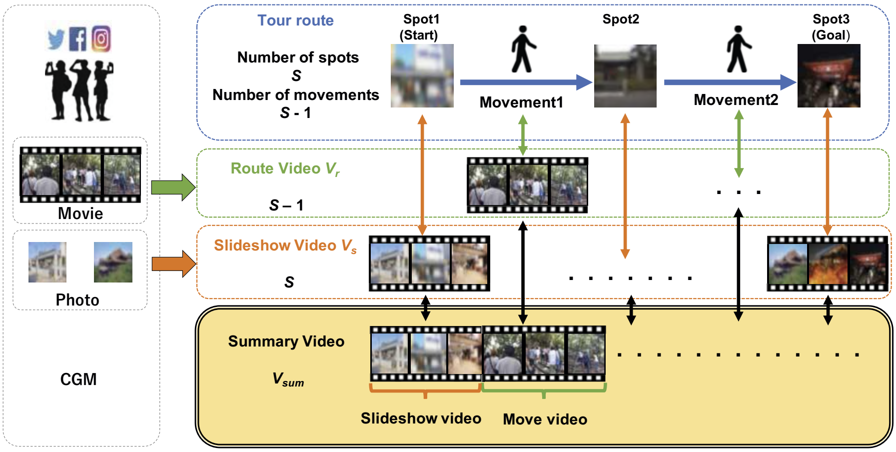

Figure 4. Method of making summarized video

Tourism video summarization problem

A slideshow video for a spot $s_i(1 \leq N)$ and a route video for a movement $s_i \to s_{i+1}$ in route $r = \langle s_1, s_2, ..., s_N \rangle$ are denoted by v_s and $v_{s \to s'}$, respectively. The set of slideshow and route videos in r is denoted by V_r. The satisfaction function parameter for each video in V_r is given as λ_s or λ_0.

The summarized video v_r for r can be created by concatenating all videos in V_r after summarizing each video with its summarization rate. Therefore, the tourism video summarization problem (TVSP) is to find θ_v for each $v \in V_r$ with the following objective function (3).

$$Maximize \sum_{v \in V_r} Sat(v, \theta_v) \; subject \; to \; (1) \tag{3}$$

4.2. *Method of tourism video summarize*

Based on the above problem formulation, v_r is created along r. Fig. 4 shows an outline for creating a summarized video.

Videos of spots more important for user are summarized with lower summarization rates, and less important spot videos are summarized with higher rates. Hence, the overall summarized video v_r should have sufficient information for user so that the user's satisfaction becomes as high as possible.

We show the proposed video summarization algorithm in Algorithm 1. For convenience, $V_r = \{v_1, ..., v_{2N-1}\}$ denotes the set in which spot videos and route videos are alternately ordered in visiting order. Let $\Lambda = \{\lambda_1, ..., \lambda_{2N-1}\}$ denote the set of parameter for V_r and Δ denote a constant value for gradually increasing summarization rate (for example 0.1) in the algorithm.

In Algorithm 1, first, summarization rates of all videos are initialized to 0.0 (line 1). Second, a summarization video v_r is created by concatenating all videos in V_r taking into account the order of its elements (line 2). Then, summarization rate of the least decrease satisfaction video v_j is increased by Δ and the summarized video is recreated. This step

Algorithm 1 Video Summarized Algorithm

Input: Tour route:r, Set of videos:V_r, Set of parameter:Λ, Playback time:T
Output: Summarized video v_r
1: Initialize all summary rate θ_v to 0 for all $v \in V_r$.
2: Make a summarization video v_r by cooncatenating all videos in V_r.
3: **while** $T < |v_r|$ **do**
4: Refer to satisfaction function reflected Λ and select the least decrease satisfaction element v_j in V_r.
5: $\theta_{v_j} \leftarrow \theta_{v_j} + \Delta$
6: Remake v_r reflected v_j's summary rate.
7: **end while**
Output v_r

is repeated until the constraint of the playback length of summarized video is satisfied (line 3-7). Finally, the summarized video v_r, satisfying the constraint, is generated as the output.

5. Experiment and Result

In order to evaluate the effectiveness of summarized videos, an experiment was conducted.

5.1. Experimental overview

In this experiment, each tour route along the preference of each subject was created. The start and goal are famous tourist spots in Kyoto, Japan, between Gion-sijo station and Kiyomizu temple. Twelve subjects, 22-26 years old, answered the questionnaire for evaluation after watching summarized videos for each tour route.

Experimental procedure is as follows:

1. Create a tour route that matches the preference of each subject, and create a summarized video based on the tour route.
2. Multiple visiting spots in the tour route are shown to each subject.
3. Each subject confirms the spots and route information by searching on the Internet.
4. Each subject watches the summarized video after searching on the Internet.
5. After watching the videos, each subject answers a questionnaire.

Tab. 1 shows items of the questionnaire. Subjects answer all questions on a scale of one to five. If the subject feels that searching on the Internet is the best, the answer is 1. If the subject feels that watching the video is the best, the answer is 5.

5.2. Result

Fig. 5 shows the result of the questionnaire. The x-axis shows the question number and the y-axis shows the average value of each answer. There were no subjects who answered that Internet searching was more effective for Q1, Q5, and Q7, and the average was also larger than 4. This result indicates that watching summarized video is more effective.

Table 1. Items of questionnaire

Q1	Which one could visualize tour easily?
Q2	Which one could search information about routes easily?
Q3	Which one could search information about spots easily?
Q4	Which one did you think has higher amount of information?
Q5	Which one encouraged you to go to the tour spot?
Q6	Which one helped you to decide about the tour easily?
Q7	Which one did you satisfy?

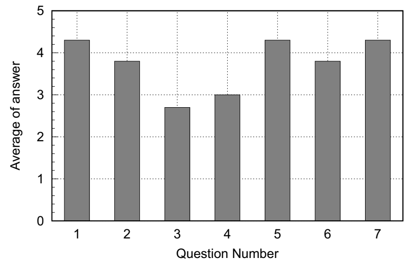

Figure 5. Answer of questionnaire. The larger the numeric value, the better viewing a video than searching by Internet

The average values of Q2 and Q6 were both 3.8. The result shows that watching video is more effective as a whole. However, some subjects answered that Internet search was more effective.

The average of Q4 is 3.0. The result shows that the effectiveness is similar between the two methods. Also, the average of Q3 is 2.7. This result shows that Internet searching is more effective.

5.3. Discussion

We consider that watching the summarized video helps users make an image of the whole tour easily (Q1), and increases user's motivation for sightseeing (Q5). Additionally, we think that our method is effective because satisfaction of subjects against watching videos was higher (Q7). A result of Q2 shows an easiness of searching a route in case of watching the summarized video is high. This result shows that our method is effective. However, there was an opinion that it is difficult to acquire route information because playback is too fast. Therefore, we need to consider the speed of playback to watch videos comfortably. It is one of our future works. The result of Q6 shows an easiness of judging about the whole tour in case of watching the summarized video is high. From this result, we think our method is effective.

However, there are some negative comments such that spot information (fee, opening hours, closed days, etc) is insufficient. Results of Q3 and Q4 have also indicated the same issue. Our method is difficult to show the detailed information because only it presents photos and video. Therefore, enriching the contents of photos and video is needed. For example, adding some comments on each photo of the spot is considered. We need to develop a more efficient information representation method in the future.

6. Conclusion

In this paper, we proposed a tourism video generation and summarization system that allows tourists (users) to experience virtual tour by watching the generated video easily. The proposed system uses a sightseeing route based on the preference of user as an input and generates the corresponding tour route video by concatenating some photos and videos selected from CGM pool. We developed a video summarization algorithm that shortens the tour video within the specified time duration while maintaining satisfaction level of the user.

We conducted experiments with 12 participants to evaluate effectiveness of our system. The subjects have evaluated two methods: the proposed method (watching generated video) and the conventional method (searching information on the Internet). As a result, we confirmed that watching videos generated by our method gives users a more comprehensive image of tour route, higher satisfaction level, and higher motivation. Moreover, it was confirmed that the acquired information volume with the proposed method is higher than the case with searching on the Internet.

Our future work includes discussion on adding more information to the tourism video, assessment of satisfaction level to improve the video summarization algorithm and improvement of the user interface in watching the video. Also, it is necessary to evaluate the effectiveness of our system with real tourists.

Acknowledgements

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Investigation User Attributes to Select Contents for Behavior Change on Sightseeing Application

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Abstract. Currently, many sightseeing spots and local governments have developed independent Web sites and mobile applications for promotion to tourists. However, local governments have developed Web sites and mobile application independently, it is causes difficult to manage the wide area content which integrate each content. The useful contents for a tourist should integrate sightseeing spots on wide region with each municipality. For reasons mentioned above, we have developed a common platform of application that can solve this problem. The application can work as a launcher application of individual web application provided by local governments. However, there is a problem that the launcher application cannot display all the contents on the screen due to limited size of the smartphone. Therefore, we considered that a method which selects the contents focusing on the user's behavior change. We guess the content which induces the behavior change differs depending on the user. Thus, we needed to clarify that user's attributes are correlated with activities on the sightseeing application. In this study, we clarified that the influence of contents could be different depending on user's attributes. As a result, we clarified the statistically significant relationship between some of user's attributes and each content.

Keywords. behavior change, mobile application, sightseeing, recommender system, urban sensing

1. Introduction

Currently, Web sites and mobile applications have been utilized in various situation by the spread of smartphones. It is causes changes on tourist behavior. Previously, tourists gathered information of the sightseeing spots from the pamphlets and so on. Currently, the tourists can obtain the latest information by Web sites and mobile applications. Therefore, many sightseeing spots and local governments who paying much attention for tourism have developed independent Web sites and mobile applications for promotion to tourists. However, local governments have developed independent Web sites and mobile application, it is causes the difficult to manage wide area contents which integrate each content. To solve the problem, the prefecture's Tourism Division have developed portal

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Web sites and portal applications to integrate the information of the sightseeing spots in each municipality. The problem now arises: the amount of information that the portal Web sites and portal applications can provide is reduced than information of independent Web sites and mobile applications. To solve the problem, we have developed the applications with a common platform. This application works as launcher of independent contents that provided by local governments.

In Japan, expectations for tourism projects such as the Tourism-based Country Promotion Basic Act and the Olympic Games in 2020 have been gradually increasing, and various sightseeing spots should cooperate to develop the tourism business. In addition, the Japan Tourism Agency promotes DMO (Destination Management Organization) as an organization for accelerating to develop sightseeing spots. For reason given above, tourism business should integrate the region sightseeing spots with each municipality.

However, as we have mentioned before, it is difficult to develop the Web sites and mobile applications that integrate the information on the sightseeing spots. Our applications with a common platform can solve this problem. Meanwhile, there is a next problem: the launcher application cannot display all the contents on the screen due to limited size of the smartphone. This problem is common problem for the mobile applications using many contents not only for the sightseeing applications. A large number of studies have been made on this problem [1,2]. Among them, many existing applications adopted especially system that recommend contents from user's preferences and attributes. The most of these applications mainly focused on investigating record of user's activity on virtual world such as Web shopping or Web browsing. Thus, there are many researches which investigate the effect verification by using a log on Web sites or smartphone operation. However, it is difficult to verify the effect of recommendation to the tourist because it needs actual activity of user on real world. Therefore, there are much less researches that the recommend of tourism contents is correlated with tourist behavior. In this paper, we investigate that user's preferences is correlated with activities on the sightseeing application.

2. Purpose

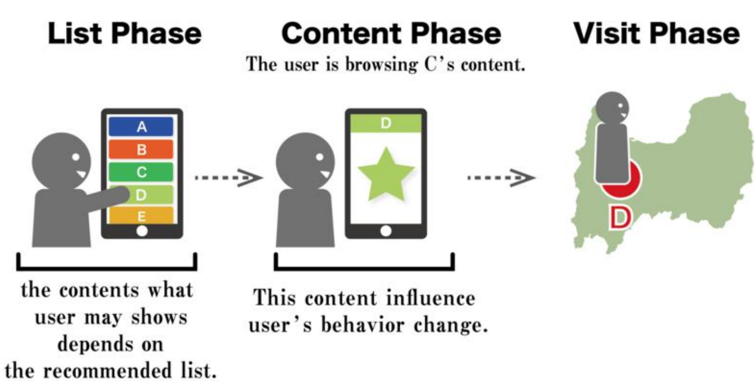

Figure 1. Three phase of sightseeing application.

First, we considered the user's behavior change on sightseeing applications. The term "the user's behavior change" can be defined as follows: the user actually visits the sightseeing spot after browsing the relevant contents and induced by the contents in the application. The user's behavior changes of our sightseeing application consist of three phases. Figure 1 shows that three phases of that.

The term "List Phase" can be defined as the phase that the users browse and select the page which has listing several links of the contents. The term "Content Phase" can be defined as the phase that the users browse the page which has the individual content for the relevant sightseeing spot. The term "Visit Phase" can be defined as the phase of the users actually visits the sightseeing spot. We have to introduce some recommendation mechanism in the List Phase and the Content Phase in order to induce the user's behavior change.

In this study, as we have mentioned before, there are the problem that the mobile application cannot display all the contents on the screen due to limited size of the smartphone. Accordingly, we focus on the mechanism of the List Phase. Our application can select suitable contents for user's preferences in the List Phase and show the list of links to the actual contents. The selection of contents in List Phase is important because the contents that user may show depends on the recommended list. Namely, the mechanism of recommend links can induce the user's behavior change for sightseeing applications. Moreover, we guess the content which induces the user's behavior change differs depending on the user. To take a simple example, sightseeing spots which induce the behavior change are different in youth and elderly users.

The purpose of this study is to examine relations between contents and user's attributes when the application user occurs the behaviors change.

3. Discover TOYAMA

In this study, we have developed Discover TOYAMA that is the smartphone application for sightseeing in Toyama Prefecture, Japan. This application is officially provided by Toyama DMO. Discover TOYAMA can integrate multiple contents of many sightseeing spots in Toyama. Each individual content is provided as a Web-based application (Child App). As shown figure 2, the top screen of Discover TOYAMA provides two facilities. One is Child App List that shows list of links to individual contents. Another shows the Recommend Spots List that shows list of recommended spots by the application based on user's attributes. The user can input their attributes into the application. The attributes include user's gender, age, residence, purpose of trip, travel plan and so on.

Discover TOYAMA has functions to record the log of user's actual behavior. This application can record user's location by GPS, and operation log on the application. Therefore, we can investigate by using both information whether user's behavior changes are induced or not.

The user can view information of sightseeing spot through the Recommend Spots List and Child App. The difference of them is the degree of detail about presented information. Child App has comparable functions to general mobile applications to browse detailed information about the spot such as overview, location, access, pictures, related event schedule and so on. On the other hand, Recommend Spot has function to show only simple information in single window.

Figure 2. Discover TOYAMA has two types of content.

4. Methods for Calculation of Induced Users

The user's behavior change may be induced by both two functions described above. However, Child App has more detailed information than Recommend Spot. Therefore, we assumed that the Child App is more effective than Recommend Spot. In the section, we calculate number of induced users who changed their activity affected by the application. Moreover, we investigate the effectiveness of each functions and confirm the assumption.

4.1. Definition of the Content That Induces the User's Behavior Change in Discover TOYAMA

The user's behavior change by the Discover TOYAMA means that the user actually visits the sightseeing spots which is not include in the travel plan after browsing the contents of the application. Therefore, Discover TOYAMA necessary to recommend the content of sightseeing spot that not include in the user's travel plan in order to induce the user's behavior change. The recommended sightseeing spots are selected based on questionnaire described before.

Based on the above, the contents that induce the user's behavior change in Discover TOYAMA should meet the following condition 1 to 3.

1. The contents of the sightseeing spots that are not included in the travel plan
2. The user browses the contents meets condition 1
3. Visit the sightseeing spot meets condition 1, 2

4.2. Recommend Spots List

Recommend Spots List recommends sightseeing spot which is not included the travel plan input by the user. Therefore, the Recommend Spots satisfy condition 1.

For checking condition 3, we should obtain users location to confirm whether the user visited sightseeing spots by Discover TOYAMA's GPS function.

Next, we obtained the Recommend Spots of all user's Discover TOYAMA, and we examined the number of users who visited the Recommend Spots. The result is shown in Table 1.

Visited Users was defined as the number of users who visited Recommend Spots. In addition, Not Visit Users was defined as the number of users who did not visit Recommend Spots even spots are shown in application. In addition, Rate was defined as the ratio of Visited Users in the sum of total users.

Table 1. The number of users who visited Recommend Spots.

Visited Users	Not Visit Users	Rate
15	1222	1.21%

4.3. *Child App List*

Currently, the number of Child App is not so many as they do not fit in the top screen. Therefore, Child App List shows all contents of the sightseeing spot that even if the spot includes the user's travel plan.

Next, we can obtain the number of activation for Child App from the each user's operation log. The activation means that the user browses the relevant sightseeing spot.

For checking condition 3, we obtained the user who visited the sightseeing spot by Discover TOYAMA's GPS function after activating Child App. The result is shown in Table 2.

Visited Users was defined as the number of users who visited the sightseeing spots after activating Child App. In addition, Not Visit Users was defined as the number of users who did not visit the sightseeing spots after activating Child App. Moreover, Rate was defined as the ratio of Visited Users in the total number of users who activate of any Child App.

Table 2. users who visited the sightseeing spot of Child App after activating Child App.

Visited Users	Not Visit Users	Rate
146	261	35.87%

4.4. *Child App List for Different User's Attribute*

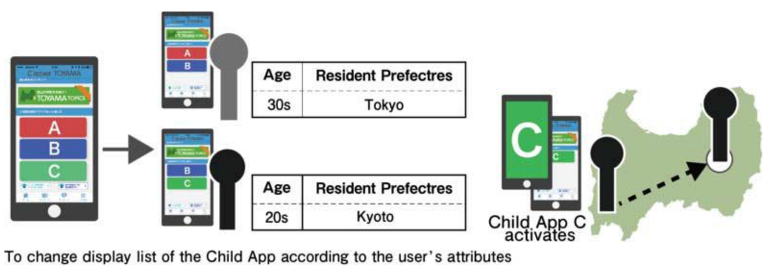

Figure 3. Child App List focusing on the inducing the behavior change.

As shown in Tables 1 and 2, the ratio users who induced the behavior change by Child App was larger than the ratio users who induced the behavior change by the Recommend Spots List. It is cause that ease to induce the user's behavior change depends on the degree of detail about presented information. Therefore, in this study, we focused on Child App List. In addition, we clarify that the user's attributes are correlated with induce the behavior change by Child App.

Next, we assume that the tendency of Child App to induce activity changes differs depends on the user's attributes. In Figure 3, there are two users who have different attributes of residence and age. Therefore, it causes different tendency of Child App to induce for each user. In this case, Discover TOYAMA may change that Child App List depends on the difference of the tendency. For example, the tendency of Child App A and B to induce above users is relatively high, and the application preferentially shows only the two applications on the top screen.

To realize above application facilities, we clarify a type of user's attributes that mainly affect tendency of Child App which induced the behavior change.

5. Results

Table 3. Child Apps on Discover TOYAMA.

Child App's name	Sightseeing spot	Description
tulip app	Tonami Tulip Gallery	This application introduces the Tulip Fair in Tonami city. This application has view of stamp rally and view of model courses.
mikuruma app	Takaoka Mikurumayama Museum	This application introduces the festival in Takaoka city. This application has view of map.
jouhana app	Johana Shinmeigu	This application introduces the Johana Hikiyama Matsuri Festival in Nanto city. This application has view of map.
tkk app	Tateyama Kurobe Alpine Route	This application introduces the Alpine Route. There is wall of snow in Alpine Route.

We describe how to obtain the user's attributes that induce the behavior changes by each Child App. In this study, we focused on four Child Apps that are the tulip app, mikuruma app, jouhana app and tkk app. Those Child App's description is shown in Table 3. Discover TOYAMA obtained the user's 18 attributes by Web questionnaire. Among them, we focused on three questions that are the resident prefectures, gender and age. We can analyze that induced the behavior change by each Child App using obtaining these attributes. In addition, we clarify whether it is different that inducement the behavior change each Child App by analyzing of user's attributes. Next, we clarify whether the items of each attribute shown in the Tables 4 to 6 have significant different characteristics between Child Apps. We analyzed using the Chi-square test [3,4]. The Chi-square test is a verification method using chi-square distribution. In this study, we determined that this tests statistic is significant at the 0.1 significance level. As a result, we clarified the statistically significant relationship exists that is correlated with the resident prefectures and age for each Child App. In addition, we clarified the statistically significant relationship exists that each Child App is correlated with the age. On the other hand, we did not clarify the significant characteristic exists that is correlated with the gender for each Child App.

Table 4. In the resident prefectures, the number of users who induced behavior change by each Child App.

	Hokkaido	Iwate	Miyagi	Fukushima	Chiba	Tokyo	Kanagawa
tulip app	0	1	0	1	1	0	0
mikuruma app	1	0	0	0	0	2	1
jouhana app	0	0	0	1	0	0	0
tkk app	0	1	0	1	1	0	0
	Toyama	Ishikawa	Nagano	Shizuoka	Aichi	Kyoto	Total
tulip app	11	0	0	1	2	2	19
mikuruma app	22	1	0	0	0	0	27
jouhana app	5	0	2	0	0	0	8
tkk app	5	0	0	0	0	1	9

Table 5. In the gender, the number of users who induced behavior change by each Child App.

	Male	Female	Total
tulip app	13	6	19
mikuruma app	21	6	27
jouhana app	6	2	8
tkk app	8	1	9

Table 6. In the age, the number of users who induced behavior change by each Child App.

	Under 20s	20s	30s	40s	50s	60s	70s	Total
tulip app	2	5	2	5	5	0	0	19
mikuruma app	0	3	2	8	7	5	2	27
jouhana app	0	0	2	4	2	0	0	8
tkk app	0	0	1	2	6	0	0	9

6. Conclusions

In this paper, we clarified that the influence of Child App could be different depending on user's attributes. As a result, we clarified the statistically significant relationship between Child App and specific attributes that are resident prefectures and age. Therefore, we considered that we can realize the Child App List focused on the inducement the behavior change shown in the Fig. 3. However, there were not enough data to obtain sufficient results. Thus, in the future, continuous examination of this study would more clarify Child App is correlated with the user's attributes. Child App is expected to continue to increase, because we will be developing some Child App. Moreover, we will find out some the condition that induce the behavior change by many data and various Child Apps. In the next, we incorporate the system using these conditions into Discover TOYAMA in order to experiment to induce the user's behavior change. In addition, we will advance study on another method that induce the user's behavior change.

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A Proposal of IoT System for Small and Medium Factories in Japanese Manufacturing Industry

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Abstract. Recently, IoT (Internet of Things) technology has been attracting considerable attention, and it is utilized in various fields. Especially, IoT of the manufacturing industry is considered to lead to high productivity, quality improvement, and energy efficiency improvement. Some governments support manufacturing industries to introduce IoT nationwide. However, introductions in Japanese manufacturing industry are not well developed. In addition, SMEs (Small and Medium Enterprises) have the majority in Japanese manufacturing industry. Thus, SMEs' IoT investment is small and introduction of IoT in this field is not progressing. In this study, we propose an IoT system that is relatively inexpensive and visualizes the production process. We have developed the introduction system with low cost by different ideas. Moreover, we actually set up this system in the factory and evaluated this system. As a result, we could confirm the usefulness of this system.

Keywords. IoT, manufacturing industry, Small and Medium enterprises

1. Introduction

Recently, IoT (Internet of Things) technology which connects various physical things to the Internet has been attracting considerable attention. We are able to collect the real-world data with the spread of IoT. In addition, we are able to analyze the collected data and give feedback to the real world. Therefore, we consider introductions of IoT benefit in various fields. Especially, the expectation toward IoT is increasing in the manufacturing industry. It is because that IoT of the industry is considered to lead to high productivity, quality improvement, and energy efficiency. For example, Germany is implementing a national project called Industry 4.0 [1] which aims at automating production, reducing production costs, and improving productivity by visualizing the production process. The United States is also implementing the national policies of IoT [2]. On the other hand, the introductions of IoT in the industry are not developed in Japan. In particular, the introduction rate of IoT in SMEs (Small and Medium Enterprises) is extremely low. Therefore, in this study, we conducted the fieldwork at SMEs in Toyama Prefecture for the purpose of investigating the introduction situation of IoT in Japanese SMSs' manufacturing industry.

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We implemented the fieldwork in the company which was one of the top manufacturers of electronic components. It has factories which manufacture electronic parts used for mobile phones and personal computers. We found three issues of the introduction of IoT and how to utilize IoT. Firstly, it is difficult for the company to invest the IoT system, because the average of IT investment amount is 0.2 to 0.3% of the annual sales. Therefore, the company cannot introduce the high cost IoT system. Secondly, the employees at the factory desire to visualize the operating state of the machines that produce the electronic components and the total operating time of the machines in a day at the factory. If they can estimate the total operating time, they can calculate the production volume of parts to grasp the approximate production volume without counting the parts. To visualize them will be a help to adjust the production volume. Finally, they desired to visualize the panels that express the machine's state attached to the machine. In many Japanese factories producing products, they have panels attached to the side of the machine like those in Figure 1. Employees use multiple panels to show the machine's state and the causes of troubles to others. They can always grasp the detailed machine's state throughout the factory by checking the state of the panel.

However, the cost of attaching the sensor is about 50,000 yen per a machine, and there are about 80 machines in the factory. Thus, we must introduce IoT in the new method to reduce the introduction cost.

Based on the above, the purpose of this study is to design a system that reduces the introduction cost, senses the operating state and machine's detailed information (panel state), and visualizes it by using a Web application. In addition, this high versatile system is not only used in a specific factory, but also in various factories as well.

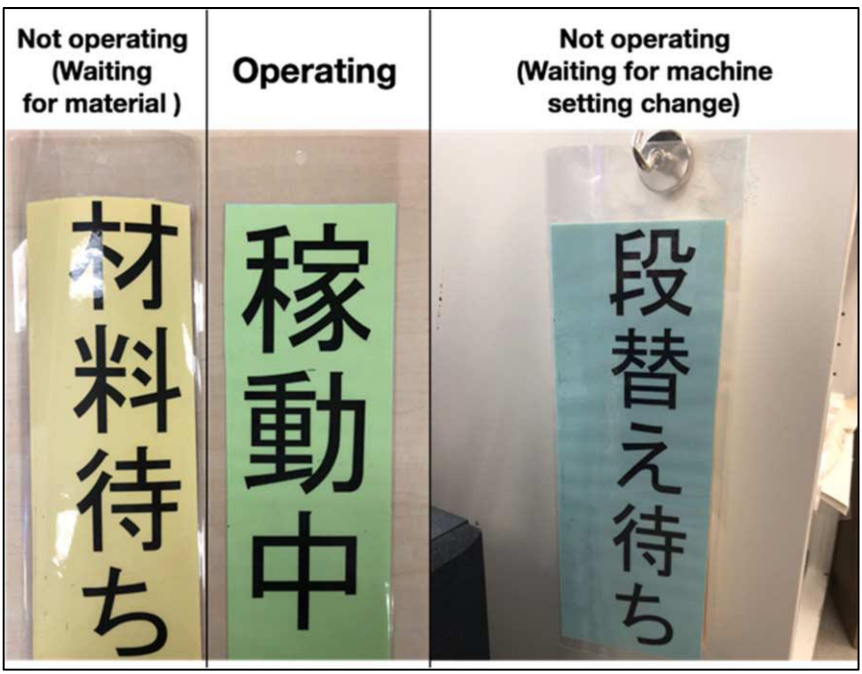

Figure 1. The panels showing the machine state

2. Proposed system

The previous chapter described about issues of introducing IoT to SMEs and the purpose of this study. In this chapter, we describe the proposal system. This system has three functions which sense the operating state of the machine and the panel state, record the sensed data to the database, and show the data by the Web application. Figure 2 shows the function of this system.

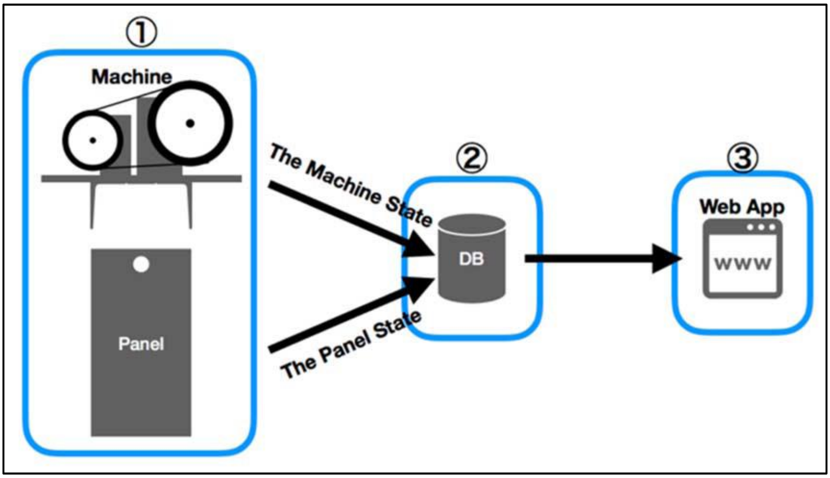

Figure 2. The function of this system

2.1. Operating state sensing

It is important to develop the device which can be used at any factory and machine when we develop it. The easiest way of estimating method for the machine's the operating state is the output of electric signal from machines. This method is reliable because the electric signal information has only 0 or 1.

The factory can sense the machine's operation by the above method if they ask a maker of the machine. However, they need to change the maker that they ask and it is burden for them because all machines in the factory are not manufactured by the same maker. In addition, it is expensive to ask the maker for it. Therefore, we need to produce inexpensive and versatile device. We focus on the vibration of the machine because we found that the operating machine was vibrating through the fieldwork. Thus, we obtain the machine's oscillating data by using the acceleration sensor, and estimate the operating state from the machine's oscillations.

2.2. Panel state sensing

Even if the machine state can be automatically obtained by the sensors, we cannot know the machine status from the data. Therefore, the panels have been used to show the status in the factory. We can use the buttons and displays to handle the information or the internet system to collecting data; however, the cost of this system increases for the extra items. Moreover, the employees must change their conventional work process by introducing this system. Therefore, we produced the device with an electronic circuit which senses the type of panel at the forefront instead of using extra items such as displays and buttons so that employees can indicate the machine's state without changing the conventional work process.

3. Implementation

This chapter describes the implementation of this system. The system consists of three components: sensing and transmission for the data, storing data in the cloud, and showing the data by Web application. Figure 3 shows the overall figure of the system.

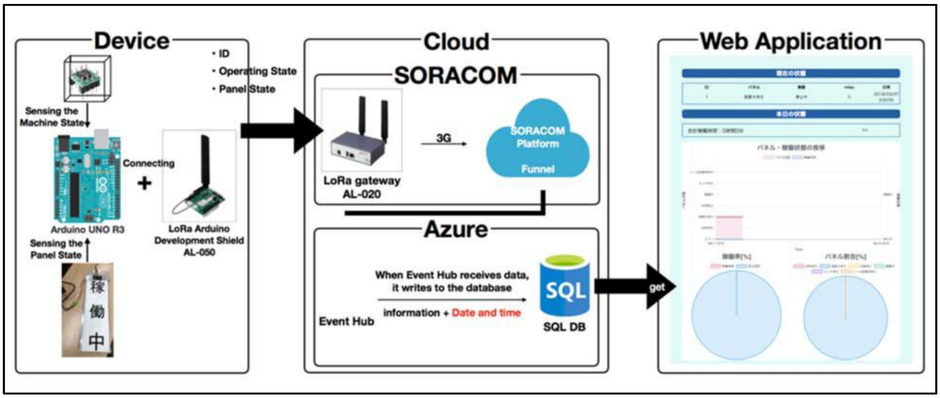

Figure 3. Overall figure of the system

3.1. Device

This device has three functions. The first function is to estimate the operation states (operation / non-operation) from oscillations of the machine. The second function is to sense the panel's state (operating / reason for not operating) by the added electric circuit of the panels. The third function is to transmit the operating state and panel's state to the cloud.

We use 3-axis acceleration sensor module (KXR 94 - 2050) to sense the oscillations of the machine.

In addition, we produced the panel with an electronic circuit by pasting the irons plate. Figure 4 shows the created panels in this study. There are 6 panels that are used in the factory of the fieldwork.

The device can estimate the machine state and panel state using Arduino Uno R3. Moreover, this device transmits information using SORACOM Service (SORACOM Air for LoRaWAN). In addition, this device is connecting ABIT's LoRa Arduino Development Shield (AL-050). This device transmits the ID for identifying the device, the operating state and the panel state every 5 minutes.

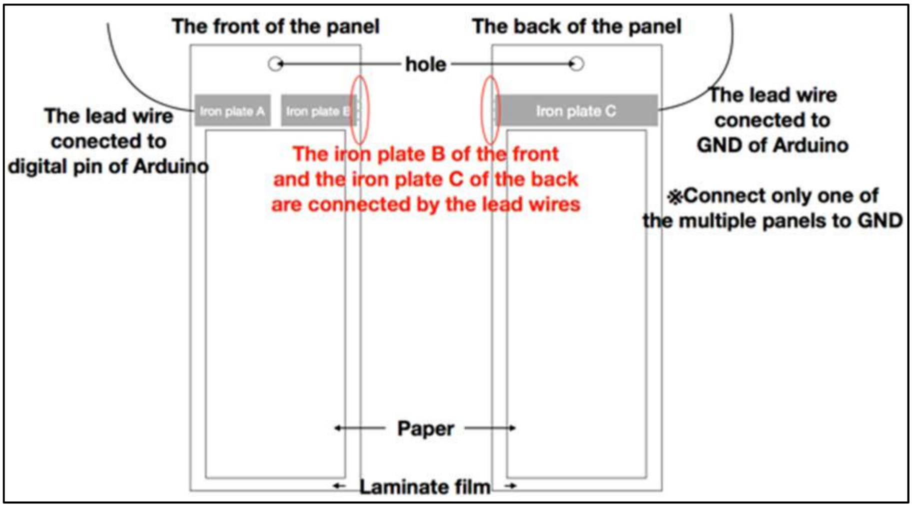

Figure 4. The panel produced in this study

3.2. Cloud

This system has the function that transmits the data to the cloud and records it to the database. We placed ABIT's LoRa gateway (AL - 020) of the receiving terminal in the factory. The LoRa gateway transmits the received data to the cloud (SORACOM platform) using the 3G network.

Next, Soracom platform sends the data to Microsoft's Event Hubs of Azure using the cloud resource adaptor called Soracom Funnel. The data is processed by Event Hubs and stored in Azure's SQL server.

3.3. Web application

We have developed a Web application for viewing data of database. This Web application has two types of pages. The one is to show the arrangement plan of the machines in the factory. The other is to show the state of a specific machine (operating state and panel state) in detail. This Web application has a mechanism to shift to the detailed page by clicking the machine on the arrangement plan page. Figure 5 shows a detail page of Web application. This detail page shows the current state, the transition graph of the state, the total operating, the operating rate, and the rate of the panel for each day. The company will be always able to check the state of all the machines in the factory by this Web application.

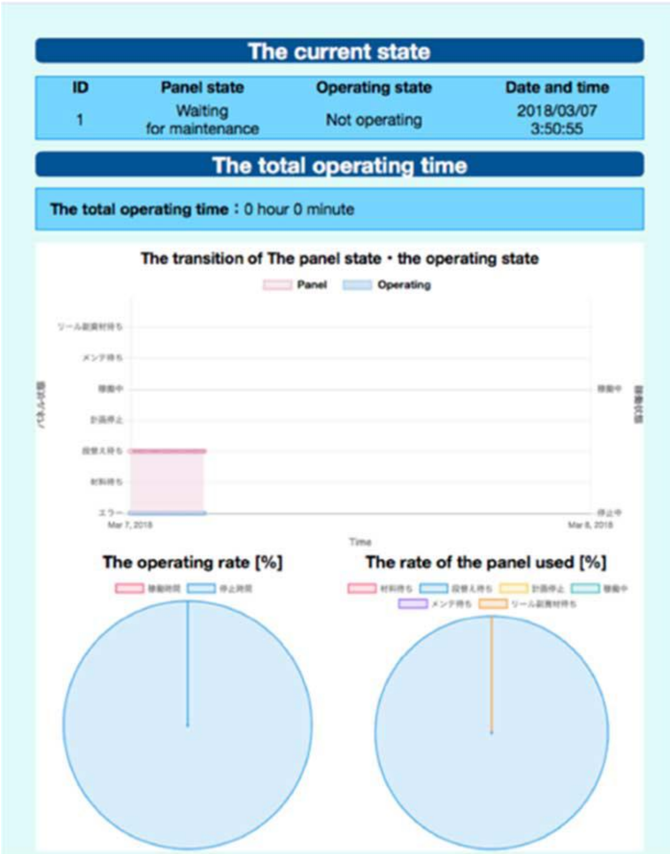

Figure 5. The detailed page of Web application

4. Basic experiment

As mentioned before, this system estimates the operating state (operating or not operating) by the oscillations of the machine using the acceleration sensor. In this section, we describe the algorithm to estimate the operating states. Firstly, we attached an acceleration sensor to the machine in order to obtain oscillating data. Then, we determined an algorithm to estimate the operating state from the acceleration data.

We attached an acceleration sensor stored in a plastic box of the machine. Then, we gathered the data for about 30 seconds using Arduino and stored the acceleration data to the SD card on Arduino. We gathered data of two patterns whether machine is operating or not.

4.1. Result

First, we focused on the cycle of the vibration. Figure 6 and 7 show the results of composite acceleration value from 3-axis acceleration and analyzing FFT (Fast Fourier

Transform). When we analyzed, the number of data was 1024 and the sampling rate was 56/sec. The Figure 6 shows the results of analysis of not operating machine. We concluded that the cause of the amplitude marked at 14 Hz was the influence by the vibrations from the whole factory. As the Figure 7, it shows a lot of amplitudes but no periodic cycle of machine's vibration. As the result, we cannot adopt FFT to analyze acceleration data to estimate operating state.

Second, we focus on the average of the acceleration value. Table 1 shows the composite acceleration average and its dispersion value when the machine is operating or not. As the Table 1shows that the average value in operating is larger than that of in not operating, and the dispersion value in operating is also larger than that of in not operating. In addition, the difference of the dispersion value is larger than the difference of the average value.

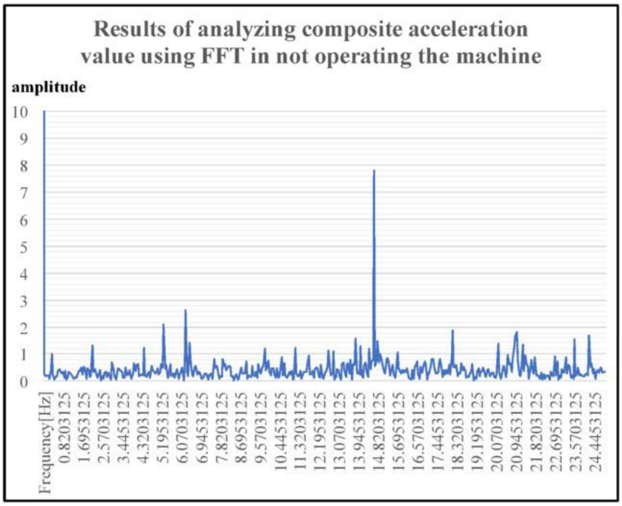

Figure 6. Results of analyzing using FFT in not operating the machine

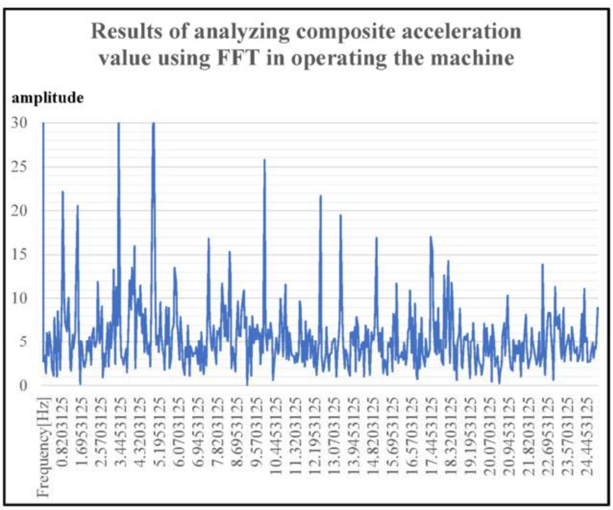

Figure 7. Results of analyzing using FFT in operating the machine

Table 1. The average and dispersion of the composite acceleration in operating and not operating.

	Operating	Not operating
Average value	783.9904207	777.2084574
Dispersion value	305.7046146	8.072090473

4.2. Estimation algorithm

Figure 8 shows a flowchart of an algorithm for estimating the operating state of the machine used in this study. This device obtains the vibration of the machine from the 3-axis acceleration sensor as acceleration data. Next, this device calculates the composite acceleration value from gather the data. This device calculates the dispersion value from the latest 100 composite acceleration values. Finally, this device estimate that the machine is operating when the calculated dispersion value is equal or over to the set threshold value. Moreover, it is necessary to adjust the threshold for each machine for its features. We set the threshold value to 200 in this study.

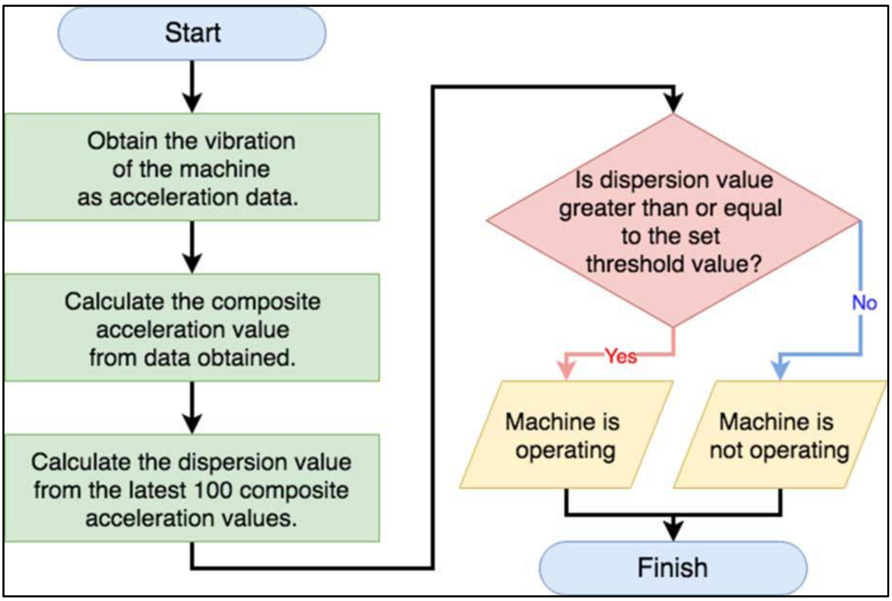

Figure 8. The flowchart of an algorithm for estimating the operating state of the machine

5. Evaluation

We evaluated the accuracy of this algorithm for estimating the operating state. In particular, we verified the difference between the actual operating time and estimated operating time stored in the database.

We attached this device at the machine and checked the operating state's correct data of the time at the factory. Next, we checked the operating state's data of the time in the database. Finally, we compared the actual data and the measurement data.

5.1. Result

The Figure 9 shows the transition of the actual operating state and the estimate operating state. As the Figure 9 indicates, the time lag occurred on this system. However, it can be said that this system estimated the operating state almost precisely.

The Table 2 shows the actual time and the time recorded in the database when the machine state changed. As the Table 2 indicates, the time recorded in the database was behind the actual time. We considered that there were two reasons. Firstly, the time information was added when the data transmitted to Event Hub. Therefore, there is the time lag between actual time of changing state and the Event Hub received the data's time. Secondly, the device calculated the dispersion value from the latest 100 composite acceleration values. Therefore, this device detects a change after a short time when the operating state changes.

As the Table 2 indicates, the time lag between the actual time and the estimated time of the status of starting the operation was wider than that of the status of stopping the operation. We considered that it is due to high threshold, and the calculated total operating time was shorter than the actual total operating time.

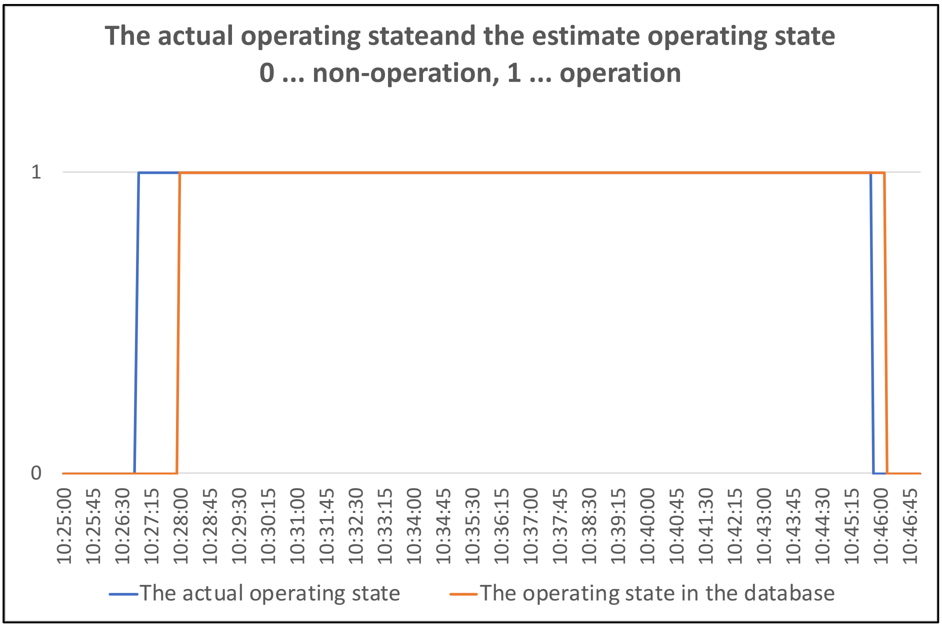

Figure 9. The transition of actual operating state and estimate operating state

Table 2. The actual time and the estimate time when the machine state changed

	Starting an operation	Stopping an operation
Actual time…1	10:26:52	10:45:46
Estimate time…2	10:27:57	10:46:07
Time lag (2-1)	65[s]	21[s]

6. Conclusion

In this study, we proposed the system that reduced introduction cost. In particular, we focused on producing the device

This device has two benefits. Firstly, the device estimates the operating state using the acceleration sensor. Moreover, this system has a high versatility. Secondly, this system does not change the work process of employees by using the same panels. In addition, this system is able to estimate the operating state almost precisely. However, total operating time is measured shorter than the actual one on the system. Therefore, we need further consideration to adjust the threshold value and the number of data held by Arduino.

We put 4 devices in the factory in this experiment. When we actually introduce this system to the factory, we need to put hundreds of devices. Therefore, it is necessary to evaluate this system in an environment where hundreds of devices are put.

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Revival of the Neural Networks and the Intellectual Property Nightmare

Shubham RATHI [1]

Abstract. With the 'third wave' of Artificial Intelligence, there is a massive revival and upsurge in AI related product development. An important entity behind the AI architecture, the neural network needs to be studied carefully that adequate protection for its innovation can be secured. A key feature of a Neural Network, the Neural weights hold the inferential rules and knowledge, thus are a new way to embody knowledge and information, a new form of intellectual property to which IP laws will have to adapt. We present our discussion that sheds light on the nature of this innovation and brings to context why it is relevant to secure Intellectual Property for Neural Weights. We also rebase our arguments in the backdrop of the debates that were set off on this same topic in 1990. This paper traces the shape of this problem ever since its conception and brings to the fore the newer and expanded notions behind Neural Networks, AI and their place in the intellectual property laws.

Keywords. Artificial Intelligence, Copyright, Intellectual Property, Neural Networks, Neural Weights.

1. Introduction

The discussions around Artificial Intelligence (AI) and its tremendous impact are not new. Since almost a decade now, AI is producing output that is novel and ingenious. As this field continues to get further mainstream, as with any new technology, a lot of legal challenges are expected. For AI though, these challenges are not new. With the advent of mainstream AI in 1990s, there were massive discussions about the legal, especially the Intellectual property aspects of this radical technology by scientists, professors and legal experts. Since technology has a tendency to develop at a rate superior to the law [1], this paper takes the stride to create the technological context required for policy makers to understand and evolve the current law to fit into new dimensions that AI is evolving into. In this paper, we bring to the fore the intellectual property aspects (copyright) of Artificial Intelligence (Neural Networks) building on the discussions recorded over the last 30 years. In Section 2, we speak of the brief timeline of AI connecting it to the resurgence in this topic. In Section 3, we talk about the relevance of this discussion in the context of AI technologies that will soon beget the questions we seek to raise. Section 4, collects and builds on the arguments raised in 1990s by thinkers on the then Intellectual property aspects of Neural Networks. We base this section in the fundamental ideas of AI that are unchanged while focusing on the nitty-gritty of tech law and newer AI innovations that

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are in constant evolution. Section 5 discusses possible methods of detecting copyright infringement in Neural Networks and Section 6 concludes by throwing light on the larger inspiration of this paper, if machines are capable of ‘thinking’ and their legal standing.

1.1. What are Neural Networks?

The term ‘Neural’ is derived from the human (animal) nervous system’s basic functional unit ‘neuron’ which are present in the brain and other parts of the human (animal) body. (Artificial) Neural Network, in general is a biologically inspired network of artificial neurons configured to perform specific tasks that traditionally can be thought as exhibiting reason. Computationally spoken, Artificial neural networks can be viewed as weighted directed graphs in which artificial neurons are nodes and directed edges with weights as connections between neuron outputs and neuron inputs [2]. The Neural Network technology is not new but has recently seen a technological uprise with the advent of Deep Learning. Neural Networks are different from computer programs by virtue of their learning style (by feeding it data), they are capable of inventive output.

1.2. What is the issue?

Since neural networks are different from conventional computer programs, there is some uncertainty about the application of intellectual property laws. One issue is the copyrightability of the set of weights: do the weights satisfy the Copyright Act’s definition of a computer program and if the set of weights be said to be a work of authorship? One could argue that the network, and not a human, actually authors the weights. However, the network could also be regarded simply as a tool used by a human author, where the author chooses the data and presents it to the network. There is a confusion on how much of a Neural Network is a tool and how much is it an innovator. While humans have to be necessarily involved in the creation process but that should not make the human as its inventor. Example, If a computer scientist creates an AI to autonomously develop useful information and the AI creates a novel result in an area not foreseen by the inventor, there would be no reason for the scientist to qualify as an inventor on the AI’s result. An inventor must have formed a ‘definite and permanent idea of the complete and operative invention’ to establish conception of the result. The scientist might have a claim to inventorship if he developed the AI to solve a particular problem, and it was foreseeable that the AI would produce a particular result [22]. Spoken precisely, if a neural network is producing output not fed to it during training and non-obvious to a person skilled in the art, which is the Neural Network is producing results outside of its domain, it ought to be considered as an innovator and not a tool. An example of this phenomenon, Alphago Zero is discussed in Section 3.2

Some aspects of Neural Network protection are well studied and caught up with law. It is widely accepted that to protect a net we need to protect three things: (i) the pattern of interconnectivity among the units, (ii) the weights on those connections, and (iii) the input and output categories, i.e., the labels that tell us what kind of numbers to put into each input [5]. The pattern of interconnectivity (the neural architecture) is rightly protected by Patents. There is little or no clarity on how the Neural Weights and the labels must be protected or whether to protect them or not since Neural weights are machine’s way of embodying knowledge, a feature that the law still needs to adapt. Arguably, a machine, and not a human being, actually authors the weights in a neural network, since the human operator merely feeds data into the machine and does not know what weights (the substance behind the invention) will result after the training [6].In the context of neural networks, defining the invention is made even more difficult because of the changing nature of the invention [6] due to constant learning and updation. Since a great deal of effort may go into acquiring data and training a net, the numeric value and sequence of the weights may have considerable value, and, as a result, may be subject to unauthorized copying. The enormous investment that one might make to acquire and process data, and then to use this data to train a neural network, is all reduced to one set of easily copied weights. Accordingly, protection against theft of this valuable property is essential. This issue became quite a rage during the second wave of AI (1990s) and incited a flurry of publications and discussions around this same topic. This topic took a back foot in the later years when the second wave subsided and eventually was lost in history. Now, with the third wave of AI development, this topic is more relevant than ever before. Today we not only have Neural Networks, but its evolved version: Hierarchical Neural Networks. The role of the human has been pushed even further aback in the development stack. In 2014, Google researchers were able to demonstrate that Turing complete languages were possible using Neural Networks [17]. This research paved way for think-tanking Software 2.0, the next gen framework for writing programs composed of Neural Network weights. Microsoft is doing active work in Neural Program Synthesis where neural networks learn to synthesize programs. Naturally, the conventional copyright laws will come into question when the expression of software is not a programming language but Neural Weights. Over the years, the complexity of this issue has only become more dense. Through this paper, we hope to revive this discussion that has remained dormant for 28 years in the relevant limelight of use cases today.

2. Resurgence in the topic

The World Intellectual Property Organization (WIPO) organized a Worldwide Symposium on the Intellectual Property Aspects of Artificial Intelligence in 1990 where the problematic nature of intellectual property laws for AI were discussed. In 1990 again, Lawyers wrote eloquently about the challenges posed by Neural Networks in the Intellectual Property Framework. There is very little literature relevant to this topic in the later years. The legal domain still seems to be riddled with a lot of problems spoken earlier. A peek at the historical timeline of AI connotes that this lag was because of the pace of technology. On seeing the timeline of AI and the progress of Neural Network research, it becomes evident that this downturn was because the technology had not caught up with the problems that were hypothetically posed in 1990. AI was starved of training data and what training data existed demonstrated that, depending on the architecture of the Neural Network, there would be some Neural Networks that could not be trained. Which is, the fate of Neural Networks and the problems hypothesized were not pertinent anymore.

2.1. Breakthrough Caused by Deep Learning

The application of 'Deep Learning' in neural networks was a big break through that allowed the subject to move forward. Deep Learning is a type of Machine learning that allows a program to improve with more exposure to data and experience. As evident, the lack of quality data was a huge bottleneck in the growth of Machine Learning via the Deep Learning approach.

There have been three waves of development in the deep learning history: Deep learning known as cybernetics in the 1940s–1960s, deep learning known as connectionism in the 1980s–1990s, and the current resurgence under the name deep learning beginning in 2006 [8]. Major literature around the legal issues on the topic also emanated with these waves.

The second wave of neural networks research lasted until the mid-1990s. Funding for AI based start ups started withering when the products made were sub-par. Simultaneously, other fields of machine learning made advances [8]. In mid 1990s, deep networks were generally believed to be very difficult to train. We now know that algorithms that have existed since the 1980s work quite well, but this was not apparent circa 2006. The issue was perhaps simply that the algorithms were too computationally costly (solved by increasing model and dataset size) to allow much experimentation with the hardware available at the time [8]. This third wave of popularity of neural networks continues to the time of this writing, though the focus of deep learning research has changed dramatically within the time of this wave [8]. It is most pertinent that the legal and scientific community builds on top of the problems our predecessors of the second wave unearthed while we brainstorm and resolve the newer challenges the fast changing technology landscape poses to us.

3. Technology Landscape

As with any computer generated invention, there is often a caveat that the invention is actually computer 'assisted', to say: the role of the computer is limited to that of a tooling. This was perhaps true until a few years ago when parameters, data and even training was manual. Referring about Neural Networks, Andrej Karpathy, director of AI at Tesla goes on to state "I sometimes see people refer to neural networks as just 'another tool in your machine learning toolbox' .. Unfortunately, this interpretation completely misses the forest for the trees." [9] Neural Networks have transcended their roles as tools. They are increasingly applied in domains beyond computer science, in arts and music - domains which are classically referred to requiring creativity. Works derived out of deep creations (neural networks) are even of artistic value and so further the cause of IP protection. Neural Networks have also forayed into Software. Source code currently is protected as a literary expression under copyright. As the domain of Software Engineering evolves, we expect to see a shift in the way we write software as we transition into 'Software 2.0' where Software expression may not be literal after all. We need to encompass this change in the current Intellectual Property framework by revisiting the legal stance on copyrightability of Neural Weights.

3.1. Software 2.0

Andrej Karpathy popularized the idea of Software 2.0. Software 1.0 is the classical stack of software development as we are familiar with, written in various programming languages having basic programming operations: input, output, arithmetic, conditional, and looping. As Andrej envisions, In contrast, Software 2.0 is written in neural network weights [9] without human intervention. Andrej mentions this as an ongoing progress in many domains: Visual Recognition, Speech Synthesis and recognition, Machine Translation, Games, Robotics and Databases. How soon or how late we are to deal with IP issues around these domains remains a speculation. Although, what seems certain is that sooner than later, the role of neural weights and the nature of IP afforded to them will have to be rethought. If the Software 1.0 written in programming languages is allowed Software copyright, do we also anticipate that its successor, written in neural weights (collection of numbers) is also capable of receiving the same perk? The answer to this seems Yes and No. The copyright law protects works "expressed in words, number, or other verbal or numerical symbols or indicia, regardless of the nature of the material objects . . . in which they are embodied Law"[18]. Which is to say that the manner of expression does not affect the copyrightability and thus protection should also extend to Neural Weights. Problems may arise when determining the Structure, Sequence and Operation (SSO) aspect of the work since Neural Weights are amorphous set of numbers that until juxtaposed on a specific neural network will mean nothing. Infact, even its developers may not be certain of its sequence or structure. For cases such as these, the existing legal regime is still to proactively think and respond to these paradoxes ever since they were was first thrown up in 1990. With the advent of Software 2.0, these questions have renewed relevance.

3.2. Alphago Zero

Intellectual Property is conferred for products that have artistic value or embody new knowledge/ creation. Software 2.0 seeks copyright for Neural Nets on the basis that they are an evolved version of the current Software regime. We can also argue that Neural weights are also in fact new knowledge. Alphago Zero is a classic example of knowledge that is harvested, learnt and applied independently by an AI system. AlphaGo Zero (AGZ), is the successor to AlphaGo, the first AI program to defeat a world champion at the ancient Chinese game of Go. Go is an ancient abstract strategy board game for two players popular in Asia. Though trivial at rules, this game is leaps and bounds more intricate than chess. Compared to chess, Go has both a larger board with more scope for play and longer games and many more alternatives to consider per move [19]. The complexity of Go is astronomical so much that number of possible moves exceeds the number of atoms in the universe [19]. AGZ may be said to be the first computer invention that in true sense fulfills the 'sweat of the brow' doctrine as unlike Alphago or even IBM's Deepmind, AGZ infers the Go rules by playing games against itself and decides on a winning strategy (self-play reinforcement learning). AGZ is not bounded by the existing knowledge/ rules of Go players. The known strategies of Go are referred to by names in language. It is hypothesized that strategies discovered by AGZ are beyond the limits of human language to express the compounded concepts [21]. This learnt language is devoid of any historical baggage that it may have accumulated over the centuries of Go study. As David Silver, of DeepMind puts it "Its more powerful than previous approaches because by not using human data, or human expertise in any fashion, we've removed the constraints of human knowledge and it is able to create knowledge itself" [20]. This 'knowledge' is in fact complex game play strategy held in the Neural Network weights. The connections that AGZ derived is knowledge, and not information simply because prior to it, it was unknown to even the best Go players. Interesting to note here is that AGZ not only authors great strategies, but also the base training data underneath it. Simply said, Neural Networks in this particular case not only learns to connect the dots, they create the dots too and thus plead the case for copyright, again. Neural Weights for a program like AGZ are extremely valuable for the resources needed to derive them, and then for their utility. Outside the Go game, the Deepmind team is applying AGZ methods for varied problems like Protein folding [11]. If this research moves forward, soon AGZ trained Neural Weights may embody intricate knowledge about the protein biology which could be of use in cancer research.

3.3. AutoML

Google's Machine Learning platform, AutoML is a hierarchical neural network architecture that automates the process of manually designing machine learning models. In lay mans terms, this technology lets an AI build AI. As AutoML gets more mainstream and generic, the source behind the Master Neural Net's efficacy (its Neural Weights) shall be of vast value. If coupled with Software 2.0, this technology shall be among the first to demand, and then monetize its copyright over the Neural Weights.

4. Questions Raised

As discussed in the previous section, there are two forms of copyright protection that we could claim behind a neural weight. First, the software copyright that is applicable to protection and distribution of software code. Second, the intricate knowledge that the system has discovered and needs to be protected. For the latter, the most pressing question for copyrights behind Neural Weights is, if the law can recognize the intellectual creativity behind a series of apparently random numbers that not even the neural network's creator can recognize? The author opines that the law does not need to 'recognize' the creativity but rather interpret it. When the copyright office reviews a software copyright application for a source code, the jury does not dissect the code per instruction to hold up if the code genuinely does what it claims to do. The copyright application drafted in carefully worded techno-legal language helps the jury make a decision on the application. As long as the result is an original work of authorship, the copyright criteria is met. It is the inventors task here to recognize the originality and then interpret it for the application process. Similarly for the case of Neural Weights, as long as the inventor is able to establish originality of the neural weight forms, the copyright process should not be any different.

4.1. Knowledge-Information Paradigm in Neural Networks

In WIPO's 1990 symposium, Prof Thorne McCarty made a compelling example and deduction as to how knowledge was arrived at in Neural Nets. When learning the lexical disambiguation from the Brown Corpus [2], task was to construct a set of rules that will correctly classify the words in the tagged text. This task was given to a human annotator

[2]500 naturally occurring passages tagged by hand such that every word in the text is classified in a lexical category.

and then to a Neural Network. The error rate with human was found to be 30% and the Network at 3.5%. The reason for machines superior performance was because the network internally made 12,000 rules against the 350 made by the human. Prof. McCarty notes, “From the point of view of intellectual property law, what is the valuable intellectual product here? Surely, it is 12,000 lexical disambiguation rules .. The ‘knowledge’, here is simply represented by a pattern of weights in the network” [14]. This statement provokes us to also ponder whether this byproduct of the neural network is knowledge or is it information? Knowledge is protected via various IPs, information on the other hand information being mere facts, is not protected. This question can perhaps be reduced to investigating if any kind of mental process or ‘thinking’ went behind unearthing it. The problem of speaking precisely about thought with regards to computers was identified by Alan Turing, one of the founders of computer science, who in 1950 considered the question, “Can machines think?” He found the question to be ambiguous, and the term ‘think’ to be unscientific in its colloquial usage. Turing decided the better question to address was whether an individual could tell the difference between responses from a computer and an individual; rather than asking whether machines ’think,’ he asked whether machines could perform in the same manner as thinking entities [22]. The Neural Network certainly does not have a mind of its own to ‘think’ these extra rules. But its result is a product of machine thinking better known as representational learning. Prof McCarty states “Intelligent agents construct internal representations of the external world, and they process these representations in various ways to achieve their goals”. Which is, for any given problem, an AI agent transforms its problem to a set of features and abstracts pattern collection, connections and thus distills knowledge which human perspective to the problem could not have achieved earlier. This byproduct hence is not mere collection of facts (information) but representational awareness or machine thinking imbibed by a network.

4.2. *Dimensions of the current law*

One major hurdles when copyrighting neural weights is that material from a non-human entity is not copyrightable. Section 313.2 of the U.S Copyright compendiu adds that ‘The (copyright) office will not register works produced by a machine or mere mechanical process that operates randomly or automatically without any creative input or intervention from a human author’[18]. It is held here that the process is not merely mechanical (not a byproduct of only trial and error) and certainly not random. They are carefully arrived at after intensely orchestrated feature extraction and pruning.

We also need to evaluate if neural networks fall within the Copyright Act’s definition of a computer program “a set of statements or instructions to be used directly or indirectly in a computer to bring about a certain result”? Does this definition adequately describe neural weights? They are certainly not “statements” in the conventional sense of the word, nor do they appear to be “instructions” both terms imply some form of sequential execution or interpretation of individual elements. Neural weights, on the other hand, cannot be taken individually; they must be taken in their entirety and, although the correct functioning of the neural network depends to a great degree on their sequence, it is not possible to predict the order in which individual weights are used [3]. Thus the SSO doctrine (Sequence, Structure, Organization) is brought into question. We can draw an analogy to the traditional software: the same way that normal software exists in two forms, the human-readable source code and the machine-executable object code, it can be argued that the training facts are analogous to source code, while the resulting neural weights are analogous to object code. One must then contemplate the mysterious and irreversible process that connects this particular "source code" to its "object code".

Perhaps neural weights are little more than mere facts and data albeit in some arcane representational form that defies human perception. Should this then place them outside the protection of copyright law, notwithstanding their originality or the intellectual creativity needed to derive them? [3]

4.3. Neural Weights: Databases or Byte Code

We can consider Neural weights to be akin to a compilation and hence protectable as a database, or it can also be likened to Byte Code and thus considered as "object code". It could be argued, in countries like USA where databases are not protectable under copyright law, that these Neural Weights are just data. They are data only in the same way that a program written in the Java language is data, to bring Java code to life, a Java Virtual Machine 'interprets' each numeric "instruction". Thus we arrive at another conundrum: If the Neural Weights are just numbers, and Java bytecodes are just numbers, then why should Java bytecodes receive copyright protection but not Neural Weights? Both control software-implemented machine behavior. This is a logical fallacy in the law that must be addressed. There is a conceptual issue that arises repeatedly that is best expressed by the question: What is the difference between data and executable code? The answer is: it all depends on what the computer is doing with the information. For example: if a computer stores a binary file on a disk, then it's just data. If it loads that file into RAM, then it's just data. But if the contents of that file is used to control the data processing actions of the computer, then it becomes executable code (either being executed directly by the CPU or interpreted by some other software like a JVM or BASIC interpreter). Hence we arrive at the conundrum, Should weights be considered Databases (compilation of works, data or a collection of other materials arranged in a systematic or methodical way) or Byte Code (form of instruction set designed for efficient execution by a software interpreter)? Weights are most analogous to Byte Code. It is the 'instruction set' for a Neural Network but definition of Databases maps most closely to it. So it is an argument between function and form. The function of a Neural Weight is most analogous to the Byte Code but its form is most analogous to Databases. The law has to adapt to understand this conceptual shift in which we present the role of Neural Weights.

5. Enforcement Hurdles for Neural Weight Copyrights

Besides the fact that copyright for Neural Weights is far ahead of the notion that law has kept pace with and that a human inventor is necessary, there are enforcement hurdles that need to be brought to the fore. Chiefly, how does one detect and prove copyright violation? One simple answer is already well known: we could easily employ the map-maker's trick of inserting false information into the program. As road maps often carry non-existent streets, so neural nets could be trained to display the initials of the original author when given an obscure or otherwise innocuous set of inputs. Behavior like this from a competing net would give compelling evidence against independent creation [5].

However, this only prevents other people from copying the network. If another group turns out to be working independently on the same problem at the same time, the copyright obtained by the group which succeeds first has no effect on the other group, unless that other group actually copies what the first group has done.

Copyright prevents only literal copying of the network or a part of it. Although copyright is infringed by someone who copies chunks of a copyright program, it is not infringed by anyone who copies only the underlying principles or ideas to build their own version. For instance, changes of perhaps 10% seem to have little effect on the performance of the net. In view of that, protecting the exact weights is insufficient. If small variations on the initial set of weights doesn't degrade performance, how might we protect against someone who copies the original set, varies them randomly by a few percent, then claims independent creation? [5] A possible solution to this would perhaps be to embed the creators identity in the Neural Networks. A digital watermarking technology to detect intellectual property infringement of trained models was proposed in 2017 [13]. Another less intrusive plan might involve a sui generis specialized version of copyright protection for trained neural networks, perhaps one that would include the idea involved as well as its expression. Such a copyright might have a relatively short duration, say, five years. In that way, a developer could have a limited franchise for a new product without totally squelching progress [7]. It is even possible that in the future, when neural networks become so large and complex as to display reasoning powers, creativeness, and even personalities, the law will be amended to recognize them as artificial beings, in the nature of technological corporations, with separate rights and legal standing to enforce them.

6. Conclusion

This paper brings to the fore a valuable intellectual property (Neural Weights) that so far has little/ no protection. While the law takes its course in deciding the appropriate turn the policy must take, this phenomena also exposes the timeless question about the pet topic of IP scholars: how to treat output generated by an artificial intelligence. The concept of copyright dates back to the 15th century and even now most of the legal literature is derivative of the principles accepted then which did not imagine the notion of computers or their inventive output. The larger context of this paper places the question: Can computers think? (and hence create novelty) into the academic forum via the intellectual property mode. The result of this paper is intended to revive the dialogue for the need of copyrights for Neural Weights and subtly also add to the chorus of legal and scientific literature that discusses the legal status of such innovations.

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Governing Data Trade in Intelligent Environments: A Taxonomy of Possible Regulatory Regimes Between Property and Access Rights

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Abstract. Companies have been analyzing data from their own customer interactions on a smaller scale for many years. But only recently, they understood the potential treasure trove of non-traditional and less structured data (such as machine-generated data and social media data) that can be mined both for internal marketing purposes and for licensing to third parties.
From the business perspective, the protection of this data is needed to secure the significant economic investment that the "new data economy" can require. Otherwise, data holders may lack the incentives to share the data they own and control, because of the risk that non authorized users may "free ride" on their investment.
Granting property rights is often suggested as a solution to overcome the incentive problem. In the case of data, while relying on contract freedom may seem the favourite solution, between those extremes a spectrum of possible "halfway" approaches has been proposed. They range from "quasi-property" or "semi-commons", with a liability-like regime, to access rights, requiring to license extractions and reuse of data on FRAND terms.

Keyword. ambient intelligence, internet of things, digital single market, data-driven economy, data ownership, quasi-property, semi-commons, intellectual property rights, access

1. Setting the Stage of Ambient Intelligence

For the last two decades, scholars, journalist, and IT consultants, have been presaging what has been labelled the "ambient intelligence", a vision of a foreseeable future technological ecosystem where the human will be surrounded by a seamless environment of computing, advanced networking technology, and specific interfaces, enveloping the physical environment and distributing the technology focus and its computing power from computers to a multiplicity of everyday objects [1] [2].

The term was first used in 1998 in a series of workshops commissioned by consumer electronics company Philips [3] but was given its most significant boost as a key part of the European Commission's Sixth Framework Programme for Research and Technological Development in the area of Information Society Technologies [4].

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Not surprisingly in an area of innovation, the terminology used by researchers, industry participants and governments is not fixed. The expressions “Internet of things” [5], “Everyware” [6], “Ubiquitous” [7] or “Pervasive computing” [8] sometimes are used interchangeably, other times in different but overlapping contexts and with wider or narrower scopes of meaning [9].

Amidst the wide array of challenges posed by this vision of forthcoming reality [10], until now, the central question of research has been the impact of ambient intelligence (AmI) and of profiling techniques on individual autonomy and refined discrimination. Unauthorized and abusive access to the data collected, loss of control [11], dependency, social exclusion, unwanted and unwarranted surveillance, and more in general privacy [12], trust [13] and security concerns [14] [15] have been identified as possible disbenefits of these technologies [16] [17].

Others paid attention to the challenges that such technologies pose to the classical understanding, construction and concept of identity [18] [19], affected so intimately that many scholars refer to the multiplication of identities [20] and the digitisation or informationalisation of the human person [21], [22].

A special emphasis has been overall put by international [23] [24] and European policy [25-29] to the questions about ownership, access and trade in digital data that flow through the AmI, and potential data market failures that may require regulatory intervention.

Data and information are, by nature, non-rival. Many people can use the same data at the same time without any loss of information content for any of these parties. Even if I have it, it doesn't exclude you from having it too. The dramatic reduction in the cost of copying of digital content significantly reduces the natural excludability barriers conferred on information by its material carrier and raised questions about data free-riding [30].

Ensuring excludability requires technical and/or legal intervention to define and attribute exclusive property rights.

On the merits, an active legal debate has emerged, commenced in Germany, but soon become global.

The present contribution aims to add its voice to the debate, being structured in the following parts.

Whereas Sections 1-3 succinctly describe the Ambient Intelligence scenario, summarizing its main characteristics and features and introduce the data-ownership issue, Section 4 critically examines the traditional research focus on personal data and suggest that any analysis on the concept of ownership on data in the context of the Internet of Things (IoT) should be applied to all sorts of data (including non-personal).

In Sections 5-6 the article reviews existing legal frameworks dealing with data and describes the *status quo* where no ownership in data is formally assigned as a *de facto* property regime assigned to information industries with strong bargaining power.

An assessment on the legal instruments and landscapes which may affect commercial operator’s access to and ownership rights over data is carried out in Sections 7-9, including a detailed discussion of forms of protection for commercially valuable data alternative to full-property.

Section 10 draws the conclusion that relying on contracts seem by far the favourite solution in the political, economic and academic fields, even if the Commission’s investigations failed to reached a definitive position and called for more research to bring economics up to speed with this question.

2. Data as Engine of Revolution

Electronic systems, sensors and other objects distributed throughout the physical world via the constant monitoring of our actions and behaviour will, themselves, generate and produce massive amounts of personal data and information concerning our identity and behaviour.

This new stage has been possible by the passage from a model of people accessing internetworked computing services almost exclusively via a limited number of personal desktop computer to a “many people to many machines” model [31].

In this world where a wide array of miniaturised computing devices (processors, tags, tiny sensors) will be integrated into a multiplicity of everyday objects, software agents will work with an incomparable greater amount of information, captured not only through the websites we visit but also through the actions we make and the decisions we take in the physical world, including the conversations we have, the places we visit, the people we meet, the things we see, smell, eat and (even perhaps) think, among many other human activities.

The idea of such proactive instead of interactive computing [32] is that we need not provide deliberate input, but are ’read’ by the environment that monitors our behaviour.

Control over such big amount of information is now increasingly possible thanks to the development known as “big data”, which refers to gigantic digital datasets extensively analysed using computer algorithms [25] [33-34].

These technologies however only generate an enormous amount of data, which may not reveal any knowledge until profiling technologies are applied.

Profiling can be described as the process of knowledge discovery in databases, of which data mining (using mathematical techniques to detect relevant patterns) is a part [35], carried out by software programs trained to recover unexpected correlations in masses of data.

Profiling technologies are the crucial link between an overdose of trivial data about our movements and interactions with other people or things and applicable knowledge about our habits, preferences and the state of the environment.

Consequently, they generate new knowledge, or better discover knowledge that we did not know to be hidden in the data [36] [37].

Therefore, profiling creates an added value in a mass of data, of which we don’t yet know what is noise and what is information [38]. The resulting new knowledge consists of group profiles which should indicate that all people with a specific mix of attributes entail a specific characteristic [39].

Data vendors sell access to their databases and data analytics to downstream firms which in turn use the data to improve their product positioning. Bergemann and Bonatti [40] distinguish three main types of data vendors depending on the source of the data: (1) financial data providers (Bloomberg or Thomson Reuters), including credit rating agencies (Equifax, Transunion, Moody's or Standard & Poor's); (2) Data brokers, e.g. LexisNexis and Acxiom, that compile huge databases on individual consumers from publicly accessible sources, e.g. social media, blogs and from their online purchases, browsing history [41]; (3) Online aggregators, e.g. Spokeo and Intelius, that mine publicly accessible data to create consumer profiles.

Other business models enable data owners to collect and commercialize the value of their data without selling (and revealing) them. It is the case of multi-sided markets or platforms, as Amazon or e-Bay, which aggregate and analyze these data and use them to facilitate matching sellers and buyers.

3. Property Interests in Data

In any case, what is crucial in order to realize this economic value [24] is to ensure a possibility to make the data available to third parties on the basis of transfer or licence agreements.

A data owner can sign a contract with a data user that forbids any distribution to or re-use by third parties. However, that contract is not enforceable towards third parties who are not signatories to the contract. It is possible to obligate the licensee to ensure that any obligations under the data licence are also passed on to anybody who receives a sublicence. Furthermore, the licensor may be awarded direct contractual claims against such third parties. Otherwise, once the data are out in the open, the data owner has no legal means to enforce its rights.

In response to these challenges, a number of ownership-like types of technological solutions are emerging. One such example is the AURA platform—a Personal Information Management system (PIM) [42] —which was recently introduced by Telefónica in Spain and which allows end-users to control relevant data that their mobile operator holds about them (eg. the user's geolocation) and to decide with whom these data will be shared.

To that end, the Commission's 2017 Communication on Building a European Data Economy [26] considered the possibility of a legislation on a data producer's right as a possible way to incentive sharing data initiatives, enhance new business models for the exploitation of the data and unlock their economic value.

Understand who owns data, what possibilities exist for protecting against use by third parties and whether an hypothetical owner's right could coexist with the rights of data subjects in personal data under data protection law is considered «*a pivotal factor affecting a growing number of potential data users and an increasing range of data-related activities*», which plays «*a fundamental role in sustaining and developing the emergence of a European data-driven economy*» and is on the political agenda as part of the Digital Single Market Strategy for Europe [43].

On the contrary, an uncertain legal framework for data ownership, access, and trade inhibits the realisation of the full economic benefits of non-rival data.

It may potentially cause companies to hold back on data sharing initiatives and overcomplicates negotiations and restrict or slow down the extent of exploitation and innovation within data-driven industry sectors.

4. Setting the Scope of Data Ownership's Research

The legal debate on data ownership has been until now focused on the merits of granting full ownership rights to natural persons over their personal data. Several scholars have proposed allocating default entitlement of property rights on personal data to data subjects [44] [45] designed as a form of guarantee for data subjects' (human) rights, rather than as a regime of commercial exploitation of human identities

[46], due in part to the general refusal of a commodification of personal identities [47] [48].

Even after the legal developments in personal data protection, recently culminating in the GDPR, the situation is not apparently [45] [49] changed. The GDPR gives some specific rights to data subjects[2], but refrains from defining a residual ownership right in personal data. In any event, after the GDPR, it is more difficult to think of any data ownership, without also thinking about ownership of personal data [50].

This paper advocates that distinguishing between personal and non-personal data for the purpose of evaluating if any data ownership right would be appropriate is practically useless.

The recently issued proposal for a Regulation on a framework for the free-flow of non-personal data in the European Union (hereinafter the "Proposal") aims to put in place a comprehensive EU framework enabling free movement of data in the single market, "together with" the Union data protection legal framework, in particular Regulation 2016/679 (GDPR)[3]. That legal framework already ensures the free movement of personal data within the Union, so that the Proposal aims to complete such framework addressing the broader market for non-personal data storage and processing services and activities.

As a consequence, approaching the data ownership issue from the sole perspective of the legal regime of circulation of personal data is unnecessarily restrictive.

Of course, this does not amount to denying the differences between personal and non-personal data nor the impact of such differences on the circulation of data. But governing the mobility of data in the single market, placing - if needed - property rights on data (in general), does not affect in any event the obligations under data protection law under Regulation 2016/679 (GDPR). Hypothetically, personal data may be owned by data producers, controllers or processors, in the same way as non-personal data, but within the applicable limits imposed by the GDPR.

Therefore, it may be time to stop thinking in terms of ownership right in personal data and to focus research's attention on the legal regime that should better regulate collection, store, and transfer of all sorts of data (including non-personal) [51].

This focus of research follows the consideration that AmI is not only about personal data.

AmI systems don't need to identify a specific person in order to operate. For example, Fitbit's privacy policy stated that the technology produces "de-identified data that does not identify you", which may be used to "inform the health community about trends; for marketing and promotional use; or for sale to interested audiences"[4].

At the same time, the owner of the profiling system may have a strong incentive to make sure that the perception of movements, temperature, position, pressure remains anonymous as, in this case, relevant legal prescriptions, like the right of the subject to obtain information about the logic of any automatic processing of data concerning him, does not apply.

Moreover, identifying people with their precise names or addresses is becoming useless, since, in order to create a profile and to provide customized services, it may be

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[2] including the right not to be subject to data processing without a legal basis, access, limited re-purposing, the right to be forgotten and the right to data portability.

[3] Proposal for a Regulation of the European Parliament and the Council on a framework for the free flow of non-personal data in the European Union, COM(2017) 495 final, pg. 3.

[4] Fitbit Privacy Policy of August 10, 2014, at www.fitbit.com.

sufficient to know, in some cases, only the categories to which a person is likely to belong [52].

As Pagallo [53] observes, Apple pioneered the incorporation of differential privacy techniques [54] in its data collection efforts for iOS and macOS, e.g. the reuse of health data through their apps for statistical purposes. The statistical purpose implies that the result of processing is not personal data[5].

Also Facebook uses differential privacy-supporting technologies to report audience reach data of its targeted advertising system [55][6].

As the aforementioned examples show, reasoning of data ownership in intelligent environments requires considering data as a whole, without focusing only on personal one.

5. The Current Normative Framework in relation to Data Ownership

At the current stage, ownership rights in data are only very partially defined. Most European countries do not have specific laws in relation to the ownership of data [56], besides, where applicable, copyright, database and trade secrets rights.

Such legislations, in any case, do not recognise a property right in data as such, rather, at most, provide for certain defensive rights which protect data against unauthorised access.

Neither it is possible to imagine that this type of right could originate by an authoritative act of the EU. According to Article 345 of the Treaty on the Functioning of the European Union (TFEU), "*the Treaties shall in no way prejudice the rules in Member States governing the system of property ownership*". Therefore, property ownership is explicitly excluded from the powers conferred upon the EU. It would only be possible if data ownership was categorised as intellectual property because Article 118 of the TFEU empowers legislative bodies of the EU to "*establish measures for the creation of European intellectual property rights to provide uniform protection of intellectual property rights throughout the Union*". The European Commission however expressly excluded that data ownership may be configured as a "*super- IP right*" [27].

6. The Current State: a *de facto* Property Regime of Data

In the absence of legally specified ownership or residual rights, exclusive data ownership thereby becomes a *de facto* right allocated by the bargaining power distribution between parties [57]: who has the data can effectively prevent others from

5 Recital 162 GDPR defines statistical purposes as "any operation of collection and the processing of personal data necessary for statistical surveys or for the production of statistical results". The meaning of statistical purposes can be interpreted broadly and does not only cover uses for public interest but may also include private entities doing research in pursuit for commercial gain (M. Corrales., M. Fenwick, N. Forgò, *New Technology, Big Data and the Law*, Springer, 2017, 36).

6 Facebook's Data Policy available at https://www.facebook.com/full_data_use_policy states: "We do not share information that personally identifies you with advertising, measurement or analytics partners unless you give us permission. We may provide these partners with information about the reach and effectiveness of their advertising without providing information that personally identifies you, or if we have aggregated the information so that it does not personally identify you".

accessing them [58] and is the owner of all residual rights not explicitly assigned away to other parties through specific contractual provisions.

It was commented that the individual as a contracting party has less bargaining power than the information industry's company and the option to leave the allocation of the right to the parties will most likely lead to an agreement whereby the latter will retain that right. Hence, some advise introducing laws to overcome such unequal manufacturer market power [58-60].

In a previous work, I tried to resume the current debate on this stance, which may be somewhat simplistically linked back to a trade-off between a property rights model and a contractual approach [61].

In this work, I would like to show that between those extremes a range of possible approaches has been proposed.

7. The "Full- Property Approach"

Economists are generally inclined to think that well-specified property rights are an efficient way to organize an economy since they reduce transaction costs and uncertainty and thereby increase the efficiency of markets.

If the market works well in enabling transactions in other commodities, covered by property rights, it would presumably work for transactions in data as well [62]. Just like with first labour (Locke) or occupancy (Pufendorf), those who *first* collect the data, or generate derivative data from a primary data sets are best entitled to keep their possession, because without them the data would not be existent in the IoT environments. Under this interpretation, all data seem to be explicable and justifiable as belonging to the data collectors because they first do such data collection [50].

Where personal data are involved, propertizing data may also be a way of forcing companies to internalize the costs associated with the collection and processing of data, in the hope that this will lead to greater privacy [63].

Discussing the practical legal modalities of such a right, however, many acknowledge severe theoretical and practical difficulties, starting from the question to whom an ownership right on data should be given [59] [63]. Since data can be copied, multiplied, and mixed with other data and modified, it might be technically very complicated to trace the data transactions, to locate each data and finally say who is the last holder of the data, unless we want to permit data co-ownership.

In any case, the first question that needs to be asked is another. An assumption is widely made that data may be subject to property rights. However, focusing on the issue in terms of "ownership" may be misleading since few jurisdictions treat data as a form of property or simply have different concepts of what property is. Accordingly, the question is whether information is of a tangible or an intangible nature and can be the object of ownership independently from (ownership of) the carrier. In many jurisdictions which follows the model of German law, the object of ownership must be of a physical, i.e. tangible, nature. Consequently, if the "thing" is not physical, as it may be the case with respect to data (seen as an object separate from the carrier), that particular object cannot be "owned" [64].

But even if they were, a main distinction should be drawn between the civil law and common law understanding of ownership [65], which may define the owner's privileges in very different way.

Common law allows private parties more freedom in the types of ownership interests which they can create. Ownership can be dynamic, depending on how large the "bundle of different interests and rights" that it encompasses from time to time [49]. On the other hand, the civil law tradition recognizes a limited number of property rights and a limited number of legal objects that can be subjected to these property rights (the so-called *numerus clausus*) [66].

Accordingly, a mistaken assumption that data is property may lead to reliance on statutory provisions which do not in fact, apply. This does not mean that no primary right (in the sense of the maximum of powers, rights, privileges, and immunities) may be designed for data, but rather that it is necessary to be cautious about extending the traditional concept of property to data ownership and whether it would be more accurate to call it "entitlement".

8. The "Semi-Commons" or "Quasi-Ownership Approach"

Some have argued that IPR-like mechanisms are more suitable tools for the purpose of governing data. Since data are non-rival and someone else can use the same data without harm to the previous user, data have different economic properties compared to tangible physical goods. The economic characteristics of data markets are thus comparable to markets for intangible intellectual property.

Heverley [67] sees data as subject to ownership regimes similar to copyright, patents, trademarks and trade secrets. The underlying issue in all these regimes is a dynamic relationship between limited exclusive private rights and exceptions for common use or access – a hybrid ownership regime labeled as "semi-commons" or "quasi-property". It has been defined as a category of property-like interests, which consists of "*situations where the law attempts to simulate the functioning of property's exclusionary apparatus through a relational (liability-like) regime*" [68]: it is a "*relational entitlement to exclude specific actors from a resource given a specific event, a given type of behavior, and/or a given relationship between the actors*" [69].

However, any recognition of a new property right as a particular form of regulation of the market needs an economic justification [70]. Intellectual property exists only where there is a public goods problem and people need incentives to invest, "*i.e. to spend time and money in the creation of new works*" [71].

Most authors observe that there is no evidence of an incentive problem regarding the production and analysis of non-personal data and there is no economic justification for the creation of a new system of data ownership based on the incentive argument. For instance, Hugenholtz [72] argued that data are often a by-product of profitable economic activities and do not require additional incentives.

Although exclusive ownership rights should give financial incentives to the data producer and owner, each owner may affect other owners, excluding them from realizing the potential benefits of economies of scope in the aggregation of datasets. The excessive fragmentation of ownership rights leads to under-utilization of data.

In particular, as it is technologically feasible to keep data secret and protect them against copying and leaking to the public, many argue that the creation of a new system of data ownership is not advisable [72], [73]. Moreover, the recognition that all data are produced mostly automatedly by machines and sensors built into machines excludes that data might be considered as intellectual creations covered by copyright law, traditionally linked to human creative work.

8.1 The "trade secret approach"

A form of quasi-property [74], that may combine the above explored "semi-commons" advantages in relation to data is trade secrets. It has been argued that trade secrecy law has a number of default rules that might be useful for governing data-trade [75], [76]. This law has the same goal of data owners in giving firms/individuals control over commercial exploitations of private information and the power to prohibit their unauthorized uses. Therefore, some scholars [77], [46] suggest to adopt default licensing rules evolved by trade secrecy, like the general rule that if the licensor has provided data to another for a particular purpose, license rights are non-transferable unless the licensor grants a right to sublicense, at the same terms as the license imposes and the data cannot be used for other purposes without obtaining permission for the new uses

This mechanism may allow overcoming some issues related to the intrinsic free alienability, typical of property rights and inappropriate for the information economy.

9. From Property towards Data Access Regime

The question remains whether the data producer's right is the proper approach to tackle the problem. The data producer's right seems to be only one option, and indeed one that is situated at the very interventionist end of the regulatory scale. Hence, others suggest that "ownership" of data should be looked at from a different angle: businesses should not focus on acquiring ownership of data, but on gaining and providing access to data, regardless of their source. As the number of sources and data grows, if you can't use one, you jump to another one, so that the variety on offer will make control or ownership in practice more difficult to operate. Hence, we should not focus so much on who "owns" the data, but who can use them, and for what purpose.
Some scholars propose a more targeted and non-waivable data access rights granted to who has a legitimate interest in access the data so as to conduct data analysis. That would specifically react to situations in which a manufacturer would otherwise try to reserve related markets for itself.

Reichman and Samuelson [78] suggest constructing a liability principle-based regime to protect investors against unfair extractions but requiring to license extractions and reuse on Fair, Reasonable and Non-discriminatory («FRAND») terms. The object is to provide a blocking period against appropriation so that the originator can exercise monopoly pricing in this period subject only to public interest limitations. An automatic universal licence should come into effect as soon as the blocking period ends.

The same approach is proposed by the international law firm Bird & Bird, which issued a White Paper [79] suggesting the creation of an ownership right in data, which should be non-exclusive, in order to allow for a shared use of data by different actors.

The new right would have a mandatory data transfer obligation on FRAND terms and conditions, similarly to what is already known in relation to standard-essential patents.

The Max Plank Institute for Innovation and Competition in its Position Statement on the European Commission's Consultation on Building the European Data Economy took inspiration from Article 20 GDPR and suggested to adopt the data portability right as a general regulatory approach to extend beyond cases of use of personal data.

It also promoted further consideration and discussion for answering more concrete questions such as who should be entitled to claim access or whether a data holder should be remunerated for granting access to data and whether the adoption of general legislation on an access right should be preferred to a sector-specific regulations or viceversa [70].

10. Contractual Approach Remains the "King"

Despite these different possibilities to complete the current legal regime, when stakeholders were asked whether they would favour the introduction of data ownership regulations, they opposed them.

Most respondents to the public consultation on Building a European Data Economy do not support regulatory intervention, whether as an ownership-type rights or as licensing obligations [28].

The majority opinion is that contract law can adequately address issues of data ownership, providing for the flexibility needed to suit the precise situation that different businesses propose. Any legislation in this area, instead, is more likely to hinder the movement of data rather than enhance the data economy.

It is generally accepted that freedom of contract should be "king" in this area and this idea has been strengthened after the CJEU's 2015 decision in *Ryanair v PR Aviation*[7], according to which if a database is not protected by the database right, freedom of contract applies, subject to any restrictions imposed by competition laws or national laws.

So far it is unclear whether this will be the definitive answer to the data ownership issue. The Commission's investigations failed to reach a definitive position, but its proposal for introducing a "data producer's right" (i.e. the owner or long-term user of the device) is still far from achieving consent.

The Working Paper on the economics of ownership, access and trade in digital data by the European Commission's Joint Research Centre [29] declares to be unable to offer policy solutions yet to the question whether a better specification of the scope of data ownership rights would improve efficiency and reduce data market failures.

Likewise, the legal study on Ownership and Access to Data prepared for the European Commission DG Communications Networks, Content & Technology by the international law firm Osborn Clark [80] concluded that it may be necessary to wait for a further evolution of the commercial landscape in order properly to formulate what, if any, legislative intervention would be most appropriate.

While policymakers call for more research to bring economics up to speed with this question, the mid-term objective of this document was to analyse and to set out the possible scenarios of data governance, which may be expected in the foreseeable future.

Such scenarios are the result of a path from full property rights towards complete contractual freedom, passing through the quasi-property approach and the liability-like regime typical of intellectual property rights.

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[7] CJEU, 15 January 2015, C-30/14, *Ryanair v. PR Aviation*, [2015] ECLI:EU:C:2015:10. For a comment, see M. Borghi, S. Karapapa, Contractual Restrictions on Lawful Use of Information: Sole-source Databases Protected by the Back Door?, *European Intellectual Property Rev.*, **37** (8) (2015), 505.

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Privacy and Data Protection Issues on Smart Tourism Destinations – A First Approach[1]

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Abstract. Data lies at the core of all smart tourism activities as tourists engage in different and personalized touristic services while traveling or in holidays. From these interactions, a digital data trail is seamlessly captured in a technology embedded environment, and then mined and harnessed in the context of Smart Tourist Destinations to create enriched, high-value tourism experiences for tourists, as well as granting destinations with competitive advantages. The perceived enjoyment has to be considered within the legal framework of data protection by exposing potential risks to data protection and privacy, as well as the available answers given by the General Data Protection Regulation.

Keywords. Privacy and Data Protection, Smart Tourism Destinations

Introduction

Smart Tourism Destinations (hereinafter called STD) emerge from the technological foundations of *Smart Cities*, themselves based on the *Internet of Things* (IoT) and the *Cloud*, as enabled by *Big Data Analytics*. However, while these subjects have been examined extensively within Privacy literature, their specific interaction and legal consequences at STD is still to be explored. As a matter of fact, this is perceived and pointed out as a missing issue by the Tourism Science literature regarding STD, being this paper a sort of primer endeavor[3]. With technology being embedded within destinations environments, addressing the potential needs and desires even at an unconscious level of travelers, STD are designed for enriching those experiences and to enhance the competitiveness of each destination.

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[3]Even being tourism the world's largest industry, with receipts of almost 1,200 USD Billion in 2017, and growth expectations of 4% to 5% for 2018, according to the UNWTO Barometer, notwithstanding internal tourism.

Regarding the connection between Tourism and ICT, we're facing a specific context, where the relationship of clients with providers through their apps/services is generally short-lived, which makes trust-building, as costumers loyalty, much harder [10]. Moreover, the need for real-time information *in situ* is so imminent that tourists might be easily persuaded to forego their data. On another hand, benefits or "*perceived enjoyment*" (evoked by engaging content and interactive system features) are heightened [10], suggesting that personal data and privacy concerns might be temporarily suspended. At the same time, tourism activities take place in locations outside of the usual realm of the traveler and are often facilitated by unknown local service providers, which decrease risk perceptions and therefore personal data and privacy concerns [20]. Nevertheless, these risks are amplified as the number of connected smart objects grows and are multiplied by the complexities involved in multiple vendors and interoperating systems. The following illustrative examples provide insight towards possible personalized and smart value-added services STD can offer, as full historic or environmental immersions through smart optics devices or augmented reality. Further, location-based services could alert users on promotional offers in restaurants that are close to them at any given time. Besides, estimated waiting time in restaurants can be accurately quoted, to the minute, so guests can get a drink in the bar while waiting for their table. Aware on customers' special dietary circumstances in regard with their medical condition, as well as religion restrictions, tourism service providers may provide for meals that suits their preferences. As for transport, real-time information about the tourist's destinations, which particular direction to get on, and also the ability to respond (i.e., by suggesting alternatives) to unpredictable events in real-time are envisioned. RFID tags on the luggage during check-in, in order to make it easier to locate the luggage after the plane lands in the destination, is also configured in STD scenarios. All this allows tourists to get much more from their travel and helps fulfilling the experiential travelling potential of the destination [8]. So, it is argued that privacy and data protection research is needed in the Tourism context, balancing the tradeoff value and affordances added by STD and its legal protection. The paper is organized as follows. Section 1 refers to the background of STD, describing briefly its origin, constituents, added-value and objectives. Section 2 provides some of the most important risks that can be appointed to STD regarding privacy and data protection, and its corresponding compliance to the General Data Protection Regulation[4], as the current basis of the Privacy and Data Protection Legal system in the European Union. Section 3 concludes the paper and provides some clues for future directions.

1. Smart Tourism Destinations

This section describes the constituents of STD, objectives and derived added value.

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[4]Regulation (EU) 2016/679, of the EP and of the Council of 27/04/2016, on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (General Data Protection Regulation), applicable from the 25th May of 2018.

1.1. *Smart Tourism Destinations*

In order to characterize more closely the utility functions layered in tourism destinations, it is worthy to point out that successful destinations are composed by five tourism dimensions: transportation, accommodation, gastronomy, attractions and ancillaries services, which can be structured into six axes or "6As" as the literature describes [7], namely: i. Attractions, which can be natural, like as mountain or a seaside; artificial, as amusement parks or sports facilities; or cultural such as music festival or a museum; ii. Accessibility refers to the transportation within the given destination; iii. Amenities characterize all services, namely accommodation, gastronomy and leisure activities; iv. Available Packages; v. Activities; and vi. Ancillary Services (e.g. daily use services such as bank, postal service and hospital).

By applying *smartness* into tourism destinations, STD are then additionally defined as *"tourism supported by integrated efforts at a destination, to find innovative ways to collect and aggregate/harness data derived from physical infrastructure, social connections, government/organizational sources and human bodies/minds in combination with the use of advanced technologies to transform that data into enhanced experiences and business value-propositions with a clear focus on efficiency, sustainability and enriched experiences during the trip"*[4]. This embracing concept comprises three core elements [6]:

i. Reliance on smart technology infrastructures, wireless sensor networks (IoT) and integrated communications systems, e.g. sensor technology, ubiquitous Wi-Fi, near-field communication (NFC), smart mobile connectivity, radio-frequency-identification (RFID), sophisticated data warehouses; data mining algorithms, also considered vital to creating a smart technology infrastructure [5]. IoT could support in terms of providing information and analysis as well as automation and control. For instance, chips embedded to entrance ticket, or a smartphone app, allow tourism service providers to track tourists' locations and their consumption behavior, enabling location-based advertising. In addition, cloud computing services may provide access to solid web platforms and data storage through public electronic communications network. It also encourages information sharing, a fundamental feature for STD. For example, a sophisticated tour guide system could serve massive number of tourists without being actually installed on any personal device, even allowing personalizing experiences.

ii. A Smart Destination is conceived as "*an innovative tourist destination, built on an infrastructure of state-of-the-art technology guaranteeing the sustainable development of tourist areas, accessible to everyone, which facilitates the visitor's interaction with and integration into his or her surroundings, increases the quality of the experience at the destination, and improves residents' quality of life"* [6]; and

iii. Smart business networks, referring to the number of applications at various levels supported by a combination of Cloud Computing and IoT.

1.2. *Smart Tourism Experiences*

The shared *purpose* of all omni-channel stakeholders of a smart tourism ecosystem is the availability of enhanced/enriched, high-value, meaningful and sustainable tourism experiences through smart services and products [7]. Therefore, and at least potentially, STD enhance tourism experience through the offer of products/services that might be customized in order to meet each of visitor's unique needs and even implied desires, as for understanding the needs, wishes and desires of travelers becomes increasingly critical for the attractiveness of destinations. Hence, tourism data has multiplied, geometrically [3]. This data is being conveyed through several sources: i.online social networks; ii. online reviews/ratings; iii. intelligent location sensors in interaction with mobile devices; iv. transactional communications based on reservations by transportation/hospitality undertaking (airlines, hotel, restaurants and rental car businesses, namely)[5]. Each of these sources provide a massive size of digital traces (data trails or digital footprint), resulting in multidimensional sets of data, known as Big Data [14]. This massification of real-time (tourism) data, from different sources, analyzed by IoT industries, has created big pools of data to mine. Hence, SDT can be considered both as consumers and producers of big data. Besides, tourism data reveals specific features, as it holds strategic value, allowing the detection and prediction of future behaviors and trends, allows for the analysis of development and optimization processes of products/services, retention of customers, and ultimately is useful for future decision-making. This flow of data, inherently cross-border, may consist in personal data, geographical, transactional data (derived from queries/searches, purchases, and other exchanges), feedback data, respectively. These data can reveal commercial preferences of its users, rendering enormous interest for economic operators, and allow cities to better plan for future tourists in terms of mobility, popular attractions, and other potential issues. By managing Big Data, tourism organizations can extract valuable insight from information that could elevate them to a new dimension of customer experience and improve the way they interact with customers, hence gaining competitive advantage [8]. As STD experiences are achieved through intensive personalization, context-awareness and real-time monitoring [8], [9], this entails legal risks, demanding a careful analysis within data protection framework (as approached in the following section).

2. Risks of Smart Tourism Destinations to Privacy and Data Protection

In this section we explain concerns that STD technologies entail to privacy and data protection.

2.1. *Risks Inherent to a Huge Digital Footprint*

Is well known that the use and combination of advanced techniques of *big data analytics*, which include machine learning (ML), data mining techniques (DM), content analytics crawlers (mining unstructured content), potentiate known risks hampering privacy and data protection [22]. As deployed algorithms reach beyond usual analytics, leading to the finding of inferences, connections and relationships between data even for neither originally unforeseen nor previously unknown onuser pictures, real names and can also often be used as unique or near unique identifiers across multiple databases. Based on these correlations, predictions will be made, and a new algorithm can be created and applied to particular cases in the future. The following risks are fueled when information (e.g. mobility data) is conjoined and matched with data from other sources of publicly available information (e.g. Facebook or Twitter postings,

[5]These activities reveal aspects on destination/origins, way-finding preferences (beach, sports, culture, restaurants, etc.), spending capacities, and on behaviors (family tourism, leisure, night clubs, events, etc.), etc.

blogs entries, etc.) and analysis revealed users' social interactions and activities, as occurred with public bike data[6] or smart tourist travel cards [25].

a. Identification and re-identification[7] of individuals from allegedly anonymised or pseudonymised data. Alleged concerns relies on the fact that integrating large collections of data from distinct sources of available tourism datasets, even with apparently innocuous, non-obvious or anonymized resources, may enhance a jigsaw of indirect correlation of identification and re-identification; this scenario could escalate if there is access to rich information resources via the web. Thereby, personal information set through re-identification intrinsically abides to legal requirements, as identification not only means the possibility of retrieving a person's name and/or address, but also includes potential identifiability by singling out, linkability and inference [23] [8].Data collected by the ubiquitous computing sensors, are, in principle, personal data[9] or "personally–identifiable information"[11], as the processing of non-sensitive data can lead, through data mining, to data that reveals personal or sensitive information, thus, blurring the conventional categories of data.In principle, when data is rendered *anonymized* (recital 26, GDPR) all identifying elements have been irreversibly eliminated from a set of personal data and cannot leave space to re-identify the person(s) concerned, therefore, it is deemed to be no longer personal data and IoT developers are be able to release, sell or publish the data without data protection requirements. Conversely, de-anonymization strategy in data mining entails that anonymous data is cross-referenced with other sources to re-identify the anonymous data. Thus, the processing of datasets rendered anonymous may never be ensured. When personal information is *pseudonymized*, identifiers are replaced by a pseudonym (through encryption of the identifiers). In turn, pseudonymized data continues to allow an individual data subject to be singled out and linkable across different datasets and therefore stays inside the scope of the legal regime of data protection[10].

b. Profiling of individuals. The integration and matching techniques of tourism datasetsknowledge can be produced about users and hence the creation of profiles: consumer, movement, or social profiles. Profiling vests companies, public authorities to determine, analyse or predict people's personality, behaviour, and preferences without their cognition, and make also possible to refer these behaviours and attitudes to perfectly identified individuals. Such processes may and are likely to epitomize privacy invasiveness or even waiving the data subjects' control upon their data. The GDPR prohibits automated individual decision-making that significantly affect individuals (Arts. 22(1) and 4(4)), such as profiling. However, secret-tracking and decision-making on the basis of profiles are hidden from any individual, which is left without meaningful information about the "algorithmic logic" which develops these

[6] See, J Siddle, "I Know Where You Were Last Summer: London's Public Bike Data Is Telling Everyone Where You've Been" (2014),http://vartree.blogspot.co.uk/2014/04/i-know-where-youwere-last-summer.htm

[7] See Art. 29 WP Opinion 6/2003 on the Re-use of public sector information, Opinion 3/2013 on Purpose Limitation", and Opinion 6/2013 on Open Data and Public Sector Information (PSI) reuse.

[8] EDPS Opinion 05/2014 on Anonymisation Techniques, p. 10

[9] Art. 29 WP Opinion 4/2007 on the Concept of Personal Data.

[10] EDPS Opinion 05/2014 on Anonymisation Techniques, p. 10.

profiles and has an effect on the data subject[11]. In fact, "(…) *analytics based on information caught in an IoT environment might enable the detection of an individual's even more detailed and complete life and behaviour patterns.*[12]" Likewise, in a STD, this can lead to an exclusion/denial of services/goods, e.g. denial of insurances, exclusion from the sale of certain touristic or high-end products, shops or entertainment complexes, even essential utilities for those unwilling to share personal data [12]. Tourism service providers are adapting their serviceable approach to meet the "personalization" expectation [13]. Personalization is attained by collecting and utilizing personal information about needs/preferences (facilitated in a STD scenario), to be able to provide offers and information fitting perfectly clients' needs. Therefore, user's input and feedback are used to build profiles and recommender systems in the form of trail packages, which for some can be considered a risk of "data determinism", in which individuals are not merely profiled and judged on the basis of what they have done, but also a prediction of what they might do in the future[14].

c. *Repurposing of big data*. Automatic capture of big data through sensors is collected for secondary unauthorized purposes, or for abusive marketing activity, this way, undermining the purpose specification and use limitation principles.

d. Surveillance under the disguise of service provision and desensitizing effect. Data subject's interactions in a smart destination environment will be increasingly mediated by or delegated to (smart) devices and apps. Most of the destinations are using video-surveillance systems as sensors to supply real-time information on public transportation, traffic, in the domains of emergency and personal safety, navigation, and access to tourist information on the go, which all provide value to the user: safety, convenience, and utility in daily lives, as well as in vacation. Such information is transmitted via, for e.g., smart remote controllable digital CCTV cameras that can zoom, move and track individual pedestrians, ANPR (number plate) recognition, GPS, Wi-Fi network tracking reliable facial recognition software, location-based service apps (LBS)[10]. It has been argued that such devices desensitize users about providing location-based information because of the ease with which it happens and the "coolness" factor that comes with it. These developments require devising specially protected digital spaces for children which are particularly vulnerable in the face of data processing practices.

e. *Failed consent.* In this intelligent environment, it is dubious to give or withhold our prior consent to data collection [15], as it seems to be absent by design. The awareness that the ubiquitous sensors are so embedded in the destination that they literally "disappear" from the users' sight, so that they will not even be conscious of their presence and hence consent to the collection, can be envisaged within STD. We can, at some extent, concede that the obtaining of such consent, in STD contexts, would be defined in a mechanical or perfunctory manner, or as a "routinization". We note also that as for CCTV, ANPR and MAC whilst tracking and sensing, the notice in the form of information signs in the area being surveilled, or on related websites, does not conform to the consent. The issue of the IoT, also within a STD, is that its sensorization devices are explicitly designed to be unobtrusive and seamless, invisible in use and unperceived to users[12] and thereupon, users do not hold the opportunity give their

[11]EDPS, Opinion 3/2015, p. 8

[12]Art. 29 WP Opinion 8/2014 on the on Recent Developments on the Internet of Things

unambiguous, informed, specific (intelligible that specifies the exact purpose of the processing), explicit, and granular consent[13]. However, consent is not yet part of a function specification of IoT devices, and thus, they do not have means to display "*provide fine-tuned consent in line with the preferences expressed by individuals*," because smart roads, trams, tourist office devices are usually small, screenless and lack an input mechanism (a keyboard or a touch screen)[14]. Regarding the amount and assortment of these interactions, it is just too onerous for each data subject to assess their privacy settings across dozens of entities, if any, in order to ponder about the non-negotiable tradeoffs of agreeing to privacy policies without knowing how the data might be used now and in the future, and to assess the cumulative effects of their data being merged with other datasets [14]. Reverting to other legal grounds, processing personal data relies on "public interest", which can sidestep the need for consent (health, national governmental agencies gather data for e. g. e-Government systems, e-Health). Nevertheless, this possibility should not conceal any eventual "third-party interest". As most commercial systems rely on the "legitimate interests" ground, even if they are "the vaguest ground for processing[15], and offers a lot of scope for industry to process data if they can claim a "legitimate interest", delegation of the task of balancing commercial interests and user fundamental rights to the controller themselves [12].

f. Imbalance. Smart technologies often produce situations of imbalance, where data subjects are not aware of the fundamental elements of data processing and related consequences, being unable to negotiate their information, which leads to a side consequence of enhanced information asymmetry [2].

2.2. *Compliance to the GDPR*

At this point, we should underline that access and reuse of information within the framework of a STD collides with legal standards for which the GDPR was designed. So, we will now bestow attention to the following fundamental principles, which all organizations must follow whilst processing personal data related to any STD environment.

a. *Lawfulness, Fairness and Transparency.* For a first, these principles require that when the data is collected, it must be clear as to why that data is being collected and how the data will be used (Art. 5, clause 1(a)). Even so, big data algorithms producing results are usually invisible and opaque to the user, and its results often impenetrable to laymen; algorithms can learn and change in a semi-autonomous way, making them hard to document, also due to their copyright protecting the software and trade-secret shield [12]. We are attentive to a right to know the "*logic of the processing*" applied to our data (Recital 63, and Arts. 13(2) (f), and 15(1) (h), respectively).

b. Purpose Limitation (Art. 5(1) (b) Big Data analytics, inherent to STD, often engage in processing data for purposes that had not been initially scheduled, or still to be

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[13] Art.29 WP Opinion 15/2011 on the definition of consent.

[14] Art.29 WP Opinion 8/2014 on the recent developments on the Internet of Things.

[15] EP report on "Big Data and Smart Devices", available online at http://www.europarl.europa.eu/RegData/etudes/STUD/2015/536455/IPOL_STU(2015)536455_EN.pdf.

discovered. This principle prevents arbitrary reuse[16], and calls for a "compatibility assessment of the new purpose"[17]. The 29 WP states that "*By providing that any further processing is authorised as long as it is not incompatible (...), it would appear that the legislators intended to give some flexibility with regard to further use. Such further use may fit closely with the initial purpose or be different. The fact that the further processing is for a different purpose does not necessarily mean that it is automatically incompatible: this needs to be assessed on a case-by-case basis*". This Opinion sets out an approach to assessing whether any further processing is for an incompatible purpose. Recital 50 of the GDPR states that in assessing compatibility it is necessary to take account of any link between the original and the new processing, the reasonable expectations of the data subjects, the nature of the data, the consequences of the further processing and the existence of safeguards. Anyway, in practical settings, companies "*repackage data by de-identifying them (using pseudonyms or aggregation) or creating derived data, with only the original dataset being subjected to data minimization. The repackaged data can then be sold on and repurposed in a plethora of ways that have little to do with the original reason for data generation and without the need to give notice or consent to those that the data concerns*"[17].

c. Data Minimization (Art. 5 (1) (c). In substance, smart technology purports the massive collection, aggregation and algorithmic analysis of all the available for various reasons, such as understanding customer buying behaviors and patterns or remarketing based on intelligent analytics. Organizations need to be clear about which data is deemed to be *necessary* and *relevant* for the purposes of the processing, or excessive.

e. Accurate and up-to-date processing (Art. 5 (1) (d). Results drawn from data analysis may not be representative or accurate, if sources aren´t accurate as well (*i*.e. analysis based on social media resources are not necessarily representative of the whole population at stake). Machine learning itself may contain hidden bias which lead to inaccurate predictions and profiles about individuals. Profiling involve creating derived or inferred data, leading to incorrect decisions (discriminatory, erroneous and unjustified, regarding their behaviour, health, creditworthiness, recruitment, insurance risk, etc.[18]). Even exercising the "*right to be forgotten*", where data subjects will have the right for their data to be erased in several situations, for e.g., when the data is no longer necessary for the purpose for which it was collected, or based on inaccurate data, it may be difficult for a business to find and erase someone's data if it is stored across several different systems and jurisdictions. Further, inaccuracy of data endangers the data "*quality principle*" and triggers abstract strict liability for damage [27].

f. Storage Limitation (Art. 5 (1) (e). This principle is becoming part of the *"*lifecycle governance strategy" retention policies of companies[19], such IBM, that defensibly dispose irrelevant data instead of keeping data archived forever. Retention schedules allow unnecessary data to be disposed of as it is no longer of business value or needed to meet legal obligations.

[16] 29 WP Opinion 03/2013 on Purpose Limitation, p.21.

[17] Big Data, Artificial Intelligence, Machine Learning and Data Protection, UK, ICO, 2017.

[18] Big Data, Artificial Intelligence, Machine Learning and Data Protection, UK, ICO, 2017.

[19] See http://public.dhe.ibm.com/common/ssi/ecm/wv/en/wvw12356usen/WVW12356USEN.PDF

*g***.** *Accountability* (Art. 5(2). This principle requires organizations to demonstrate compliance with all the principles in the regulation, requires maintenance of records of processing activities, and to appoint a data protection officer (DPO). However, an organization's records may change as new correlations in the data are discovered which prompt different uses.

h. Privacy by design (Art. 25) is an approach in which IT system designers should code preemptive technological measures aimed to address data protection and privacy concerns applied to the very same technology that might create risks [24]. However, there is a lack of a privacy mindset in IT system designers[20], as reported by ENISA[21] "(…) *privacy and data protection features are, on the whole, ignored by traditional engineering approaches when implementing the desired functionality. This ignorance is caused and supported by limitations of awareness and understanding of developers and data controllers as well as lacking tools to realise privacy by design. While the research community is very active and growing, and constantly improving existing and contributing further building blocks, it is only loosely interlinked with practice*."

3. Conclusions

The preceding analysis brings out that smart tourism is becoming a big contributor and benefactor of ubiquitous, always-on data capture about customers towards enhanced tourism experiences, and competitive markets. The apprehension here is to understand if the affordances of the technology, the personalized services, and enhanced experiences can cope with data protection obligations without a micro-targeting and profiling. Smart tourism raises big issues with respect to information governance [18] and about correctly deriving the "added" value from information in an open and ubiquitous info-structure. As for now, the current assumption is that all captured information is extremely valuable and necessary to organizations and will be freely provided by the smart tourists who seek enriched tourism experiences [19]. Moreover, the lack of privacy and data protection mindset of engineers and coders working in IoT/cloud business poses a very large problem for the future [12]. It is suggested that STD are to proceed with test prototyping and research before the implementation of new technologies and services in large-scale real-life environments, such as the Mobile Living Lab [13]. Finally, besides addressing related information security issues according to the NIS Directive[22], future research regarding mobile devices and tracking will be needed, following the adoption of the new *ePrivacy* Regulation[23].

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[20]For illustration purposes, we quote [17]"*Our findings indicate that software designers frame privacy mainly as a matter of information security (...) secrecy and internal permission systems in the organization; other principles, such as notice, consent, and rectification, were hardly found as part of the designers' perception of privacy. (...) designers perceive privacy as a theoretical-abstract concept, rather than an applicable principle in designing information systems. Moreover, they demonstrate an ambivalent attitude towards the issue whether they are responsible for addressing privacy concerns. (...) The organisational culture of commercial companies (...) ignored or discouraged consideration of PbD*".

[21]ENISA 2014 Report on "Privacy and Data Protection by Design – from policy to engineering", p.50.

[22]Directive (EU) 2016/1148 of the European Parliament and of the Council of 6 July 2016 concerning measures for a high common level of security of network and information systems across the Union.

[23] Prop. Regulation of the EP and of the Council concerning the respect for private life and the protection of personal data in electronic communications, COM/2017/010 final - 2017/03 (COD).

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Applications and Security Risks of Artificial Intelligence for Cyber Security in Digital Environment

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Abstract. Everyday more and more devices communicate information over the Internet and the growing demand for protection has become a real challenge for civilization. While security IT systems based on conventional intrusion detection technique are simply not effective in detecting, assessing and countering cyber-threats, the use of AI based systems, thanks to their autonomy, fast paced threat analysis and decision-making capabilities, may guarantee confidentiality, integrity, and availability within the digital environment. However, increased use of AI in cyber defense may create new risks. The aim of this paper is to show experimented applications of AI for cybersecurity, raise awareness on emerging security risks that may hamper the potential of these applications in digital environment and identify possible technological solutions, best practices and legislative interventions to prevent these risks and mitigate intentional and unintentional harmful outcomes of AI based technologies.

Keywords. Artificial intelligence, cybersecurity, security risks, deep learning, artificial neural network, digital environment, malicious use, autonomous systems, intrusion detections systems, lack of control, liability, safety, accountability

1. Introduction

On August 2016, during the DEFCON conference[2], the Paris Hotel in Las Vegas hosted the final round of the Cyber Grand Challenge which was run by the US Defence Advanced Research Projects Agency (DARPA).[3] Seven teams built fully automated artificial intelligence systems to compete in a "no-human allowed" game of "capture the flag"; a fast bug hunting contest on binary code in a highly competitive environment. DARPA's aim was to stimulate development of autonomy in cyber and create unsupervised, autonomous AI hacker, able to quickly discover, prove and resolve bugs in a computer security system. The winning team – US security firm ForAllSecure – received 2 million USD as prize money to continue developing its technology. During the same time period in Las Vegas, the Black Hat conference[4] was held and the security firm SparkCognition unveiled what is said to be the first artificial intelligence powered "cognitive" antivirus

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[2] DEF CON® 25 Hacking. Website: https://www.defcon.org/html/defcon-24/dc-24-index.html.
[3] U.S. Defence Advanced Research Projects Agency. Website: https://www.darpa.mil/.
[4] Black Hat USA 2016. Website: http://www.blackhat.com/us-16/.

system called DeepArmor[5]. Both these events show how strongly governmental organizations, private companies and security researchers rely on future development of artificial intelligence technique to ensure protection of the cyber sphere from unauthorized intrusions.

As everyday more and more devices communicate information over the internet, the growing demand of protection has become a real challenge for civilization [1]. Conventional IT security measures, which rely on fixed algorithms, speed, skilled machines, and human expertise, are simply not effective in detecting, assessing and countering cyber-attacks. The implementation of AI techniques creates cyber security tools that utilize flexible learning and that are capable of real-time detection and evaluation in order to nearly instantaneously formulate a solution [2]. Drawing on today's advancements in AI techniques and applications, we can tackle a number of major problems raised in the current cyber security scenario, e.g. the detection and prevention of cyber-attacks. This tremendous opportunity comes, however, with an array of risks that require attention and action from legislators, economists, civil servants, regulators, educators and AI researchers. This paper is organized as follow: Section 2 shed the lights on advantages and technological weaknesses **of** intrusion detection and prevention systems (IDPS) used nowadays to ensure cyber protection. Section 3 explains how AI technique could overcome various vulnerabilities and shortcomings of these conventional cyber protection devices and presents some experimented application of AI techniques to cyber defense. Section 4 analyzes security risks that arise from the developments of AI based cybersecurity technologies to better identify potential technological and legal interventions to ensure that the impact of AI on digital environment is net beneficial.

2. Intrusion Detection and Prevention Systems

In 2011, Cisco IBSG researchers predicted that, in a world population of over 7 billion people, there will be 50 billion devices connected to the Internet by 2020 [3]. The growth of the Internet is directly proportional to the number of cyber threats and of potential victims of cyber-attacks and unauthorized intrusions. In addition, these cyber threats sprung from a variety of profiles that can't be targeted in advance, ranging from bored teenagers experimenting with the Internet to rogue states and terrorists deploying direct cyber-attacks. This is the reason why protection of sensitive data from computer intrusions – heather unauthorized access (external intrusions) or malicious use of data (internal intrusion) – today has been regarded as a challenge for civilization [1].

Cyber threats are on the raise and cyber-attacks are becoming everyday more complex thank to the use of multiple redundant attack vectors, to multiply the effects, but also making it more difficult for the response teams to analyse [4]. In order to secure critical business information and safeguard data from increasingly sophisticated and targeted threats, single individuals, governmental organizations and private companies spend millions of Euros in wide variety of technological tools, which help system security administrators protect IT assets. Traditional tools of cyber defence are: firewall, intrusion detection systems (IDS), and intrusion prevention systems (IPS) [5]. While an IDS is designed to identify attacks and alert the system administrator to any malicious event to investigate, an IPS is able to prevent malicious acts or block suspicious traffic on the network. IDS and IPS are not mutually exclusive and for decades have been used

[5] SparkCognition, DeepArmor. Website: https://sparkcognition.com/deeparmor-2/.

concurrently, at least until security experts and vendors realized that these tools could be combined to form an Intrusion Detection and Prevention System (IDPS) [6] capable of ensuring twice the protection [7]. The introduction of IDPS was a significant milestone in the development of effective and practical detection-based information security systems. It is the emblem of good security because it combines monitoring, detection and response and effectively help to achieve security goals of confidentiality, data integrity, authentication and non-repudiations [7]. To get straight to their technical aspects, there are software based IDPS, which are installed on a host computer to analyse and monitor all traffic activities in the system application (Host-Based IDPS) [8] and hardware based IDPS, which are located on an entire network to capture and analyse the stream of data packet sent to a network (Network-Based IDPS) [8]. They are primarily focus on a) detecting and identifying possible intrusions, b) analysing information about the intrusions, c) and attempting to stop the intrusions and report them to security experts/administrators.

2.1. Detection Methods: Anomaly Detection and Signature Detection

The purpose of IDPS is to monitor network traffic for intrusions. These intrusions are recognized through two main detection methods: checking variations in routine behavioural patterns (anomaly detection) or patterns matching (misuse or signature detection) [8].

IDPS anomaly-based detection identifies activities that are different from the reference baseline of accepted network behaviour – given by a human expert – or pattern of normal system activity, learned by the system's analysis of the past activity of the monitored network. Deviations from this baseline cause an alarm to be trigged. On the other hand, IDPS signature-based detection compares potential malicious activity to those that match a defined reference pattern of known attacks or known abnormal behaviour. This process relies on the fact that each intrusion leaves a footprint behind – called signatures – that can be used to identify and prevent the same attack in the future. The human administrator has to create a database of previous attack signatures and known system vulnerabilities that can be used to identify and prevent the same attacks in the future [10]. Usually IDPS combine these two detection methods because of their complementary nature. However, even if these methods are used together, currently used cyber security system aren't able to fulfil the desired characteristic for effectively protecting individuals, organizations and companies from an ever-increasing number of sophisticated attacks.

2.2. Anomaly and Signature Based IDPS, Advantages and Disadvantages

An IDPS should have certain characteristic in order to be able to provide effective and efficient security against serious attacks.

They should be able to: a) guarantee a real-time intrusion detection; b) minimize false positive/negative alarms; c) minimize human supervision d) do constant self-tuning; e) adapt to system changes and users behaviour over time. However, currently used cyber security system aren't able to fulfil this desired characteristic. The most critical and obvious technological "lacks" are: lack of automations [11,12], lack of effective detection [10], lack of predictability of the attack and of effective detection of multiple attacks [13] and lack of flexibility [14]. In sum, combination of speed and skilled physical devices and human expertise intervention is no longer sufficient in defending cyber infrastructures from more sophisticated cyber threats. In this complex cyber scenario, cyber defence system need to be: a) autonomous; b) able to effectively detect a wide variety of threats without trigger false alarms and reducing the number of false positive/negative rate; c) flexible; and d) robust. Employment of artificial intelligence techniques in cyber security systems can overcome the weaknesses of the commonly used intrusion detection techniques and, as a consequence, could AI play an effective role in the improvement inconsistencies and inadequacies of currently used cyber security systems. In the following section, will be analysed how application of AI techniques can facilitate cyber security measures, especially in terms of effective detection and decreased false positive and false negative rates, the major issues of intrusion management.

3. Artificial Intelligence: The Future Trend in Cyber Security

As seen in Section 2, considering the complexity of the digital environment, IDPS based on conventional intrusion detection technique (like statistical analysis [9] or rule-based) which rely on fixed algorithms, cannot guarantee enough protection for a cyber infrastructure. Their need for a known data pattern for decision making, and continuous human intervention make these cyber security systems ineffective for contrasting dynamically evolving cyber intrusions. All the major issues of security measures analysed in the Section 2 can be overcome by applying AI techniques. AI is a research discipline of computer science that relies on both software and hardware development, that provides method for solving complex problem that cannot be solved without applying some intelligence [8].

Intelligence is simply the capacity to express an appropriate behaviour in response to changes and opportunities in a defined environment [9]. It can be divided into stages of the independent decision-making process as perception, reasoning, and action. Going back to cyber security AI developed flexible techniques which provide learning capabilities and automatic adaptability to conventional systems – hardware and software – used for fighting cyber intrusions. Intelligent cyber security systems can handle and analyse a large amount of information (perception) and, in case of detection of malicious activity, can analyse this information relying on their experience of previous episodes of intrusions (reasoning) and make intelligent decision on which is the proper counteraction (action). All this in real time and without interaction with human analyst-experts. AI researchers have developed a myriad of tools to secure human behaviour and some are already been experimented in the field of cyber security. This section will focus on the potentials and functionalities of the most promising AI tools: artificial neural network-based intrusion prevention and detection systems.

3.1. Artificial Neural Network Based Intrusion Prevention and Detection Systems

ANN is an information processing model that that simulate the structure and the functions of the biological neural system [12]. Like the brain, which is composed of neurons that transmit signal to each other through synapses, via a complex chemical process, the ANN is a net of nodes (processing elements) interconnected by links that transfer numeric data and can transform a set of inputs in a set of desired outputs [13].

If integrated in IDPS for monitoring network traffic, ANN can overcome the shortcomings of other analysed intrusion detection techniques. Thanks to their *inherent speed, their flexibility* and, most of all, their *learning capabilities*, they are able to stop multiple attackers, quickly predict known pattern of intrusion – even if they do not match the exact characteristic of those that system has been trained to recognize – and reason on information and learned previous episodes of intrusions (experience), to identify new type of attacks pattern, without generate false positive/negative. In few words, IDPSs that rely on ANN are robust, flexible, adaptable and can accurately identify unknown attack without the rule or interaction with the human expert [14]. The results of tests conducted on a neural network offers a promising future in the identification of attack against computer systems. However, security risks triggered by use of AI systems for cyber defense are a matter of concern for both security and legal experts.

4. Security Risks of Artificial Intelligence in Cyber Security

As seen in the introduction and Section 3, more recently AI has been increasingly playing a leading role in cybersecurity's industry.

Since most network-centric cyber-attacks are carried out by highly skilled professionals, which use malware, DDoS, phishing, ransomware, and quickly adopt emerging technologies (e.g. Bitcoins for ransomware payments), private entities and governments are investing in fundamental research to expand the scope of capabilities of AI. Thanks to its autonomy, fast paced threat analysis and decision-making capabilities, AI can enable systems to efficiently detect, defend, and, finally, respond to cyberattack by exploiting the vulnerabilities of antagonist systems. Public curiosity and distress about AI has focused, in particular, on deep, multi-layer machine learning approaches, like neural networks (Section 3.1), seen, nowadays, as essential tools for providing protection. However, less attention has been paid on increasingly pressing security dangers arising from development of AI in cyber security. Next section analyses in details the two major risks that may hamper AI's potential for cybersecurity: possible malicious use [15] of AI systems in digital domains and lack of control [17]. On this basis, interventions are proposed to better investigate, prevent, and mitigate these potential risks. Mapping these criticalities is also vital in order to better appreciate the unique normative challenges of these complex technologies and their impact on current legal systems [18]. These legal issues will be briefly mentions in the Conclusions but are beyond the scope of this paper. They would need further study and a paper on their own to be properly addressed.

4.1. Possible Malicious Use of AI Systems in Digital Domains

A central concern at the nexus of AI and cybersecurity is the potential for malicious uses of AI based systems capabilities.

Because of its generative nature, intelligent systems and the knowledge of how to design them, can be employed for both beneficial and harmful ends. Focusing on the digital security domain, a relevant example is given by AI systems that examine software for vulnerabilities, that might have both positive and malicious applications (e.g. through cyber criminals training systems to hack). Powerful technology falling into the wrong hands (e.g. rogue states, criminal groups and terrorists) would pose grave threats to the security of digital environment. As seen in Section 3, using AI on the defensive side of cybersecurity, makes certain forms of defence more effective and scalable, such as spam and malware detection. But at the same time many malicious actors have natural incentives – which include a premium on speed, labour costs, and difficulties in attracting and retaining skilled labour – to experiment with this powerful technology and develop more sophisticated AI hacking tools, able to evade detection and creatively respond to changes in the target's behaviour. According to a recent report on the potential malicious use of AI [17] – released by the University of Cambridge and jointly written by twenty-six security experts – further progress and diffusion of efficient AI and machine learning based systems in cyber environment might, first of all, expand the set of actors who are capable of carrying out an attack, the rate at which these actors can carry it out and the set of plausible targets[6]. This claim follows from the qualities of efficiency, scalability, and ease of diffusion that characterize AI based systems[7] and implicate an expansion of existing threats associated with labour-intensive cyberattacks, such as spear phishing[8]. Furthermore, the authors of this report expect that progress in AI will enable new varieties of attacks such as: automated hacking, speech synthesis used to impersonate targets and finely-targeted spam emails using information scraped from social media. This analysis, so far, suggests that the digital environment will change both through expansion of some existing threats and the emergence of new threats that do not exist yet. But report's authors also expect that the typical character of attacks will shift in a few distinct ways. In particular, they think that attacks supported and enabled by progress in AI will be especially effective, finely targeted, difficult to attribute, and exploitative of human vulnerabilities (e.g. through the use of speech synthesis for impersonation), existing software vulnerabilities (e.g. through automated hacking), or the vulnerabilities of AI systems (e.g. through adversarial examples and data poisoning)[9]. Possible changes to the nature and severity of attacks resulting from increasing use of AI will necessitate more vigorous counteroperations [17]. However, this may bring an "escalation" in intensity of attacks and responses, which, in turn, may threaten key infrastructures of our societies. The solution may be to strengthen deterring strategies [19] and discourage opponents before they attack, rather than mitigating the consequences of successful attacks afterward. Yet, necessary (though not sufficient) condition of successfully deterring and punishing attackers is the ability to attribute the source of an attack, a notoriously difficult problem[10][20]. However, the report also identifies a wide range of potential interventions to reduce risks posed by malicious use of AI based systems in digital environment, like: a) developing improved technical measures for formally verifying the robustness end detect most serious vulnerability of the system of the system (e.g through an extensive use of red teaming to discover and fix vulnerability) [21] b) formal verification [22], c) responsible disclosure of development that could be misused (e.g. through extensive use

[6] The use of AI to automate tasks involved in carrying out cyberattacks will alleviate the existing trade-off between the scale and efficacy of attacks [16].

[7] In particular, the diffusion of efficient AI systems can increase the number of actors who can afford to carry out particular attacks. If the relevant AI systems are also scalable, then even actors who already possess the resources to carry out these attacks may gain the ability to carry them out at a much higher rate. Finally, as a result of these two developments, it may become worthwhile to attack targets that it otherwise would not make sense to attack from the standpoint of prioritization or cost-benefit analysis [16].

[8] A phishing attack is an attempt to extract information or initiate action from a target by fooling them with a superficially trustworthy facade. A spear phishing attack involves collecting and using information specifically relevant to the target (e.g. name, gender, institutional affiliation, topics of interest, etc.), which allows the facade to be customized to make it look more relevant or trustworthy [16].

[9] Today's AI systems suffer from a number of novel unresolved vulnerabilities. These include data poisoning attacks (introducing training data that causes a learning system to make mistakes), adversarial examples (inputs designed to be misclassified by machine learning systems), and the exploitation of flaws in the design of autonomous systems' goals.

[10] An example of this problem is given by the failure of the United Nations Cybersecurity Group of Governmental Experts to make progress on norms for hacking in international law. (Korzak, E., UN GGE on Cybersecurity: The End of an Era?, (2017). Available in: https://thediplomat.com/2017/07/un-gge-on-cybersecurity-have-china-and-russia-just-madecyberspace-less-safe/).

of different openness models like pre-publication risk assessment in technical areas of special concern, central access licensing models and regimes that favour safety and security) [23] c) responsible disclosure of AI vulnerabilities; d) envisioning tools to test and improve the security of AI components and use of secure hardware [16]; e) promoting a culture of responsibility through education and ethical statements and standards [17]; f) monitoring of AI-relevant resources [16]. The report also points out a number of research areas where further analysis could develop and refine potential interventions to reduce risks posed by AI malicious use like include privacy protection, coordinated use of AI for public-good security, monitoring of AI-relevant resources, and other legislative and regulatory responses.

4.2. Lack of Control

Further development of AI based defence technologies will increase the complexity of tasks they can perform autonomously, while reducing human ability to understand, predict or control how they operate.

For this reason, the activity of these autonomous systems, to which increasing difficult tasks are delegated, should remain, at least partly, subject to human supervision, either "in the loop" for monitoring purposes or "post-loop" for redressing errors or harms that arise. Progressively less effective control on AI based system used for cyber-defence will increase the risk of unforeseen consequences and errors. This safety challenge has brought a group of security researchers from MIT's Computer Science and AI Laboratory (CSAIL) and a machine-learning start-up known as PatternEx to focus not only on machine automation but also on a better human-computer interaction. In 2016 they designed a neural network based cyber security system, with a human-facing interface that only bothered its human teacher at the right time, called "AI Squared" [25]. It is not a fully automated system, but rather, relies on human control while still being efficient at predicting, detecting and stopping 85% of cyber-attacks with high accuracy, by reviewing data from more than 3.6 billion lines of log files each day. The system first scans the content with unsupervised recurrent neural network techniques and parses data generated by users for potentially odd activity. This process is called "unsupervised learning." Once the neural network has identified the anomalies, it presents its findings to human analysts. The human analyst then identifies which events are actual cyber-attacks and which are not. This feedback is then incorporated into the machine learning system of "AI Squared" and is used the next day for analyzing new logs. This system does not overwhelm the human analysts, and instead, carefully limits the information. The analysts can also give feedback anywhere at any time, either on their smartphones or computers, so that the system can always be learning. In few words, human analysts in AI Squared have the final say back and can control errors and unexpected behavior of the AI system. It is a great example of how even the most advanced AI still needs humans to truly learn—and as a result, still needs designers to craft the language that the human/machine team uses to talk to each other.

Conclusions

This paper has offered a concise analysis on how AI techniques could overcome various vulnerabilities of conventional cyber protection systems (Section 2). Some experimented applications of these techniques to cyber defense are also proposed in Section 3.

Increased use of AI for cyber defense, however, introduces new security risks that may hamper AI's potential for cybersecurity and are a matter of concern for both security and legal experts. Section 4 dwelt on these criticalities that arise from the developments of AI based cybersecurity technologies, in order to shed light on the wide range of potential interventions that can be carried out (Section 4.1) – or that are already developed (Section 4.2) – by AI researchers and practitioners so as to tackle these risks. Yet, these technological solutions to be effective must be supported by a clear legislative and regulatory framework, able to reduce threats triggered by these new technologies and increase stability without hindering research and development in the field [26]. To prevent security risks, regulators and policy makers should learn from other domains with longer experience [27] and put in place rules ensuring safety of products in the commercialisation phase (e.g. through testing, certification and insurance mechanisms), coupled with well-designed financial incentives and liability safeguards to mitigate intentional or unintentional harmful outcome of AI applications. In the cyber security domain, policy and regulations may also mitigate the dangers of lack of control on AI systems by ensuring proportionality of responses, the legitimacy of targets, and a higher degree of responsible behavior.

Contrary to popular belief, the AI industry development does not take place in a regulatory vacuum and a *de facto* AI legal framework already exists [28]. General Product Safety Directive 2001/95/EC (GPSD)[11] and the Product Liability Directive 85/374/EEC[12] apply, for example also to innovative businesses working with AI. However, the most salient characteristics of AI technology, like their unpredictable behaviour or the complexity of the ecosystem behind machine learning [18], trigger new legal issues that make the current EU regulatory framework particularly unsuited to address risks brought about by the use of intelligent and autonomous systems[13]. Admittedly, these new legal challenges of AI systems vary in accordance with the field under examination: international law, criminal law [29], civil law, both contract and tort law, administrative law and so forth. Focusing on civil law, AI security systems may rise legal issues that include, but are not limited, to liability and data governance. With regard of liability, scholars have stressed time and again the complexity of distributed responsibility [30], drawbacks of strict liability policy [18] – that may hinder technological research – and the need of new methods of accountability and insurance policy. A concise analysis of legal issues goes beyond the scope of this paper, whose primary aim was to draw attention to the security risks triggered by the use of AI in cyber defence, rather than specific policy proposals. In this respect, it is interesting the recent call for application concerning the Expert Group on Liability and New Technology recently published by the EU commission[14]. Still, it is crucial to start shaping policy and regulations for the use of AI in cyber environment while this technology is nascent. To do so, close collaboration between legislators and technical researchers and mechanisms of legal flexibility [26] are vital to shape regulation able to prevent and mitigate potential AI risks avoiding the implementation of measures that may hamper research progress.

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[11] Directive 2001/95/EC on general product safety. Available at: http://ec.europa.eu/consumers/consumers_safety/product_safety_legislation/index_en.htm.

[12] Directive 85/374/EEC on liability for defective products. Available in: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31985L0374.

[13] For this reason, the EU Commission started the process for the amendment of the aforementioned directive in September 2016 [18].

[14] EU Commision: http://ec.europa.eu/newsroom/just/item-detail.cfm?item_id=615947.

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Money Laundering Detection Mechanisms and Legal Obstacles

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Abstract. Despite the major obligations imposed by Anti-Money Laundering (AML) policies and regulations and the implementation of compliance regimes inside financial institutions (FI) (specifically Retail banking), this sector is still being affected by launderers. In this paper, we analyze the main characteristics of this type of crime, the legal implications deriving by the 4th AML Directive in the FIs duties and how technology can help in the fulfilling of those duties.

Considering the main characteristics of some ML methods, we propose a multidimensional system that combines different technology, adapted from each stage of the ML detection process that could be able to prevent and detect ML inside the banking sector. The efficiency of those systems requires an effective understanding of the main characteristics of the crime and the activity of the sector. However, also entails an articulation between AML duties and certain legal criteria that determine which evidence is lawful in criminal proceedings.

What we propose is that the same technology that could be used inside the institutions to prevent and detect the attempt or the occurrence of money laundering practices could be used in a criminal procedure as a legal evidence

Furthermore, the fight against ML represents a conflict of duties and interests. So, the adoption of a system must balance the compatibility between the protection of fundamental rights and the fight against organized crime. This paper is an outcome of multidisciplinary approach looking at the need to combine efforts and knowledge between legal studies, banking practices and technology to step forward in an effective fight against ML. The results of this work demonstrate that the use of AML software in FIs can work on prevention and detection ML inside the institutions, as means of evidence in a criminal prosecution and can also mitigate the conflicts between legal prosecution and fundamental rights like privacy and presumption of innocence.

Keywords. Money Laundering; AML software; Evidence.

1. Introduction

The progress of economics and technology are defining our modern society every day which is increasingly becoming more global and virtual.

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According to Beck, this progress entails the comprehension of modern society in a new context which produces new and important risks and the impact of those risks are undoubtedly, more than a characteristic, it is what it defines as a risk society (*Risikogesellschaft*)[2].

In this society of risk, criminal law and criminal procedure is called upon to give a response to emerging threats, whose effects are no longer limited by space or time.

As result of this new paradigm, the banking sector is one most area that felt the urge to adapt their activities to this new reality. According to a study conduct by ThomsonReuteurs (2018) more than a third of all firms overall and almost half of G-SIFIs (48%) are expecting more compliance involvement in the assessment of Financial Technology (Fintech) and Regulatory technology (Regtech) solutions in the coming year. One of the most delicate compliance issues is the prevention of money-laundering activities[12].

According to OCDE, the six largest banks have seen their compliance costs double from USD 34.7 billion to USD 70.1 billion because of acquiring new resources to fight financial crime. A recent survey by KPMG has brought to light that banks estimate the risk of AML compliance growing year on year [26][7].

Criminal law has, therefore, had to change accordingly[42]. One of those changes has been the way in which this area of law protects legal values or *Rechtsgüter*, conferring protection not only in cases where the legal value had been damaged but also where the legal value is simply at risk. To give an example, criminal law, therefore, proceeds to not only criminalize behaviours such as terrorist acts but also terrorism financing [37]. The underlying idea is to anticipate the protection of legal values such as life or others. We also have seen a shift in the material scope of traditional dogmatic concepts and principles of criminal law and criminal procedure, namely blameworthiness, criminal responsibility of legal persons and greater limitation of fundamental rights in order to gather evidence [29].

Our paper will focus on ML as it is a crime which feeds on benefits from the globalization phenomenon, advances in technology and means of communication.

After an initial overview of the current definition of ML, the especially impact in the financial system, resulting in a new approach based on risk in the constructions of the principles, policies and procedures by those institutions.

Furthermore, we will be appraising the role that technology, especially Fintech [46], can assume in preventing and detecting ML, by proposing an ideal system (AML Software) that combines different technologies that could fulfil the AML duties.

What we propose is that the same technology that could be used inside the institutions to detect the attempt or the occurrence of ML practices could be used in a criminal procedure as a legal evidence. By that, we briefly refer the assessment and the impact of this software in digital forensics investigation [26][31][33], specially the validity of evidence gathered using those systems [29][44].

Lastly, we examine the conflicts of duties and rights that may arise as a result of the necessity to tackle ML and how technology can mitigate those conflicts.

2. Money Laundering

Money Laundering (ML) is a practice that is evolving and attracts attention due to its specific characteristics, methods and impacts[2].

One of the goals commonly attributed to criminal acts is profit. ML is the processing of these criminal proceeds to disguise their illegal origin (FATF) [21].

With these practices, criminals put at risk the integrity, the stability and the confidence in the financial system. Some risks additionally experienced by FIs are the following: reputation risk, operational risk, concentration risk and legal/compliance risk [35].

According to the United Nations the aggregate size of ML in the world could be approximately USD 2.1 trillion which is equivalent to 3.6% of global GDP [1] and the amount of money generated from criminal activity in the main illicit markets in the EU has been estimated at €110 billion per year, corresponding to 1% of the EU GDP [14].

For criminals to benefit fully from the proceeds of their crimes, these criminal proceeds need to be laundered [13]. The laundering process includes different phases: placement, layering and integration.

The need to fight this criminality is self-explanatory. By intercepting illicit profits (from, for example, activities such as drug trafficking, fraud or terrorism) criminals do not benefit from their illegal activities and have less money to fund them (trafficking, terrorism) [45].

The financial system has to strike a balance between a competitive and sophisticated approach to business and the prevention of ML through it.[9] This means that FI are expected to identify, assess and understand the Money Laundering/Financing of Terrorism (ML/FT) risks to which they are exposed and take Anti-Money Laundering and Combating Financing Terrorism (AML/CFT) measures commensurate to those risks in order to mitigate them effectively. The risk assessment provides the basis for a risk-sensitive application of AML/CFT measures [15].

Following this procedure, i.e. assessing the risk, FI can then determinate the level of diligence that is due, whether due diligence based on KYC (know your costumer) and KYP (know your partner) or an enhanced due diligence that basically reflects a greater scrutiny to ascertain additional information about an individual or legal entity[41].

On the one side, KYC consists of policies and procedures that require FI to conduct due diligence on all customers to determine and verify their identities, source of funds and nature of business, KYP, on the other, demands from a FI an active approach in knowing and obtaining reliable information on potential business partners, specially to understand the standards used by them in fulfilling compliance's requirements, in processes such as customer identification, account monitoring and screening. This is

[2] The most recent 4AMLD, the Directive EU 2015/849 (article 1, no. 2), ML is defined as: "(a) the conversion or transfer of property, knowing that such property is derived from criminal activity or from an act of participation in such activity, for the purpose of concealing or disguising the illicit origin of the property or of assisting any person who is involved in the commission of such an activity to evade the legal consequences of that person's action; (b) the concealment or disguise of the true nature, source, location, disposition, movement, rights with respect to, or ownership of, property, knowing that such property is derived from criminal activity or from an act of participation in such an activity; (c) the acquisition, possession or use of property, knowing, at the time of receipt, that such property was derived from criminal activity or from an act of participation in such an activity; (d) participation in, association to commit, attempts to commit and aiding, abetting, facilitating and counselling the commission of any of the actions referred to in points (a), (b) and (c)".

fundamental to set up an environment of trust that all stakeholders are stepping up and complying with AML/CFT policies [16].

3. AML Software

3.1. Risk-based Approach

The risk-based approach (RBA) is central to the effective implementation of the revised FATF[17] International Standards on Combating Money Laundering and the Financing of Terrorism and Proliferation, which were adopted in 2012.[22][18][17]

The determination of the nature of the risk and its level is paramount to the definition of the pattern of risk associated with a certain client and, consequently, the level of diligence that is required from the FI[21].

Usually, levels of diligence encompass the standard Costumer Due Diligence (CDD), Enhanced Due Diligence (EDD).

CDD information comprises the facts about a customer that should enable an organization to assess the extent to which the customer exposes it to a range of risks. These risks include money laundering and terrorist financing. Standard due diligence requires FIs to identify their customer as well as verify their identity. In addition, there is a requirement to gather information to enable you to understand the nature of the business relationship. This due diligence should provide you with confidence that FIs know who their customer is and that their service or product is not being used as a tool to launder money or any other criminal activity[3].

Simplified due diligence is the lowest level of due diligence that can be completed by a customer with the simplified due diligence criteria then their only requirement is to identify your customer.

This is appropriate where there is little opportunity or risk of your services or customer becoming involved in money laundering or terrorist financing.

EDD lists specific cases that must be treated as high risk situations, namely where the customer, or the customer's beneficial owner, is a politically exposed person (PEP), or there is a relationship with a respondent institution from a country that is not part of the European Economic Area (EEA), or there is a complex and unusually large transaction, or unusual pattern of transactions, that have no obvious purpose.

3.2. AML Software

The RBA is critical to the effective implementation of AML policies and has been adopted by IFs that are privileging software that put into practices their RBA model.

For Sullivan[43] there are four phases of a risk-based approach to AML: identification, analysis, management and review.

[3] According with the Directive (EU) 2015/849, CDD means identifying the customer and verifying the customer's identity on the basis of documents, data or information obtained from a reliable and independent source; identifying the customer's beneficial owner and taking reasonable measures to verify their identity so that the obliged entity is satisfied that it knows who the beneficial owner is; assessing and, as appropriate, obtaining information on the purpose and intended nature of the business relationship; and conducting ongoing monitoring of the business relationship. This includes transaction monitoring and keeping the underlying information up to date.

Identification means the AML risk is able to identify the general risk to all FIs (this could include either a customer-related or issue-related risks) and a particular risk of the concrete institution based on there own characteristics such us principle activities, products, location, etc.

Then in FIs, there should be an understanding of the risk, its nature and level of risk (analysis). The formula used to decide the level of risk should be included in the policies and procedures. Procedures and policies should be built upon this knowledge (management)[8] and reviewed to see if they are effective.

Perform KYC analysis according the FIs procedure and perform regular review of the clients (includes the management of the clients' classification related to other regulations such as Markets in Financial Instruments Directive II (MiFID II) (when is an Investment bank) and Tax regulations (such as foreign Account Tax Compliance Act (FATCA) and Automatic Exchange of Information (AEOI).

AML software is used in the finance and legal industries to meet the legal requirements for FIs and other regulated entities to prevent or report money laundering activities. At a technical level, AML software implementation is riddled with obstacles. There is the question of quality, volume and heterogeneity of the analyzed data, the diversity of sources, the costs of executing and maintaining a system, the non-uniformity of standards, concepts and procedures. Yet there are many offers in the market. They often capable to combining different techniques such as Data Mining (prediction, classification, clustering, regression, and others), Artificial Intelligence (particularly, Machine Learning [3] and Robot-advisors [24]) and Encryption[38], using Public Key Encryption (EPKE)[35], and qualified electronic signatures in the communications.

There have been studies and projects on using Blockchain [34] to payments, trade, financing, verification of customers and counterparties identity, especially important between trades with FI's located in third countries or small FIs that do not have the same standards of procedures regarding identification and CC or lack the capability of implementation of automatic systems to assist them in those procedures. However, we are, at the present moment, in an early stage of Blockchain applications.

4. A multidimensional AML software: a proposal

4.1. General considerations

For that purpose, we present a cloud-based proposal with an Investigative Software AML platform that should be integrated into the internal control system of the bank, by implementing a unified financial crime platform focused on strengthened AML capabilities and integrated different solutions such as Customer Due Diligence (CDD), transaction Monitoring, sanctions Screening and Case Management applications.

Taking into account what has been said about the technologies used in AML software – namely that the main objectives of an AML system are to collect the largest number of data from different sources by combining and analyzing the data based on external information and peer groups, comparing the data with the established risk standards; monitor behavior and confront it with risk patterns and during this process of analysis and verification, preserve data security and privacy – we envision a system capable of combining a set of techniques to be integrated into the core banking system (when this is able to integrated different elements such as Opening new accounts;

Processing cash deposits, withdrawals, payments and cheques; calculating interest; Customer relationship management (CRM) activities; Managing customer accounts; Scoring and analyze risk and Maintaining records for all the bank's transactions) [16].

This system should be able to capture and auto-fill basic personal identity information, assess group and analyze the information available throughout the FI, with qualified applicants from a risk perspective in a cloud computing access interface, allowing the centralization of information, availability and access authentication.

4.2. Client Onboarding

In the domain of banking activities (Retail bank), when an opening account, the bank should identify the client, verify the authenticity, integrity and completeness of the information provided. Based on that information, the system must automatically determine the acceptance or rejection of the client or, if needed, solicit more information. This could be done by the core banking system (when include that option) or by a core bank account opening system.

Also, the system must determine a control structure that is able to analyze variables and choose a direction to go based on given parameters. The flow control details the direction the program takes. Hence it is the basic decision-making process in computing; flow control determines how a computer will respond when given certain conditions (pre and post conditions) and parameters.

In this case, at first the details required and, subsequently, the acceptance or not is determined by the system using condition texts based on control structures like [IF-THEN-ELSE Statement] [28].

Second, the system must compare the information given by the potential client with "Watch lists", where data mining techniques and machine learning might prove useful.

All this process is mostly built on a rule-based approach for determining and verifying the existence, nature and the level of risk.

The opening account procedure should be carried out in a virtual environment using cloud platforms and qualified digital certificates. After approving the client, the software should create a virtual identity (ID), that does not reveal, directly, his personal information, to be used in all operations where the client is involved.

4.3. Filtering

Based on a RBA, there is a need to determine the existence, nature and level of risk [16][19][21] [36] To that end the system might use Intelligence Artificial in Data Mining, Ontologies [5][10]and Fuzzy Logic [31].

Briefly, AI in Data Mining is used to classify the risk (classification), establish different patterns of risk based on third parties' information - as peer group analysis (regression), determine future behavior expectations (prediction) and then group a set of clients (called a cluster) that are more similar and demand a specific level of diligence.

The use of fuzzy logic is an approach to computing based on "degrees of truth" rather than the true or false and is used to determine the semblance of information that could help the system to find similarities and detect connections [32].

The ontologies based on risk is crucial to find patterns of risk and understand relations that is required to extract knowledge and to represent and share risk knowledge in a given application domain.

4.4. Monitoring

Banking records are the main sources for identifying ML. However, it is necessary to process and cross-reference information (deposits, credits, applications) with a client that might assume different roles (beneficiary, issuer, trustee...). The monitoring process entails the interconnection of data arising from different operations. This is a process that accompanies the relationship between customer and bank. The pattern of risk established in the "opening account process" can change, considering the customer' behavior and the data provided. So, based on the information extracted from this process, the level of due diligence required can change also and, because of that, it requires different measures to fulfil those obligations. Increasing diligence is an intensification of this procedure [39].

In this process, the system must combine Data Mining techniques, Artificial Intelligence in Data Mining to construct Artificial neural networks (RNAs) and support vector machine (SVM) and use a Multi Agent System [24][40].

To implement this system, it requires to bring together sufficient data do deploy the techniques. So, the system must be able to exchange massive volumes of data that need to be stored during the monitorization process and then be managed. This requires technology able to select, compile and cross-referencing of information Bank's storage systems need to be a completely centralized enterprise storage.

By that purpose, we use a data warehouse, as repositories of organizational information where the data is located. For the analysis of the information is carried out operations of discovery in the information (able to identify and extract the data) through the segmentation (Clustering) grouping of the information that contains common elements.

It is important to use a cluster type methodology to group the data, based on common elements and pre-knowledge of suspicious behavior, in order to extract relevant information. Clustering allows the analysis of these correlations to determine profiles and detect suspicious patterns. The classification as suspicious or not will depend on rules set according to the client's profile, but also on regulatory rules on the nature of suspicious behavior. Through the data mining derived from the transaction movements, the client profiles are updated, grouping them into clusters and generating set of classification rules [6].

These are the so-called historical series that enable a better analysis of past events, supporting present decision-making and predicting future events. Data in a data warehouse is not volatile, that is, it does not change, except when it is necessary to make corrections to previously loaded data.

Alternative could be use a blockchain database that is able to store data indefinitely. Her inefficiency yet is her ability to process the information in time but the ability to storage data from different sources.

Pattern recognition is a mature field in computer science with well-established techniques for the assignment of unknown patterns to categories, or classes. Usually a pattern recognition system uses training samples from known categories to form a decision rule for unknown patterns. The unknown pattern is assigned to one of the categories according to the decision rule. The application of this technique is to find "unusual" or "suspicious" transactions, we can use pattern recognition techniques to try to classify previously unseen transactions into the client's profile. While pattern recognition techniques require that the number and labels of categories are known, clustering techniques are unsupervised, requiring no external knowledge of categories. Clustering methods simply try to group similar patterns into clusters whose members are more similar to each other.

Thus, the system must express these standards as a formula or set of instructions that can be applied to new and unseen data. Without supervision, because the FI does not know which data is "fraudulent", the model should mark any behavior that does not fit the profile and should be considered an "anomaly". The construction of Artificial Neural Networks and Support Vector machine are data mining models with non-linear learning capacity, namely in the performance of classification and regression functions.

Artificial Neural Networks are fundamental in identifying and classifying patterns. Throughout monitoring, the data relationship should predict the cross-referencing of the different operations involving the clients, assuming the role of account holder, beneficial owner or trustee.

Additionally, it is important to establish a social network analysis. This allows to understand the client's network of connections, their role and interactions, as well as areas and volumes of transactions. More analysis can reveal critical roles and subgroups and vulnerabilities within the network. The data resulting from this analysis should be analyzed, leading to the creation of news clusters.

By using AI it is possible to construct artificial neural networks of construction and identification of patterns, that is, using supervised models it is possible to recognize indicators of ML and to establish relationships with third parties, allowing visual construction diagrams, the flow of amounts between various bank account holders.

One of the difficulties of the detection is the understanding of the indeterminate concepts established by the legislation as "frequent" or "abnormal", as well as the treatment of incomplete, imprecise and redundant data. This leads us to the use of ontocube [5] and fuzzy logic algorithms. The applications of ontologies allows the system to determine and define the meaning of concepts, as a formal naming and definitions of properties or interrelationships, such as "Frequent Deposits" that is somewhat difficult to understand in the monitoring process. And in cases of lacks information's or inconsistencies can be processed using this algorithm (Fuzzy logic) so that conclusions can be drawn that may be meaningful and coherent for analysts.

In this case, we propose, as well, a multiagent system that, not only is able to capture suspicious transactions, but also it is capable of using data mining techniques to create transactional behavioral profiles, apply rules generated in a learning process in conjunction with specific rules based on legal aspects and profiles created to capture suspicious transactions; and analyze those suspicious transactions indicating to the human expert those that require more detailed analysis.

4.5. Verification and analysis

When the transaction shows some risk, the information is sent to the compliance officer to be analyzed. The main focus here is proper identification of the transactions and avoiding false positives.

The systems should provide algorithms take advantage of the large pools of data and heightened computing power available to detect patterns that might go unnoticed by data scientists.

Systems using AI can discern, for example, whether a series of transactions represents possible money laundering or a more innocent activity, such as a sudden wave of overseas expenses. According to McKinsey (2017) machine-learning algorithms can help reduce the number of false reports by 20 to 30% [4].

This should be an automatic and anonymous process, with the application of zero proof knowledge[4] and hashing[5], so that personal identity is only revealed when there is a strong indication of ML practices [11].

Using zero-evidence tests summarily allows the anonymization of the data to depend on a condition of non-suspicion. Once the "suspicious" condition is verified, the identification is revealed, without further information In this case, Zero-knowledge proof is used to allow the analysis of the transaction without revealing the identity of the persons involved[31].

Thus, it is possible, during the monitoring and analysis, through cryptographic techniques, to guarantee the anonymization of the data while being monitored and analyzed. A hash value can be used to uniquely identify secret information and find similar and duplicate records.

At this stage, Banks have been researching new ways to share customer information across their company (in a bank's departments units and also across group companies view) in a secure manner.

A blockchain-based solution is a potential solution, based on the cryptographic protection that could help keeping the information secure while having the ability to share a constantly updated record with many parties. Gathering blocks of data of information related to transactions and using a decentralized database allowing a permanent record of transactions could simplify the administrative process by reducing unnecessary duplication of information and requests[30].

4.6. Communication

After detecting a suspicious activity related with ML the system should be able to fill out a report and send it to the authorities. That report should have a digital form, able to identify the persons involved, the suspicious transactions the operations and the amount of money involved, the third parties and the reasons to justify that classification and be self- explanatory such as how the system was able to "extract" that position.

The digital evidence is the most appropriate tip of proof for this purpose because allowed not only the information that is in digital format but even allows the analysis and correlations of data that the software automatically does and storage.

In centralize model of communication (such as the USA) this system could be use in banks and have the automatic connection with FinCen' software, allowing them to share automatically the information. Attending to our Portuguese model of

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[4] Briefly, a zero-knowledge proof or protocol allows a "prover" to assure a "verifier" that they have knowledge of a secret or statement without revealing the secret itself. So, in this cause would allowed the FIs or compliance department to know that there is a suspicious transaction, according this pre-establish rules and patters but without revealing the identity of the costumer. So, during the process of analysis and exam or even the communication (if we had a central communication model) the verifier learns nothing apart from the validity of the statement. So, they will just know if the transaction is or not suspicious.

[5] Briefly, *hasing* is the use of a number to represent a piece of computer data so that it can be protected or be found quickly. The use cryptographic hashing for storage and communications allowed the system to collect and to communicate (depending on the model of communication to authorities or compliance officer) without revealing the content of the information. Another benefit of this techniques is that allowed the receptor to know if the message (the report) was altered or attack by a third party.

communication' system, law enforcements and regulators could access this digital report (with the analysis and information compiled.) or in actions of surge in the bank's facilities by accessing directly the software.

Communication between banks and authorities must be as secure and impermeable to cyberattacks as possible.

One feature we consider to be fundamental when communicating is guaranteeing authenticity and integrity of the information provided in communications. In other words, ensuring that the information received is identical to the one that was sent. Thus, considering the information security concerns, because information can be tampered with, introducing a hash function constitutes a good safeguard to guarantee the integrity and authenticity of the information [13]. Cryptographic hash functions, as we said previously, are useful to ensure message integrity. By comparing the hashes created before and after data transmission and there are differences on the combination that gives an answer on whether the information has been tampered with [15].

4.7. Learning

The methods of ML are ever-changing and can be adjusted to fool the system. So, the system must be able to learn automatically by using techniques such as Machine Learning to find new patterns and ontologies to extract new concepts from the behavior analysis [25].

5. Legal quandaries

The fight against ML calls for the analysis of several legal questions. Conflict of duties, validity of the collected evidence in a specific criminal process and data protection are some of them.

Conflicts of duties may arise as FIs have a duty to communicate and collaborate with law enforcement agencies and regulators but also need to maintain their customers' trust and the mutual confidence and respect of their costumers' privacy.

A fundamental part of the relationship between a bank and its customers is that the customers' dealings and financial affairs will be treated as confidential. This principle commonly fails in face of laws in the field of anti-terrorism, AML and illicit substances' production and trafficking.

According to AML legislation, namely the 4AML, the duty to report overrides the customer's privacy bank privacy. Nevertheless, we must not neglect that there are fundamental rights at stake and the respect of legal requirements is fundamental if evidence provided by FI to law enforcement agencies is to be used in court proceedings and also regulatory investigations.

Another possible legal quandary might lie on the clash between privacy and using of surveillance systems, especially considering that those being surveilled and scrutinized are not (yet) suspects of committing a crime. Furthermore, "whistleblowing" and collecting data are tasks given to the non-state actors. Anonymization and automatization could mitigate these concerns.

A final word to emphasize the importance, in the context of the European Union, of complying with the General Data Protection Regulation (GDPR) as to collection, analysis, storage and sharing of personal data.

In the context of the European Union, anonymization of any historical data retained within the AML software (to help identify patterns of suspicious behavior) would mitigate the risk of breaching the GDPR.

Another concern that these systems may help is with cross border institutions and the conflicts of laws and duties as well different standards of data protection. However, the European Union legislation is one of the most careful and concern with data protection. So, if the headquarters or the place where the crime is prosecuted in Europe, the evidence gather in the AML software would be accepted as a mean of evidence.

6. Conclusion

In our view technology can play a vital role in the detection and prevention of ML/FT and can represent a helpful instrument for all the stakeholders involved: bankers, because it helps to comply with their obligations regarding to AML, to regulators to help them understand the control system used by the obligated entities, to the law enforcement agencies in regards of criminal evidence and ultimately for the customer as its privacy is better safeguarded.

By using proper AML software, designed to protect personal data and minimize the intrusion in fundamental rights, a balance can be struck between privacy as well bank secrecy (protecting as well the confidentiality of banking operations, mitigating the conflicts of professional duties and the prejudice side effect of the "*whistleblower*" figure), and the need to deal with a criminal phenomenon of great complexity and wide-range effects.

For future studies, briefly I would say the challenges that online banking, mobile banking apps and online opening account bring to those questions, particularly the long distant identifications (using digital signatures, biometric data, or even selfies). Another question that is going to be "hot topic" is the adoption of blockchain and the possibility of sharing costumer's information's; Even the use of cloud computing brings questions not only safety but responsibility; And at last how banks are going to respond by the fear of sanctions actions, the occurrence of administrative proceedings or criminal charges against banks for lack of efficient and appropriate policies or compliance's process to prevent and detect money laundering.

In conclusion, using the words of Alan Turing (1950) "*We can only see a short distance ahead, but we can see plenty there that needs to be done.*"

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'Dromocrazia' and Human Rights. Big Data and Data Protection in the Information Society

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Abstract

This paper argues that the reluctance of states to engage themselves international law-making has generated a power vacuum, lending credence to claim the international law fails in addressing modern challenges posed by the rapid development of information and communication technologies. In this direction, the great economic operators tend to occupy, in an ever more exclusive way, every intermediary space between producers and consumers, assuming a strong power, subtracted to any democratic rule. Digital intelligence has become an invasive and difficult form to ward off that makes it necessary to research, also on the regulatory level, new balances to safeguard the freedom of enterprise and the right to privacy.

Keyword

Big data, Internet of things, privacy by design, data protection, human rights, cyber security.

1. Introduction

The massive use of digital tools enters into the question related to bipolarity, determined by opposite guidances of thought among those who trust in the accuracy of numbers and who considers the formation of choices and objectives a phenomenon irreducible to an arithmetic function, which can be carried out by any technological support in its

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development, constitutively, unpredictable and not precalculable [1]. On the subject a literature has developed that urges to go beyond the apparent functionality of the new economic strategies, built on the use of information, or Big Data [2], to take the pervasive aspects related to human existence and flattening of its originality in the order of an 'anonymous morality' that obscures the specificity of the ego, concerning: 'what data do not say'. The digital economy uses control instruments through everyday devices, as the smartphone, the computer, the fidelity cards, whose ease of use contrasts with pervasiveness and, above all, with transparent rules that make users aware of the purposes that the collection of those data allows to pursue. In addition to an increasingly invasive technology there are invisible controllers, identifiable in the elaborated processes of elaborating and transfer of data to third party that treat the person profiled as an subject of study and his choices as a commodity for statistical calculations [3]. The digital dimension envelops existence and obscures the awareness that beyond physical integrity, adequately protected by the distance generated by the IT tool, there are risks for the person connected to the ability of an algorithm [4] to become a key through which choices and behaviors are foreseen and oriented in a manipulation of the minds and of the imperceptible will but no less dense of effects on life. The necessary balance comes into play between respect for the limit, connected to the exercise of freedom and human dignity and the exercise of private economic initiative, guaranteed constitutionally by art. 41, together with the relationship between individual and market, freedom and security, rule and measure of the degree of civilization of every social community. The balance between divergent interests degenerates in favor of social functioning when the human being is met as a mere 'digital computation' among so many 'I' that egoistically interact without ever assuming the qualification of 'us'. Contrary to the orientation of those who consider the current effective social dynamics "strategies to abolish the ideology of the isolated Self" social networks amplify the spread of a "mass narcissism" modeled along the lines of a "moment that makes you happy (καιρός), by making the space-time distance disappear by magic" that only in some cases facilitates the formation of real social aggregations. Every time that man is deprived of the specificity of language, he becomes a "sentient entity", confined in a state of "solipsism of the ego ... alien to the dialogic discursiveness", unveiling, "for every speaker, the awareness of being a subject of hypotheses"[5].

In particular, access to the network is the main channel for the transfer of personal data and information that endorse the development of private companies [6], government agencies and large commercial networks through the commercialization of Big Data, refined information that does not causally refer to the known Big Brother because able to monitor, through the use of intelligent machines [7], thought, in the past, to automatically calculate and, today transformed into a tool for generating data and information [8]. The search engine Google, first of all, was able to use Big Data and to mature a role and a power wider than that of governments, showing the effects that can affect the management and access to information assets in 'calculate', with refined methods, present and future society and, at the same time, showing the ease of handling information: «A developed culture is not only concerned with accumulating data, but also takes care of it: it analyzes them, puts them in context, interprets them. Today, however, the information speed erases and rewrites in a continuous cycle. It is no coincidence, unfortunately, that the two professions today at greater risk of extinction are librarians and journalists. The story is likely to be reduced to a perennial hic et nunc and we - concludes Floridi - could end up imprisoned in a perennial 'now'.

2. Internet of things

The "There is no easy way to predict how these powerful tools will be used ... accumulating disproportionately in the hands of corporations seeking financial benefits or governments aspiring to even greater control. There's a chance that Big Data and the Internet of things make harder for us to control our lives, and as we become increasingly transparent to large corporations and government institutions, they become more and more murky".

These considerations shed light on the problematic issues that challenge digital society [9] in the necessary passage from the person to the data, according to an orientation that unfolds starting from the awareness of the structural transformations of lifestyles, in the organization of work, in economic processes, in modernization of the public administration that records the essentiality in the collection and management of information. From online behaviors (pages visited, purchase preferences, shared information), to data collected from various applications (faster routes, vital functions of our body, geographical position) or contained in e-mail accounts, to intelligent sensors that capture also the moods, everything revolves around the profiling of messages and techniques capable of elaborating refined digital identities [10]. Connecting Internet to any type of apparatus becomes a prodromal process to the idea of a permanent connectivity that dramatically expands the ability to collect, store, process information that allows, exceeding the limits of time and space, to aggregate a huge amount of data at low cost (for example the potential offered by the Cloud).
The IOT generates a type of integration that focuses attention on the intelligence of things: from traffic lights to refrigerators, from bracelets to shoes that guarantee a high level of service quality to the detriment of the privacy of individual users. The information is not only the general information, but the deep accumulation of interests, opinions,

consumption, displacements, in essence pieces of life that, like pieces of a mosaic, form the identity profile of everybody. Digital space is not a parallel reality, but the dimension in which an increasingly important part of real life unfolds, since every act leaves digital traces that no one can make disappear and the representation of the person is increasingly entrusted to fragmented information and scattered in databases whose location is often unknown. Also the relationship between public power and person is increasingly based on an incessant collection of data, on the 'demiurgic' function of the algorithm that classifies and elaborates profiles, indexes people as unconscious abstractions, suspended in an immaterial dimension and unable to exercise their freedom. When the person is dematerialized it is bound to coincide only with the information concerning him, which other subjects choose to select, process and reveal through search engines. In this way, that information becomes the only projection in the world of everyone's being, not a virtual double that joins the real person but an instantaneous representation of an entire life, capable of to condition individual memory, to direct relationships and destinies of everybody.

3. Big Data surveillance over time

The data collected and stored are processed to analyze individual and collective behavior based on information that, over time, shew a real impact not only on economic-business dynamics but also on espionage. The data acquired and collected for commercial purposes are becoming increasingly interesting also for the security to which they are irreversibly intertwined due to a wealth of information so massive to base and direct the whole economic activity on the value of data. The offer of free services in exchange for the massive collection of information gives to an increasingly limited number of network operators the possibility of predicting and at the same time directing the decisions of each individual.

In this direction, the great economic operators tend to occupy, in an ever more exclusive way, every intermediary space between producers and consumers, assuming a strong power, subtracted to any democratic rule. Consider the invasiveness determined by new projects and applications, destined to have a significant impact on everyday life, as in the case of wearable sensors or home automation, which traces, with intelligent objects, every action through a control that permeates every aspect of existence. The indiscriminate use of these means concerns the risks related to the dissemination of images taken with drones, equipped with micro-cameras, or the myriad of video cameras spread throughout the territory, capable of exploiting even facial recognition [11] techniques or reporting anomalous behavior.

In Italy Data Protection Authority deals with the issue of the protection of sensitive data: "it intends to acquire information on the methods of informing users, also with a view to possible consent; on the possibility that, from the design phase of services and products, the operators involved adopt technological solutions to guarantee users' privacy (the so-called 'privacy by design'); on the use of encryption techniques and anonymisation of information; on the interoperability of services; on the adoption of certification tools ".
Digital intelligence has become an invasive and difficult form to ward off that makes it necessary to research, also on the regulatory level, new balances to safeguard the freedom of enterprise and the right to privacy of workers.
It is a system that remains unrelated to the establishment of laws "which presents a problem of legitimation every time that is not knowable as the numbers that constitute the market prices [12].
Who directs this system? Prices that, with the relative variations, can certainly be equated with the rules that guide the economic system and the content of a large portion of Big Data. It is precisely this mechanism that makes the use of fragmentary knowledge possible: "the price system is the instrument through which the relevant knowledge is transmitted, the spy that shows what could be the opportunities for better investments and those to be downsized". It is a method of knowledge and discovery that assists the competitive mechanism, urging the actors to learn new balances and perspectives of knowledge. Price language is the guide of economic operators whose main objective is production at lower cost and high competitiveness along with efficiency. It is a peaceful collaboration, rooted in the coordination of the various interests [13] in which it is possible and frequent the changeability of those who, freely, at any moment, can decide to change interlocutor. The mechanism recalls, in its essential features, the "double contingency" of Luhmann in which the interpersonal relationship is formal: there are neither dialogical openings nor cultural exchanges but transit of information that prevent, for both participants, the risk of failure. The acceptance of the winnings as the loss, to which each according to their abilities, will try to remedy nourishes the mechanism of formation and improvement of order also through the creation of rules\symptom of a given social context. Frequent repetition of fortunate or less favorable situations is connected to the fluctuating progress of the market, also discussed as "the cybernetic principle of negative feed-back", determined by the possibility of sudden changes that indicate which activities should be reduced or increased, urging the adaptation to a variety of previously unknown facts.

4. Big Data and statistical surveys

Some theorists have tried to apply the theories of chaos to the behavior of stockbrokers, providing increasingly sophisticated forecasting models, developed since the 1980s. The company of an English physicist, Harding, invests annually on the management of big data - created by the financial transactions of the city of London - conceived as raw informative material whose refinement, through the algorithmic analysis, makes possible the construction of models of behavior of the stock exchange operators increasingly effective.

This is not a democratic place of dialogic encounter but of a vertical system 'scalable' by a few operators, able to concentrate gigantic economic resources with which they manipulate the security of the planet through the main instrument of control: big data.

In this perspective, the individual is exposed to forces able to reduce his personal freedom - based on the socio-economic profile of belonging, the model of life or residence - and determine its economic destiny, through information and digital creations - and the activation of powerful speculative flows able to intervene also on the price mechanism.

The era of big data has made the information produced by and on citizens the main instrument of economic power and development based on a predictability that unfolds starting from the preventive 'modeling of behaviors' extracted from Big Data [14]. It is a source of immaterial control and creation of wealth, consisting mainly of information that involves every fragment of human existence: all human behavior is potentially predictable, regular and modeled as recent studies have also shown in the criminal field.

For years man used the models made available by nature to make predictions such as the observation of phenomena such as dawn or phases and it is precisely from these studies that some theorists have come up with something more ambitious: extracting models from the apparent chaos of human behavior, to discover which, for example, the Police Department has made available a database of 30 million crimes.

Mathematical schemes and algorithms have been formulated that, better than high disciplines, give the ability to understand exactly the sequential processes, what we have around, how the waves propagate when you throw a stone into the pond or the distribution of trees in the forest.

5. The regulatory point of view

For a long time the use of Big Data has made known the advantages, the possible uses and their potential as shown by the 'Target case', one of the most important chains in the world in the large-scale retail trade that in 2000 started invest in the analysis of consumption data of its users.

It is one of the first companies to use algorithms able to predict, with a very high degree of probability, the motherhood of registered customers, collecting data for the purchase of commonly used goods, such as supplements, neutral shampoos, towels, liquid soaps and wads of cotton to be able to predict the state of pregnancy and to establish, precisely, the date of delivery in order to launch targeted marketing campaigns, anticipating competition.

This example clearly shows the uses and the actual potential of Big Data and, for those who approach this phenomenon from a legal point of view, it is an illuminating example, which demonstrates how we are faced with a real revolution.

Normally, in order to assess the legal compliance of a data processing, we first try to establish what are the aims pursued through their processing, what are the types of data processed (common data, sensitive data, judicial data, geolocation, etc.) and the tools used to perform data operations (manual or IT tools).

Who deals Big Data, very often, collects huge amounts of data and processes them not knowing a priori the result of their analysis that subsequently may decide to sell to third parties, cross with other datasets, use directly for marketing activities, to process real and their identikit starting from the formation of sensitive data, even unintentionally, whose processing is based on specific regulatory assumptions. The algorithm used to process personal data is no longer comparable to any electronic instrument that allows you to store or transmit information but is able to become a source of 'new' personal data not provided and/or collected from the data subject; a tool that returns a quantity of personal data higher than the simple sum of those already in possession.

The legislation governing the processing of personal data, the so-called Privacy Code (Legislative Decree 196/2003) also covers the content of Big Data to which, however, when they deal with other types of information must be applied in a manner and specific provisions indicated both in the Provisions of the Guarantor and in the opinions of Article 29 Working Party.

Given the less incisive and intrusive data of the individual's personality, the Privacy Code and all its important limitations do not apply. This does not mean, however, that when you process, for example, company data, anonymous data or any other type of data, you are faced with a legislative gap in which everything is permitted. However, the general provisions in force in our legal system, such as those established for example by the Civil and Criminal Code, must be respected. Particular attention must be paid to the provisions of the law on copyright (think of the Big Data hypothesis containing information, statistics, etc. drawn from a scientific research) and the provisions envisaged to protect the establishment of database (also contained in the copyright law).

6. Big Data and the risks to privacy

The right to knowledge is a 'common good' that requires to be guarded and respected with attention to human dignity [15] in the light of the substantial availability of information today managed through sophisticated technological supports. If predicting the spread of an epidemic disease allows to prioritize health interventions in the areas most in need, it may be possible to trace the personal data of individuals, or any information suitable to identify or make a physical person identifiable.

Data sets may contain data that can be traced back to specific individuals, such as a name, a date of birth, an IP address, potentially becoming dangerous when you have a connection key between them, although they come from different sources. Precisely in this direction, and because of the accumulation of information often recorded in an opaque way, the Privacy Guarantor gave a recent ruling, considerably improving the discipline envisaged at national level [16]. We are all users and at the same time producers of Big Data, so the dissemination of knowledge with regard to the protection of privacy is, at the same time, prerequisite and objective of Social Data Science, which has brought humanity to the center of scientific investigation [17]. The European Union establishes that personal data may be collected legally under specific conditions and for legitimate reasons, and that organizations that aggregate personal data must undertake to protect themselves from inappropriate use. In particular, the EU is concerned with ensuring the maximum protection of sensitive data in all member countries, that is to counter national laws that lower the standards of protection promulgated at European level [18]. On 25 January 2012, the European Commission proposed an extensive reform of the legislation on the protection of sensitive data contained in the European Parliament Directive of 24 October 1995, the so-called data protection package.

This reformulation is necessary for two reasons: first, the legislation then in force was inadequate to regulate the right to privacy on the Web and for online activities; secondly, the national laws of the individual countries, in the pressing need to adopt legislation on the matter, had proceeded in different directions, making reforming led by the EU even more urgent. The foundation of this reorganization remains the art. 8 of the Charter of Fundamental Rights of the European Union.

The data protection package makes use of a proposed regulation, which discusses "the protection of individuals with regard to the processing of personal data and the free movement of such data and will replace Directive 95/46; a proposal for a Directive concerning the "regulation of the areas of prevention, contrast and repression of crimes, as well as the execution of criminal sanctions, which will replace (and integrate) the Framework Decision 977/2008 / EC on the protection of personal data exchanged by the authorities police and justice ".

In preparation for the drafting of these tools, the European Commission had promoted statistical surveys in member countries in order to test public opinion on privacy on the web. In Italy this study was carried out between November and December 2010; in addition to questions about the general use of the network, the survey asked respondents to express their feelings (annoyance, indifference, appreciation) compared to common web marketing strategies, such as the inclusion of ad hoc ads on certain sites based to the research carried out, to which Italians were significantly less hostile (43%) than the European average (54%), as well as to the practice of providing personal information in order to obtain free services (56% against 29% of the European average). The survey revealed a general tendency for Italians to have greater confidence, compared to their colleagues in Europe, that the processing of their data was lawful and that there were adequate means to control their personal data on the web. For a part of the sample, the unusual data could also be explained by a partial understanding of the potential threat to privacy. Recently a similar survey was carried out on a sample of 28,000 citizens, known to the public under the name "Eurobarometer". The results were disclosed in June 2015 and the main data, consistent with past surveys, reports that European citizens complain about the lack of control over their data (67%) and do not trust online vendors (62%). As many as 70% of respondents fear that their data are used for purposes other than those stated, and even 89% find essential that the regulation on this subject is common to all countries. On 30 June the Commission reiterated that the completion of this reform is a priority objective, especially with a view to making the processes of the digital economy leaner and more profitable - both for citizens and for businesses - economic processes supported by technology and, in particular, implemented on the web. It is estimated that the value of sensitive data of European citizens will be one trillion euros in 2020, so it is vital to provide adequate protection measures.

In conclusion, the data protection package promotes the correct use of Big Data, whose use by the 100 leading companies in the EU, it is estimated, could save up to € 425 billion. At the same time, respect for the privacy of citizens will produce a "virtuous circle between the protection of a fundamental right, consumer confidence and economic growth". The Italian privacy law is in force the "Code regarding the protection of personal data", issued by Legislative Decree dated 30th June 2003, no. 196, which implements the directives 95/46 / CE and 2002/58 / CE of the European Parliament. This Code was amended following the Directive 2009/12 / EC with Legislative Decree 69/2012 to regulate the collection and processing of traffic and geolocation data. Once the European Commission approves the personal data protection regulation proposed in 2012, this will replace d. lgs. 196/2003. The proposal revolves around different pivotal points, including the general principle of transparency: the information intended for the data subject (term used to refer to the user) must be simple to understand and accessible (in the sense of the term that refers to the domain of accessibility on the Web). Secondly, the proposal addresses the issue of portability of data, namely the possibility of transferring data from one platform - for example, one social network - to another, and that of the right to be forgotten [19], which regulates the ways in which you can request the complete removal of your data from a specific service; this last point must, of course, adapt to the legal obligations. Finally, users have the right not to be subjected to automatic profiling based on their activity on the web. The so-called Privacy by design principle, which could perhaps be translated as "the principle of a priori protection of privacy", underlies this proposal; it aims to solve the age-old question of privacy in data mining, at least for most applications. The principle is very simple to take into account possible threats to privacy from the initial stages of all processes that use data (for any reason: dissemination, analysis, transformation, synthesis). We then proceed to a protection of privacy by default, that is with preventive measures, even at the cost of a deterioration in the quality of the starting data or extracted knowledge that is, for most applications, totally negligible. The Code establishes that traffic data must be eliminated or rendered anonymous when no longer required for electronic communications; however, prolonged use up to 6 months can be negotiated with the parties involved, who always have the right to revoke the use license. As for geolocation data, these can be used anonymously or as a result of user consent, which can always be revoked.

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[15] Cfr. J. LANIER, *Who Owns the Future*, trad. it. A. Delfanti, *La dignità ai tempi di internet*, Milano, 2014.

[16] GU n. 126 del 3-6-2014The essential reference is addressed to the discipline of profiling cookies. «Profiling cookies are designed to create user profiles and are used to send advertising messages in line with the preferences expressed by the user in the context of surfing the net. Due to the particular invasiveness that such devices may have in the private sphere of users, European and Italian legislation requires the user to be adequately informed about their use and to express their valid consent.

The art. 122 of the Code whereby "the storage of information in the terminal device of a contractor or a user or access to information already filed is permitted only on condition that the contractor or the user has given his consent after being was informed with the simplified procedures referred to in Article 13, paragraph 3 "(Article 122, paragraph 1, of the Code)".

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1st International Workshop on Personalized Health & Intelligent Workplaces Transforming Ergonomics (pHIWTE'18)

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Workshop on Personalized Health and Intelligent Workplaces Transforming Ergonomics

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Life expectancy is increasing and population is aging significantly, which to keep the current social system sustainable pushes retirement age up. The fact, than more than 95% of world population has one or more conditions or health disorders makes the target of keeping people healthy and fit for work longer a difficult challenge. Especially considering the role that working plays in such matter. Work hazards and un-healthy working lifestyles are often the underlying caused of Muscle-skeletal disorders and burnout depression.

The most common approach to avoid reduce risks, reduce exposure and avoid a harmful working lifestyle is prevention by design, *i.e. designing the work environment for a healthy and safe job execution.* In this context, use of pervasive technology, ubiquitous computing and p-health monitoring provide a key toolset to transform a common working scenario into a healthy intelligent workplace.

Smart textiles and microelectronics integrated in wearables device, have enabled intelligent biomedical clothing and the recent proliferation of Internet of Things systems have facilitated the integration of pervasive sensitive services into the environment. These, together with ambient intelligence technologies techniques and Big Data analytics, foster the proliferation of p-Health monitoring solutions.

Advances in development of inertial measurement units, activity and heart-rate sensing health watches, HR sensing garments and their wide presence in the consumer electronics market have opened a new arena for monitoring the physical workload and posture of different limbs. These Wearable and IoT sensors combined with ergonomic assessments facilitate the gathering of epidemiologic data for further big data analysis and even provide the opportunity for a prompt feedback and even for coaching through deploying the adequate personalized m-healthcare tools.

Transformation of a work environment into a careful, even healthy, intelligent workplace as deployment platform for p-Health services may support not just ergonomists, employee and employers but also society in general. Enabling the workplace as intelligent environment might be the seek solution to ensure the sustainability of the current social welfare systems. This workshop aims to bring together experts in all areas related to this transformation to create a discussion forum to discuss the challenges, progress and future work in this area.

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Empowering Ergonomy in Workplaces by Individual Behavior Modeling Using Interactive Process Mining Paradigm

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Abstract. Work-related disorders account for a significant part of total healthcare expenditure. Traditionally muscle-skeletal disorders were predominant as source of work absenteeism but in last years work activity-related disorders have increased remarkably. Too little activity at work, sedentarism, or too much work activity leads to stress. The individualized behavioural analysis of patients could support ergonomy experts in the optimization of workplaces in a Healthier way. Process Mining Technologies can offer a human understandable view of what is actually occurring in workplaces in an individualized way. In this paper, we present a proof of concept of how Process Mining technologies can be used for discovering the worker flow in order to support the ergonomy experts in the selection of more accurate interventions for improving occupational health.

Keywords. Behavior Modeling, Process Mining, IoT, Smart Environments

1. Introduction

With the arrival of new mobile personal technologies and wearable sensors, the quantity of data available for monitoring the behavior of people is dramatically growing [6]. The rapid digitization of society leads to an exponential growth data from Internet of Things (IoT) devices [3]. According CISCO Visual Networking Index Prediction[1], the number of connected things on the Internet will arise to 26.3 billion by 2020. All this information, added to information already stored in Electronic Health Records (EHR), social media or patient portals, among others, suppose a great opportunity to extract a valuable knowledge that will help to improve the quality of life of citizens[19]. Telemedicine and telehealth is being part of this IoT revolution[8]. It will be a critical piece of the digital

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transformation of healthcare. Currently, the market is already plenty of wearables and mobile apps for medical providers, disease-specific apps, such as diabetes [2], medical education and teaching, apps for patients and general public, including health and fitness apps, diet and nutrition [7]. Also apps for providing EHR access and patient information and the ability to share it with caregivers, family, or clinicians, or telemedicine and tele-healthcare stakeholders. This is useful in a large quantity o cases such as in stroke or acute trauma[4]. As seeing, the IoT healthcare market is growing at breakneck speed. It is due to the increase of chronic diseases associated with lifestyle and the fact that healthcare applications are capable of providing cost-effective solutions, improving communication between patients and healthcare providers.

This opens the door towards a new generation of sensors, lab equipment, employee wearables for working monitoring, where IoT will massively increase the amount of data available for the analysis of the ergonomy at work places, bringing a new complexity level. This makes think that precision medicine[17] can be a reality before expected although hardly exists today. Initiatives as Obamas 4P[20] (personalized, predictive, preventive and participatory) are pioneer where, in his words, *a new model of patient-powered research that promises to accelerate biomedical discoveries and provide clinicians with new tools, knowledge, and therapies to select which treatments will work best for which patients*. This can lead to use more advanced analytics, visualizations and decision support tools to improve accuracy in the diagnostics, allowing more effective and precise treatments.

In this line, Work-related disorders account for a significant part of total healthcare expenditure. Traditionally muscle-skeletal disorders were predominant as source of work absenteeism but in last years work activity-related disorders have increased remarkably. Too little activity at work, sedentarism, or too much work activity leads to stress. Work interventions should be executed to ensure a healthy distribution of work among employees and other stakeholders to avoid sedentarism that contributes to obesity or excessive workload that leads to occupational stress and depression.

Using all the information gathered from the plain monitoring of working environment it is possible to extract patterns that will allow to track, analyze and optimize the behavioral patterns of people at workplace. In this line, Process Mining [21,15], can be a powerful solution for supporting ergonomy experts in the process of understanding the patients. This technology, that traditionally was used for improving and optimizing the business processes in enterprises, is based on the application of syntactic machine learning technologies for inferring processes in an human understandable way. Process Mining techniques can be used for discover and understand processes by processing Internet of Things (IoT) data available data from monitoring environments [12]. Using these techniques it is possible to build different patterns that shows the general behaviour model of workers in an human understandable way.

Also, using Process Mining Conformance Technologies and Clustering algorithms it is possible to stratify the workers depending on their health behavior [11]. This allow to ergonomy experts to detect the workers behavioral status in an understandable way and propose actions to correct unhealthy behaviors. In addition, by comparing the personal models in times it is possible to detect behavioral changes that will support ergonomy experts in the measuring of the accuracy of their proposed actuation [11] and evaluating the distance between the current health status of the worker and their desired status.

To track the movements of the employees the facilities will provide with an accurate indication of the work activities and duration, that will be inferred, using Process Mining tools, as formal work behavioral models. Such models will allow the occupational health expert to assess work environments working life behaviors, evaluating healthy risk and detecting hazardous individual working behavior. The occupational health expert using the solution will have the opportunity to propose work interventions aiming to reduce risk and promote a healthy working lifestyle with a better and accurate knowledge of the working environment.

In this paper, we present a proof of concept on the application of Interactive Process Mining technologies for supporting Ergonomy experts in the discovery of unhealthy and unsafe patterns in monitored working scenarios. For that, we simulate individual behaviors of workers for building a Internet of Things (IoT) event logs and, applying Process Mining techniques. Then, we will show how ergonomy experts will be enabled to understand the actual behavior of workers in those scenarios.

The results shows how Process discovery Techniques are able to infer the general behavior of workers in a general way, as well as, using clustering Process Conformance algorithms, to stratify the behavior of different workers in different kind of flows depending on its evolution. This will support ergonomy experts in the understanding of the behavioral aspects of individual workers as well as detecting optimization possibilities for improving the ergonomy in workplace in a easier way.

In order to test it, we have designed a scenario based on the actions of janitors at an university. The idea is to simulate the different behaviors of janitors and on one hand present the general behavior of janitors over working days, and, on the other hand, show how the different behaviors can be discovered and presented to ergonomy experts, using Process Mining techniques.

This paper is structured as follows, the next section the simulation process is stated and the Process Mining technology used in this work is presented. In Results section, the flows inferred using Process Mining technology was explained. Finally, a discussion part concludes the paper.

2. Materials and Methods

Process Mining technology is a relatively new paradigm based on syntactical data mining framework that is though to support process experts in the understanding of the processes. Process Mining provides, algorithms, tools and methodologies to show what is really occuring inside the actual process that, usually, not correspond with the perceived one [10]. Process Mining technologies sacrifice accuracy in the learning process in order to provide more human understable processes. This easy understandability allows experts to add its own kwowledge to the learning process by correcting the actions in an iterative way. In this way, the application of Process Mining technologies can be used for supporting health experts in the management in occupational health via providing more understandable models, evaluating his actions and making them conscientious of the specific characteristics of workers in a general and individualized way.

There are three main kind of techniques associated to Process Mining:

- *Process Discovery* that are algorithms that produce graphic human understandable flows from event logs.

- *Process Conformance* that are algorithms that are able to compare logs and models in order to decide if the log is according the model or even measure the difference between two models.
- *Process Enhancement* that are tools that provide an augmented view of the process that allow highlight their specific characteristics in order to make easier their understandability by experts. For example, heat maps showing the most common paths in a flow

The general flow can provide a common view of the status, however due to the different personalities of the stakeholders, not all the actors contibute the actions in the same way to the general flow. In order to detect the differences among the individual users it is possible to use Clustering techniques [9] for creating partitions that maximize the similarity among the elements of each cluster. There are several clustering algorithms in the literature. K-Means [9] is one of the most known Clustering algorithm. This method is able to split a set of samples in a given number of partitions, maximizing the similarity among the group members. However, in our problem, the number of partitions is not known. Other algorithm available in literature is Quality Threshold (QT) Clustering[18]. This algorithm requires a threshold distance that define the maximum distance among the members of each cluster. In that case, we can define a distance and the algorithm will build the groups that maximize the similarity among their members taking the given distance as the maximum distance.

Nevertheless, clustering algorithms require a distance function between two samples in order to construct the groups. Usually, the samples are data vectors that use classical distances like euclidean. However, in our problem, the samples are synctactical ordered traces and the euclidean, and other geometrical distances that does not take into account the order, are not a good distance measures in our case. For calculate the distance over syntactically ordered data there are classical specific algorithms like Levenshtein [5] , and in case of Process Mining techniques Edition Distance Workflow Algorithm (EDWA) [11] takes into account the topology of the samples for computing

3. Results

In this paper, we will test the possibilities for detecting different human behaviors at workplaces using Process Mining techniques. For testing Process Mining in the behavior discovery in workers, we have designed an experiment via simulating different possible behaviors of Janitors at work. In this way, we have simulated 4 types of behaviors: a) Janitors that stay all day at the office, b) janitors that worked in the morning in some active tasks (Open and Closing class rooms, and Mailing delivery) and stay in the office after lunch, c) janitors that stay in the office in the morning, and perform the active tasks in the evening, and d) Janitors that performs active task during all day. We create these event logs using an Ambient Assisted Living simulator [16], that present the different activities performed by the users. We simulated a total of 140 traces 50 of type a), 40 of type b) 30 of type c) and 20 of type d). The available activities performed by Janitors are presented in Table 1.

In this table, all the possible activities performed by Janitors is presented. We have selected activities that could be collected by common domotic systems available currently in universities, like for example, card control for rooms entry, and the associated

Table 1. Set of simulated actions performed by janitors

Action	Average (in minutes)	Standard Deviation
Breakfast Room	60	15
Concierge Office	240	15
Mail Delivery	120	5
Open Classroom	120	15
Close Classroom	120	15
Lunch Room	60	15

semantic information. For example, Breakfast and lunch rooms activities are in the same location, but depends in the hour the activity has a different semantic meaning.

ID	Name	Start	End
065180c91efc4d89bae36bfa5f816b21	BreakFast Room	13/03/2018 8:21	13/03/2018 9:32
065180c91efc4d89bae36bfa5f816b21	Mail Delivery	13/03/2018 9:32	13/03/2018 11:30
065180c91efc4d89bae36bfa5f816b21	Close Class Room	13/03/2018 11:30	13/03/2018 13:28
065180c91efc4d89bae36bfa5f816b21	Lunch Room	13/03/2018 13:28	13/03/2018 14:30
065180c91efc4d89bae36bfa5f816b21	Concierge Office	13/03/2018 14:30	13/03/2018 18:52
065180c91efc4d89bae36bfa5f816b21	Home	13/03/2018 18:52	13/03/2018 19:47
068882948a1e43bb8288f539d9efcc41	BreakFast Room	13/03/2018 8:29	13/03/2018 9:28
068882948a1e43bb8288f539d9efcc41	Concierge Office	13/03/2018 9:28	13/03/2018 13:35
068882948a1e43bb8288f539d9efcc41	Lunch Room	13/03/2018 13:35	13/03/2018 14:51
068882948a1e43bb8288f539d9efcc41	Concierge Office	13/03/2018 14:51	13/03/2018 18:38
068882948a1e43bb8288f539d9efcc41	Home	13/03/2018 18:38	13/03/2018 19:46
0822d40cd7624abbb4bfe3a22d7a245f	BreakFast Room	13/03/2018 8:58	13/03/2018 10:08
0822d40cd7624abbb4bfe3a22d7a245f	Concierge Office	13/03/2018 10:08	13/03/2018 14:30
0822d40cd7624abbb4bfe3a22d7a245f	Lunch Room	13/03/2018 14:30	13/03/2018 15:21
0822d40cd7624abbb4bfe3a22d7a245f	Concierge Office	13/03/2018 15:21	13/03/2018 19:11
0822d40cd7624abbb4bfe3a22d7a245f	Home	13/03/2018 19:11	13/03/2018 20:22

Figure 1. Event Log simulated

In Figure 1 a part of the simulation resultant event logs is shown. In this log each janitor has a different ID. The name represent the activity performed, and Start and End represent the time when the action take place.

Using the logs simulated, we will use a Process Discovery system for inferring their flow associated. In order to do that we will use PALIA Suite Tool [12]. Also we apply heat maps over he flow to show the time spent by stakeholders in each one of the activities of the flow.

Figure 2 represents the flow inferred by PALIA Suite using the simulated logs. As a Heat Map we use a color gradient for representing the time spent in each one of the activities (nodes) and in the transitions the color represents the number of events occurred, that means the number of janitors that follow this path. In the flow we can see that the janitors seems follow a correct general behavior expending time in active actions (Open and Close Class Rooms, and Mail Delivery) in the same degree that static one (stay in concierge office).

Seeing this view, it can be though that, in general, janitors have a healthy behavior alternating active and static actions. However, according the simulation we know that

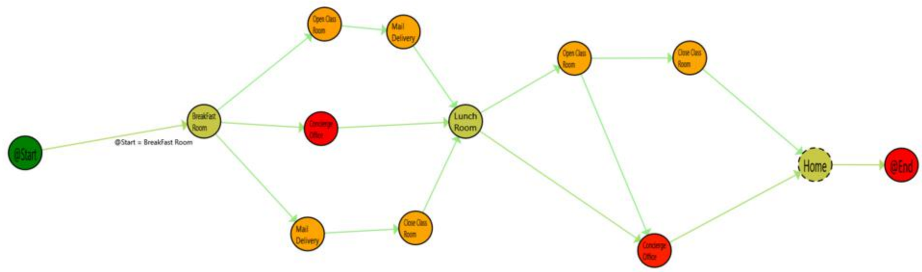

Figure 2. All Janitors behavior inferred

there are janitors that have different behaviors. In order to present how Process Mining technologies are able to detect and show the type of behaviors of janitors we will use Clustering algorithms. PALIA Suite Tool has currently implemented a Quality Threshold Clustering algorithm using a Edition Distance Workflow Algorithm. So for this proof of concept we will use this combination of algorithms in order to provide the clusters. PALIA suite allows the selection of thresholds between 0.0 and 1.0 representing the percent distance between two samples. A maximum distance (1.0) represents traces that have not common activities, while a minumin distance (0.0) represents equal flows.

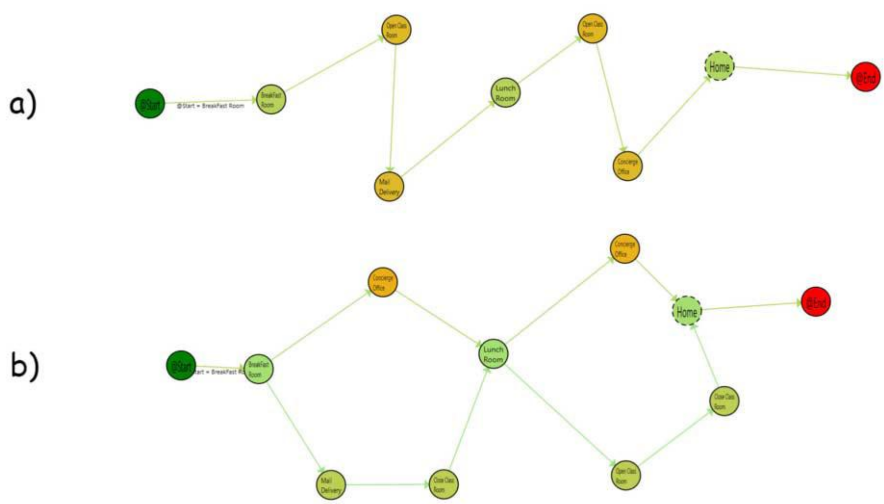

Figure 3. Janitors groups after clustering with a 0.3 threshold

Figures 3 and 4 and shows the different behaviors groups detected by the clustering algorithm. With a threshold upper than 0.4, PALIA suite consider all the traces in only one group. Figure 3 shows the results of applying clustering algorithm with a threshold of 0.3. In the Figure is possible to see people that are active almost all day a) (Stay less time in the Concierge Office) separated from those that are more static b).

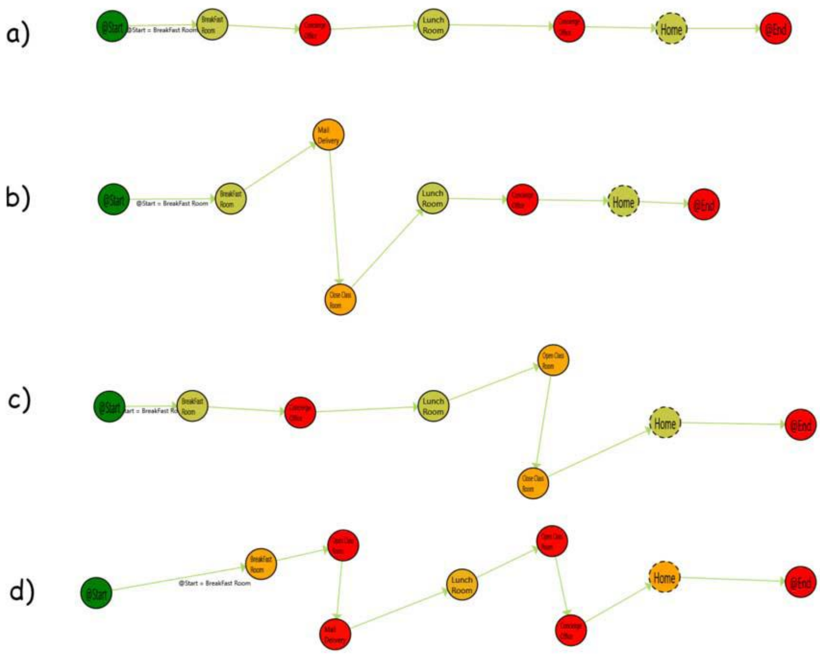

Figure 4. Janitors groups after clustering with a 0.2 threshold

On the other hand, in we apply a threshold below 0.2 (Figure 4) we can detect all the different groups that we simulated, a) those that are more inactive; those that b) are active at morning; c) those that are active at evening; and d) those that are active all day.

4. Discussion and Conclusions

The application of Process Mining over the information available in activity logs can be used for identify behavioral models that can be used for experts to optimize processes and correct anomalous behaviours. Classical data mining technologies and machine learning are able to provide better accurate models for classify actions, infer accurate models for predicting undesired situations, or even discover models that classify the behavior of the worker.

However, although the Machine Learning tools will support in the general understanding of the behavioral status of the worker, these techniques are not able to show the behavioral process in an easy an understandable way to ergonomy experts. So, although, there is possible to characterize the status of the general aspects of the workplace and compare it with individualized behavior of personal workers it is not possible to show the reasons of these differences in order to support ergonomy experts in the selection of best actions for improving the safety and health of people at workplaces.

Interactive Pattern Recognition paradigm [14] was born for providing a machine learning framework not only for understanding better what occurs inside the inferred models, but also to allow the incorporation of the experts experience within the inferred models. However, Interactive paradigm requires that the result of Machine Learning algorithms was human understandable. The application of this paradigm with Process Mining technologies can be the solution for include the expert in the middle of the learning process in order to make him conscientious of the characteristics of the problem to solve and providing heuristic clues to the automatic machine learning system for improve the accuracy and the efficiency of the inference.

In this paper we have tested a simple model with a limited granularity. The more events we add to the algorithm the more complete information flow we can achieve. However, the more complete was the workflow the more complex could be to understand, due to the higher quantity of edged and nodes in the flow. This effect is commonly known as *Spaghetti Effect* [13]. In order to avoid this undesired effect is necessary to select the adequate granularity for a better understanding of the process by human experts. Also, the selection of adequate threshold factors will allow the experts to show different situations and behaviors beyond the general process allowing them provide more accurate behavioral correction actions for individul workers.

Process Mining technologies not only can help in the discovery of the processes, but also, can support experts in the evaluation of the correction actions proposed. For example, in our case, the expert can propose to more static janitors to exchange tasks with more active ones. The experts can compare the previous flows with the new traces in order to evaluate the degree of adherence of the janitors to the intervention proposed by ergonomy experts.

In addition, as Process Mining technologies infers formal models it is possible to create simulation models [16] that can be used by experts to evaluate the intervention before propose it. This will support ergonomy experts in the selection of the most adequate interventions for optimizing the system.

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Health Promotion in Office Environments: A Worker-Centric Approach Driven by the Internet of Things

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Abstract. Health promotion in the workplace is one of the main challenges that the World Health Organization (WHO) has set in its agenda for the 21st century. Motivated by this concern, many companies across the world have reacted launching awareness campaigns and wellness promotion programs. One of the recurring problems on different application scenarios is the lack of adherence of the target audience (i.e. disengagement, early drop-out or high attrition rates). In this context, the potential of the Information and Communication Technologies (ICT) and the emerging paradigm of the Internet of Things (IoT) can play a mediating role between the proposers (i.e. managers) and the target audience (i.e employees) to increase motivation and follow-up. The presented work reviews the main challenges of IoT-based interventions for workplace health promotion and presents a participatory worker-centric concept for enhancing individuals' well-being in office environments. Our approach seeks to stress the importance of empowering workers providing to them fine-grained control of their own well-being and self-care. To this aim, we propose turning work environments into ideal confident-settings to persuade and motivate end-users attaining substantial changes that will persist over time.

Keywords. Health promotion, Internet of Things, Workplace, Office environments, Persuasive computing, Participatory sensing, User-centered design

1. Introduction

Well-being at work is gaining increasing importance on overall health promotion [1]. The attempts to design and implement interventions to foster healthier workplaces have evolved from an occupational health concern to one that includes workers' lifestyle changes [2]. The real challenge arises from setting up an ideal scenario and work-context to support health promotion and improved health-related behaviors. Indeed, for an intervention to be accepted, it requires understanding the physical, emotional and social factors that influence workers and employees to improve their everyday personal health practices [3]. The analysis on the effectiveness of workplace health promotion programs carried out until 2013 [4] shows that, although they obtained promising insights about

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positive effects, interventions fail when heterogeneous audiences are targeted. To avoid such a lack of adherence or uptake, the adoption of ICT and context-aware services can help with this endeavor. Our approach focuses on the enabling role of ICT in the ideation and creation of personalized and participatory health care interventions in work environments through a worker-centric approach. In this context, IoT can be considered an emerging paradigm to mediate the relationship between humans, in this case employees, and ICT.

The potential of IoT to enable appropriate solutions for health promotion lies on the services that it provides rather than just offering a machine-to-machine concept which enable them to interact, communicate, collect and exchange data. IoT involves different domain areas in which the digital transformation of health care is starting to be applied. Smart Home Care or Ambient Assisted Living are some examples of this new trend [5]. As a consequence, the health domain shows a tendency to move from a reactive and hospital-centric approach to a predictive and human-centered one [6]. From the insights derived from these research areas, mixing IoT, user-centered design and work environments seems promising to foster health promotion. Indeed, to the best of our knowledge, little or no pieces of research have pointed out the suitability of IoT for the work environment whereas it has proved to be a very suitable tool for health promotion. To cope with this unaddressed emerging gap, this work proposes engaging technologies to correct unhealthy behaviors associated with work environments (e.g. muskulo-scheletal disorders due to inappropriate sitting at the office) while promoting changes that stick over the time. In particular, it focuses on office environments, where its inherent sedentary nature is directly related to a decrease in the workers' health [7].

We introduce our human-centric proposal which places workers at the center of the process of caring for their own well-being. The concept here presented corresponds to our vision of a worker-centric sensing approach and aims to provide insights of transformations that workplaces could undergo to become socially-engaging places that respond to the workers' needs. Besides, this article contributes with a three-fold approach: (i) it analyzes the main health implications of office environments, (ii) illustrates the main challenges associated with the use of the Internet of Things for health promotion and (iii) highlights some specific factors that IoT platforms designed for workplaces should take into consideration.

2. Health Problems Associated to Workplaces and Related Work

The direct influence of work on individuals' physical or physiological health and wellness is a renowned problem [8]. Thereby, work environments offer an opportunity to identify unhealthy behaviors associated to this space and to correct these unhealthy practices [9]. As a consequence, the academic world is more concerned than ever about the importance of bringing well-being into the workplace, making the promotion of wellness an issue tackled from a interdisciplinary point of view [10]. Beyond occupational health and the responsibility of providing safe and hazard-free work environments, healthy workplaces must also deal with the psychological and social conditions of the work space.

The review of the consulted literature shows that assessing occupational sedentary behavior in the workplace stands out as one of the most addressed health related concerns

[11]. Its deleterious impacts on health include obesity and cardio-respiratory, metabolic or cardio-metabolic risks [12]. When considering the office environment, its influence becomes bigger driven by the health outcomes of long periods of inactivity and sitting times [13]. As example, obesity corresponds to another identified problem that also correlates to a decrement of productivity [14]. Furthermore, ergonomic-related problems arise from the physical inactivity that may result from long working hours and posture contributes to musculoskeletal disorders [15], carpal tunnel syndrome due to typing work [16] or the development of computer vision syndrome because of the exponential adoption of ICTs [17]. However, workers' physical problems are not the only ones that may occur in work environments, symptoms of stress constitute also an important challenge for enhancing worker psychological health[18]. To conclude this review, according to the literature [19], the workspace itself must be taken into account seriously for its inappropriate indoor environmental conditions which are also associated with a decrease in the workers' comfort and health.

Once identified some of the problems and unhealthy behaviors in these spaces, the second step involves correcting the bad practices that are recognized and promoting new healthy-ones that persist over time. Under this context, technology enables the possibility of monitoring human factors and provides context-aware guidance, achieving the main purpose of delivering information to anyone anytime and anywhere [20]. The suitability of the introduced Internet of Things technology is widely validated for health and well-being promotion [21] and several efforts have been made pursuing the objective of developing IoT applications for it. In this sense, the PEROSH initiative [22] elaborated a decision support framework for selecting useful wearables and a proper data collection strategy for avoiding sedentarism. Moreover, Pendersen et al. [23] presented an e-health intervention designed to increase workday energy expenditure. Other works modeled physical fatigue in the workplace using wearable sensors [24] and proposed a non-intrusive monitoring system to avoid lower back injuries [25]. Finally, some scholars evaluated a smart chair to improve the sitting behavior [26] or approached interventions for encouraging workers to take more regulars micro-breaks [27].

The results of these interventions have also been subject of meta-reviews to validate the appropriateness of the different experimental conditions and its real effect on workers health. In 2014 Malik et al. drew on the impact of health interventions on activity levels [28]. They concluded that, although some evidence of efficacious was found, the reviewed works showed a similar volume of successful and non-successful studies and overall results were inconclusive. Taking only into account the positive outcomes, they found a strong argument for pursuing research efforts in order to design physical activity interventions for promoting wellness in workspaces. A more recent work (2017) evaluated its impact in terms of health outcomes (i.e. body mass index -BMI-, total cholesterol and blood pressure). In this study, the authors detected a slight decrease on BMI associated to the fact that individuals were changing their exercise behaviors, but no significant changes in cholesterol and blood pressure levels [29]. These results seem to correspond to the existing literature which tends to be careful overstating conclusions from inconclusive data.

Despite the difficulties for making strong validations of the direct influence of technology on workers health, workplace interventions show potential for attaining some sort of efficacy through it. Increasing the effectiveness of health promotion activities involves encouraging workers to promote lifestyle changes that persist over the time. Hence, in this work we envisage to reinforce the role of end-users as a mean to design successful interventions, addressing how IoT can contribute to obtaining socially-engaging places to promote changes that persist over the time.

3. Drivers and Challenges

According to the literature, designing an adequate IoT solution that meets the requirements to foster workplace wellness awareness has to put the focus on three principal areas: (1) the technology-driven sensing solutions, (2) the recognition of the monitored activities and (3) the design of engaging user experience strategies. Hereafter, these areas are further explained in relation to the state of the art. Firstly, advances in embedded devices and sensors enable a wide range of pervasive applications and services. Wearable devices are a good example of the adoption of IoT in health care as they constitute a common variable for a wide range of applications and solutions [30]. Secondly, enabling a monitoring framework in order to obtain information related to the users' health allows to analyze user patterns and recognize unhealthy behaviors or habits. Current trends in artificial intelligence (AI) take part in the development of new services for that interest [31]. The classification of behaviors related to office environments applying AI has been addressed by Oliver et al. [32], while other works bring together sensors and data to delve into the suitability of the sensing technologies [33].

Besides the technology factors, a final requirement for workplace health promotion through IoT is related to the participation of employees. However, getting the involvement of the target audience is just the first step forward increasing their engagement and adherence to the programs. In this sense, user experience and the human factors are closely related to ease of use and accessibility of the solutions [34]. The findings obtained from the reviewed literature and the insights voiced by its authors reveal different needs and considerations that may not be well covered and should be addressed to overcome the primary objective of building healthy workplaces. Numerous scholars have pointed out the challenges associated with the design and development of IoT-based solutions and, in particular, wellness promotion mechanisms. Hereafter, we seek to address the most relevant ones that smart work environments should overcome to become suitable worker-centric health promotion tools.

3.1. Engagement in Health Interventions

Succeeding in designing an effective tool for health promotion requires the thorough analysis of the role of end-users. Besides, promoting lifestyle changes involves motivating people to change and consequently adopt more beneficial behaviors. Persuasive technology has been established as a mature proposal and engaging mechanism for this purpose [35]. Delivering a contextualized guidance depends on when and how to interact with the workers to effectively influence their behavior (e.g. just-in-time or about-to-do moments). However, the diversity of profiles makes necessary to design adaptive and personalized assets for optimizing the interactivity between people and devices to promote the adherence and adoption of the technology. Designing a strategy for involving every user in their own self-care stands out as a paramount challenge for getting such engagement.

3.2. Usable and Non-invasive Technologies

One of the biggest concerns when creating an adequate and portable access to pervasive devices is to achieve that without interrupting end-users' work tasks or minimizing their attention theft at work. Thus, creating a non-intrusive but confident ecosystem surrounding the user that allows collecting data without any effect on workers' routine or implication on its productivity [36]. However, health promotion domains are especially challenging scenarios that involve deploying sensors that can be intrusive and power-hungry, losing its autonomy. Designing multi-modal Internet of Things sensor-based systems from the principles of ubiquitous computing needs to avoid falling into over-instrumenting spaces and to be the less intrusive as possible. To achieve this goal and to assess positively the worker's satisfaction, there is a need for the development of feasible, easy-to-use and comfortable solutions.

3.3. Efficiency and Computational Limitations

One of the cornerstone challenges to tackle when planning IoT solutions is to deal with the complexity of a network that has to seamlessly enable the data collection, transmission and sharing through an infrastructure formed by sensors and devices in distributed environments. Every IoT solution should be supported by a scalable and modular architecture with an abstraction level on top of technologies or protocols. In general terms, the main purpose of a traditional IoT network architecture is to connect the physical layer, formed by the devices or ”Things”, with the Cloud layer where data is processed and managed. However, current trends seek to move this processing and analyzing capabilities from this remote Cloud to what is called the Edge (an intermediate layer that traditionally acted as a gateway or proxy). This approach, based on Fog or Edge Computing, changes the remote management of the data to a local stage, allowing data to be processed closer to where these are generated [37]. In contrast with Cloud computing-based solutions, the local processing of the information benefits those applications where time is critical and latency must be avoided. When health monitoring implies running activity recognition techniques on remote devices, a paramount factor to consider is the computational and energy limitations of its embedded technology [31]. Thus, it is necessary to evaluate which techniques are more suitable in terms of efficiency or if it is necessary to outsource that detection. The main problem arises when demanding applications compromise energy consumption, battery live or the computational capability of the remote devices. The challenge of health-related IoT solutions is to take advantage of the Edge Computing approach when its requirements involve time-sensitive data. Planning a supportive combination of edge nodes and remote devices can provide powerful means to drive health promotion ecosystems [38].

4. Approaching Wellness to Users: A Worker-Centric Proposal

Once analyzed the different trends in health promotion and the role of ICT on them, in this section we present our vision of an IoT based solution for encouraging the adoption of healthy habits in the workplace. Keeping in mind the emerging challenges mentioned thought this paper, we propose a new concept of tangible and unobtrusive instruments to provide personalized information and guidance to employees. The system is made up by a set of electronic smart devices devised with the idea of designing non-intrusive and easy-to-use technologies to obtain and analyze data related to the state and actions of workers' health. This set of devices, conceived as an electronic kit which is provided to each end-user, is comprised of an assortment of different kind of embedded sensors that enable workers to augment the work environment and directly decide and control what is monitored by the system. When placed on different objects, sensors-based devices are able to obtain data such as movement, temperature or position-related measurements that can be used to monitor how workers interact with their environment and to detect unhealthy behaviors. For example, a single smart device consisting of an acceleration sensor -or accelerometer- can be used to detect movement in different situations. Depending on where is attached, it can be used to measure: (i) Physical activity or prolonged sitting times (worker's body or chair) (ii) Hydration level (bottle of water) (iii) Caffeine intake level (coffee mug). The aim is to let the system know how and when these objects are being used (i.e. activity recognition) and to provide the users with a set of subtle interactions that let them understand if the action they are doing is being performed properly or not (i.e. ambient feedback). Based on these data, sufficient information is available to effectively influence employees and guide their habits towards healthier behaviors by applying technological persuasion techniques.

Besides the technological requirement of the concept, the central pillar of this strategy relies on involving the users on an engaging strategy that leads them to appropriate lifestyle changes. The proposed approach places the users at the center of the process of caring for their own well-being, obtaining contextualized and personalized information based on their actions and behaviors with a minimal impact on their daily routine within the workplace. Coping with the lack of adherence to wellness interventions, the presented strategy stressen the importance of empowering employees in their own choices as a tool to improve self-satisfaction. Letting workers be the master of their actions resembles the participatory sensing concept [39] and illustrates how health promotion can take advantage of involving users on their own self-care. The self-exploring process of obtaining the monitoring data reflects the idea of technology appropriation that makes the user feel and appear as the center an intelligent workplace for enhancing individuals' everyday quality of life.

5. Conclusions

Throughout this paper we have analyzed the role of technology and in particular the Internet of Things paradigm for health promotion in the workplace. To success bringing wellness into these spaces, we have gone over the main health implications of office environments and its future outcomes (i.e. sedentarism or musculoskeletal disorders). This has allowed us to understands the factors that directly correlate with the physical, mental and social well-being of workers and employees. Then, we have identified the main gaps of current IoT solutions and the challenges that should be addressed for this emerging trend to become a suitable tool for health promotion: engagement in health interventions, usable and non-invasive technologies and efficiency and computational limitations. Special attention is given to current solutions designed to respond to real workers' needs, instead of just to those that provide or deploy technology from the point of view of the things that computer scientists can do rather than the things they should do for wellness promotion.

Despite understanding that these factors are essential for designing engaging technologies to correct unhealthy practices, the lack of adherence of the target audience continues to be a recurrent problem. As a consequence, although showing some promise for its efficacy, existing literature illustrates difficulties for making a strong validation of the direct influence of workplace interventions on workers' health. Boosting the effectiveness of workplace health promotion requires increasing the participation and motivation of employees. In this way, we have presented a worker-centric approach that empowers employees and makes them feel they are the center of their own well-being while addressing how IoT can mediate providing substantial changes. Prioritizing the role of end-users and motivating socially-engaging places convert work environments into optimal settings to encourage the adoption of lifestyle changes that persist over time, succeeding on the first step for influencing on workers' health.

Acknowledgements

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A Highly Flexible Architecture for Intelligent Workplaces Enabling Easy Customization of Environments

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Abstract. Intelligent environments are a natural tool for the creation of intelligent workplaces. However, in order to be used in this way, it is necessary to face the challenge posed by the variability of the elements included in the space and the need to adjust the smart elements to the preferences of the users. This paper presents a service-based architecture that enables the creation and management of intelligent workplaces based on the concept of intelligent environment. To this end, a series of functional restrictions are presented, which simplify the design and implementation of the services to be deployed, and information models, to formalize both the space and the preferences of the users based on the concept of activity. The architecture and models presented facilitate the adaptation of a solution developed by a supplier to any type of intelligent environment in an efficient and scalable way.

Keywords. User Context Management, Microservices, Smart Space, Service Adaptation, Intelligent Workplace

1. Introduction

The inclusion of intelligent objects, Internet of Things (IoT) and advances in Ambient Intelligence (AmI) facilitate the development of new pervasive sensitive services for their inclusion in the user's vital spaces, transforming them into intelligent environments [1]. In this way, it is possible to develop services that can accompany the users in their daily life, supporting them in the performance of daily tasks, and using these intelligent environments as a means of deployment [2]. This approach allows to abstract users from the underlying technology to each service which is included in the environment, translating the capabilities of the intelligent environment into comprehensible concepts such as activities, actions or tasks. In this way it is possible to address important challenges in the development of intelligent environments such as the acceptance and adoption of the offered solution [3], which go beyond the traditional ones such as technology, security or privacy.

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Thus, the capabilities of the intelligent environment are defined through the set of services deployed in it [4]. However, although this approach allows to speak a language closer to the user, the correct functioning of each service is conditioned by the techology available at each moment and, above all, by the user's profile that interacts with the environment, that is, the context of use [5].

A clear example where this customization is very important are the workspaces [7]. A clear idea of the capabilities and needs of the user greatly facilitates the adaptation of the services deployed in the environment to ensure not only that the user can carry out the tasks that must be performed, but also accompany the user to perform them in a healthy way, transforming this work scenario into a healthy intelligent workspace.

This article presents a software architecture that allows the reconfiguration of the intelligent environment through the management and redeployment (if necessary) of pervasive sensitive services when context variations are detected. The concept of context includes both the use of intelligent objects when interacting with actors in the intelligent space and the profile of said actors.

2. System Overview

The system that describes the problem raised in this work is detailed in Figure 1. As can be seen, each intelligent environment is determined by the set of available solutions. These solutions are built by combining small services [8,9] that are proposed by a provider and will depend both on the technology available in the environment and the context of the environment, i.e., the available smart objects and how the user decides to use them.

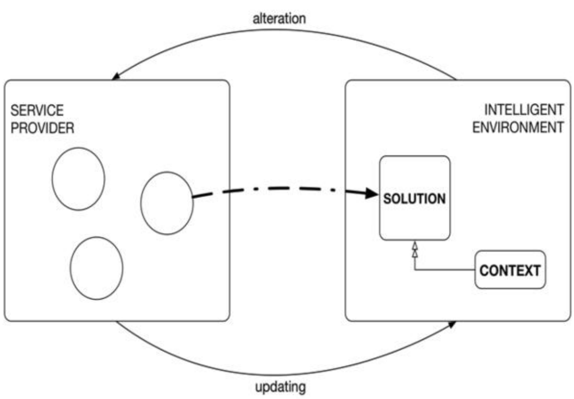

Figure 1. System overview.

Smart environments tend to undergo frequent context alterations and, in many cases, are directed by users of space. In these cases, the system must adapt in two different ways:

- Adaptation of the set of services that make up the solution according to the context. As indicated previously, the solution consists of a set of services that are coordinated to provide the requested functionalities. Since several of the

services interact directly with the objects of the space, a change of context must imply a change in the number and type of services deployed. This adaptation of the number of services can be done locally, within the scope of the intelligent environment, or remotely in the service provider. In the latter case, a process of service deployment must be produced;
- Coordination of services to meet the objectives. In addition to choosing the appropriate set of services to be deployed it is also important to define the coordination criteria between them. Service may sue the other service capabilities to carry out its mission. This coordination process should be defined from the moment in which an adaptation of the services is made to changes in context.

In the case of the adaptation of intelligent workspaces to the characteristics of the users, both the process of adaptation and the coordination of services can be simplified to offer a simple but functional solution. The set of services to be deployed will depend solely on the furniture or devices configurable in the space. The coordination of the services can be based on the preferences of the user of the space. These preferences define the mode of operation of each service without requiring them to exchange information between them.

So the functioning of the system would be the following. In the workspace a process of discovery of furniture and devices with capacity to be managed by services is carried out. Based on the information obtained after this process, the services are deployed in the service manager of the intelligent space or an adaptation is made if it is applicable. In general, each configurable element will have a service that will be responsible for its management.

On the other hand, the user transmits his profile to the space. In this profile preferences are defined in terms of the work situation in which the user is located. The services, in addition to being able to configure the space devices, must know when they should act by changing the configuration of the environment; they must understand the existing information in the user profile and finally translate it to the specific configuration of the device they serve.

This operation, although it does not seem sophisticated, poses some challenges that must be resolved in the design phase:

- How are user preferences managed?
- How do services know they must make a configuration change?

The next sections show both the high-level information models that support the coordination between services to adapt the environment to user preferences and an architecture that allows their implementation in a scalable manner. In this work, the process of deploying services has not been taken into account, assuming that these are already deployed.

3. Information Model

The fundamental element of coordination between services is the concept of activity. It is assumed that the user of an intelligent workspace is always carrying out at least some activity. From the concept of activity, two information elements are defined:

- Service-Activity Link model (SAL). Represents the activities in which the services are involved.

- User's Preferences for Activities model (UPA). User preferences stored in your profile and classified according to the activity.

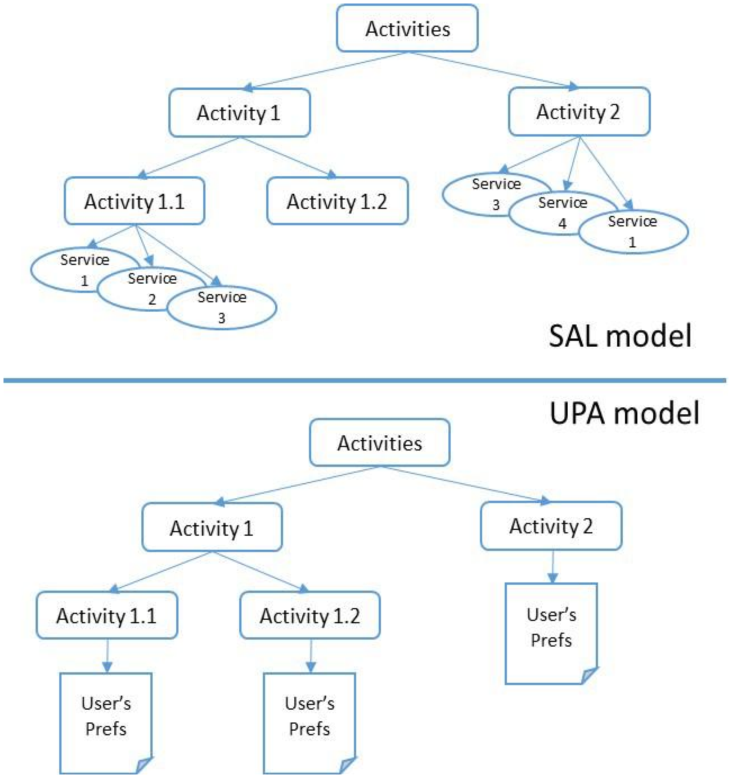

Figure 2. Information model overview.

As can be seen in the previous figure, services are labelled according to the activity in which they have to act (they can be in various activities). When a change of activity occurs, the system must notify it to all the services of the activity that ends, and to the services of the activity that begins.

The services that have been notified that the activity begins must consult the user's preferences for that activity. The information of the preferences must be made through an ontology. This ontology reflects concepts similar to furniture or devices managed by the services to facilitate the correspondence process. Therefore, the services must know the ontology in which the profile is represented and, in addition, be aware of which entity corresponds to the element they manage.

The user can alter the conditions of the workspace in two ways:

- Changing your profile, which implies that the services adjust the elements they control in another way.
- Adding new elements to the context that, associated with a control service, must again be adapted according to the information contained in the profile.

In this version has not been considered the problem of parallel activities and how to resolve their possible configuration conflicts.

4. Architecture Description

Once the information models that facilitate the described adaptation process have been defined, it is necessary to define an architecture that allows integrating the necessary functionalities so that the different services can carry out their functions in a coordinated manner.

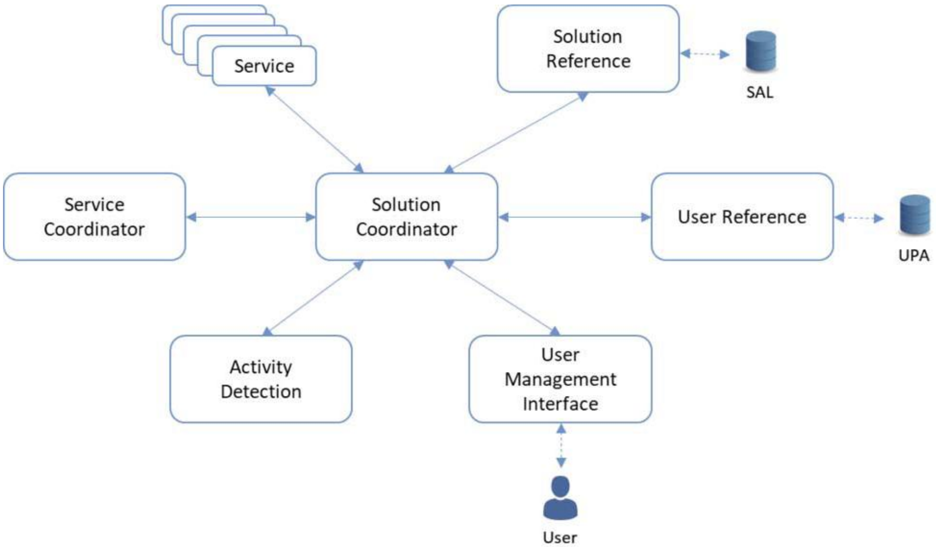

Figure 3. Architecture overview.

In the previous figure, a high-level representation of the proposed architecture is shown. The architecture is based on an intermediate element called "Solution Coordinator" that facilitates the interconnection of all the elements. In the architecture only the necessary elements are shown to carry out the functionalities described in this article. However, in a real environment it is necessary to perform context monitoring tasks, deployment management, service version management, communications interface with service provider, etc. All these elements can be integrated through the "Solution Coordinator".

Next, the rest of the elements of the proposed architecture are described:

- *User Management Interface.* It is responsible for obtaining the user's profile and sending it to the module that manages the information related to the user (User Reference). It also takes care of the interaction with the user to establish the activity that is being carried out at that moment or to make changes in the profile. A change of activity will be communicated to the "Service Coordinator" module.
- *Activity Detection.* Module in charge of detecting the activity that the user will perform. Changes of activity will be communicated to the "Service Coordinator" module.
- *Service Coordinator.* Manage activity changes Consult the services involved in the outgoing activity and the incoming activity through the "Solution

Reference" module. After knowing these services will send a message indicating the cessation or start of an activity.

- *User Reference.* It manages all the user information stored in the UPA. Respond to queries from the rest of the modules.
- *Solution Reference.* It manages all the user information stored in the SAL. Respond to queries from the rest of the modules.

5. Conclusions

The presented architecture allows solving the problem of context variability and user preferences when implementing intelligent workspaces. For this, several functional restrictions have been defined that enable the creation of solutions based on simple services with few dependencies with other services. The services are also aligned with the different elements (devices and furniture enabled) of the intelligent space where they are deployed. The coordination of these services, which in general is limited, is carried out through a series of mandatory services in architecture. These services manage information elements that represent both the preferences of the user and the specific type of services deployed. The correspondence between preferences and typology is made based on the concept of activity.

Although the presented architecture supposes a first outline of solution, it has some limitations that will have to be solved in future investigations. To begin with, the article raises general concepts and models of information little detailed. It is necessary to further detail those models specifying the fields that should be included. This is especially important in the case of user preferences. It is necessary to find an information model that is capable of collecting all the aspects of interest for the intelligent workspace.

In addition to the limitations inherent to an initial research proposal, there is one aspect that must be adequately addressed: the existence of more than one person in the work space. Although the architecture could be adapted to this circumstance, it is possible that there are inconsistencies in the preferences of the users that must be resolved through the appropriate strategies.

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Wearable Sensors Enabling Personalized Occupational Healthcare

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Abstract. This paper presents needs and potentials for wearable sensors in occupational healthcare. In addition, it presents ongoing European and Swedish projects for developing personalized, and pervasive wearable systems for assessing risks of developing musculoskeletal disorders and cardiovascular diseases at work. Occupational healthcare should benefit in preventing diseases and disorders by providing the right feedback at the right time to the right person. Collected data from workers can provide evidence supporting the ergonomic and industrial tasks of redesigning the working environment to reduce the risks.

Keywords. P-Health, Ergonomic, Wearable Technologies

1. Introduction

Work-related injuries and disorders constitute a major burden and cost for society affecting both employers and workers. The cost has been estimated to around 2.6-3.8% of GNP in Europe [1]. Musculoskeletal disorders are among the acute/chronic diseases caused by bad working conditions and unhealthy working life. In order to identify risk occupations, jobs and tasks, for interventions, as well as while planning new jobs and work stations, and to facilitate evaluations of interventions in terms of decreased exposure to risk factors, there is a need for valid, reliable and useful methods for risk assessment of biomechanical exposure.

Traditional ergonomic risk assessments are typically based on experts' observations. However, such assessments generally have a low inter-observer reliability [2], also, the inter-method reliability is often low. Further the observations

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are because of their costs limited to short periods, which may be poor representatives for the whole workday. Therefore, objective measurements and assessments of risk factors, such as the *assessment of upper arm elevation angles using standard inclinometry* [3], have got a lot of attention in the last two decades.

2. Wearable Systems in Occupational P-Health

Naturally, humans as subjects of risk assessments and interventions have different characteristics *e.g., height, weight and physical capacity*. In addition, such personal characteristics change because of *aging, gaining weight, getting injured or sick, etc*. Therefore, an ideal solution should be accessible in long term to cover and take into account such personalized changes.

Rapid developments of wearable technologies, *e.g., textiles with embedded sensors* have brought new possibilities in p-Health *i.e., preventive, pervasive, predictive and personalized health*. Integration of smart textiles and physical risk assessment algorithms can provide a system for effective risk evaluation for ergonomists, real-time feedback to workers, and assessment of work environment to organizations.

Feedback from such an integrated wearable system can be combined with gamification techniques *e.g., using game elements like between groups competition and awards* to motivate behavioral changes promoting healthy habits and following ergonomic advices. At an organizational level, the collected personalized data can be used to motivate and lead the redesign of working environment or working processes.

The aim of two ongoing projects [4] is to develop wearable systems with good usability to be worn during a full workday for measuring the position and movement of different limbs *i.e., arms, legs, wrists and trunk*. In addition, garments enabling the measurement of electrocardiogram and respiration for assessment of physical and mental stress and workload are under development. Several direct feedback concepts including visual, auditory, and haptic feedback are also under development and evaluation, which enable personalized virtual coaching for the workers.

3. The We@Work Project

The We@Work solution aims to support the worker and employer to ensure a healthy working life through pervasive monitoring for early warnings, prompt detection of capacity-loss and accurate risk assessments at workplace as well as self-management of a healthy working life.

The architecture of the pervasive monitoring solution in We@Work, see Figure 1, consists of a cloud based infrastructure, wearable sensors units and mobile applications. The cloud backend infrastructure is designed by ATOS Codex, and it is based on RedHat OpenShift Container Platform and WSO2 deployed on Amazon Web Services Cloud Infrastructure; and developments are done by Karolinska Institutet. Android applications are created by Atos, KTH-Royal Institute of Technology. Karolinska Institutet (KI) is responsible for the cloud platform for communication, storage, user management and potential big-data analysis. ATOS is responsible for notification management, by using Google Firebase Cloud Messaging, and feedbacks through the personal health record system, Pocket mHealth. Each application has a specific functionality dedicated to data gathering from sensors through Bluetooth or other sources such as questionnaires. The communication between sensing layer and cloud system is based on HTTPS protocol through RESTful APIs.

The wearable garments used in this project are provided by Z-Health Technologies AB (ZHT), Borås, Sweden. The garments include in-pocket inertial measurement units (IMUs) LPMS-B2 from LP Research, Tokyo, Japan and in-house build electrocardiogram (ECG) and thoracic electrical bioimpedance (TEB) measurements units by using embedded textrodes [5].

The ECG and TEB are used for estimating the energy expenditure while accelerometer and gyroscope data from the IMUs are used to calculate the posture and velocity of movements of arm, trunk and to distinguish between sitting and standing positions. Extracted information can be used for risk assessment and for giving of feedbacks according to recommendations. An example of recommendation for risk criteria is summarized in Table 1 [6-7]. Figure 2 is illustrating screenshots of an under development Android application and pictures of sensorized t-shirt.

Table 1. The risk assessment criteria for awkward position and movements of arm and trunk/back, prolong sitting, standing, energy expenditure.

Section/Limb	Position and/or Movement	Risk
UPPER ARM	Elevation angle > 30° < 25 % of working time and elevation angle > 60° < 5 % of working time	GREEN
	Elevation angle > 30° > 25 % of working time or elevation angle > 60° > 5 % of working time	YELLOW
	Elevation angle > 30° > 50 % of working time or Elevation angle > 60° > 10 % of working time	RED
	Elevation average generalized angular velocity < 60 °/s	GREEN
	Elevation average generalized angular velocity > 60 °/s	RED
TRUNK/BACK	Forward bending < 45° < 12.5 % of working time and Forward bending > 45° < 6 % of working time and backward bending > 0° < 6 % of working time	GREEN
	Forward bending 20-45° > 12.5 % of working time or Forward bending > 45° > 6 % of working time or backward bending > 0° > 6 % of working time	YELLOW
	Forward bending 20-45° > 25 % of working time or Forward bending > 45° > 12.5 % of working time or backward bending > 0° > 12.5 % of working time	RED
PROLONG SITTING	Less than 25 min for the last 30 min	GREEN
	More than 25 min for the last 30 min	YELLOW
	More than 55 min for the last 60 min	RED

Section/Limb	Position and/or Movement	Risk
PROLONG STANDING	Less than 30 min continuously	GREEN
	More than 30 min continuously	YELLOW
	More than 60 min continuously	RED

We@Work solutions are designed with the aim of compatibility with currently commercialized fitness and health tracking systems. In this first stage Polar A370 from Polar Elecro, Kempele, Finland is used for monitoring of physical activity and sleep pattern outside the working environment.

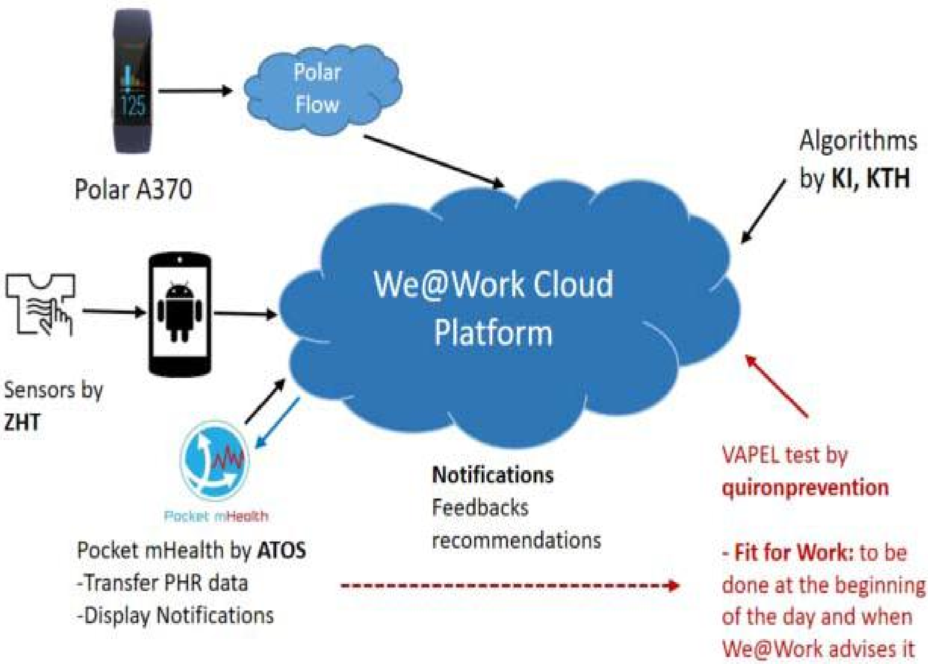

Figure 1. Architecture Framework and flow of information in We@Work

VAPEL software from Quiron Prevention is another component of the We@Work platform. VAPEL allows assessment of whether subjects are fit for work by assessing their basic executive functions, i.e. basic executive functions comprising attention span, fatigue resistance, monotony resistance, planning coordination and/or psychomotricity. Depending on working environment and level of risks in different occupations, VAPEL test can be performed at the beginning of a work shift or after detection of high level of fatigue or stress.

We@Work multiservice platform based on already popular fitness tracking systems and wearables and garment designed in this project will allow unobtrusive data collection at workplaces. Big Data analytics will provide useful information to prevent work injuries and support a healthy working life. More details will be available on the project website (http://weatwork.eu).

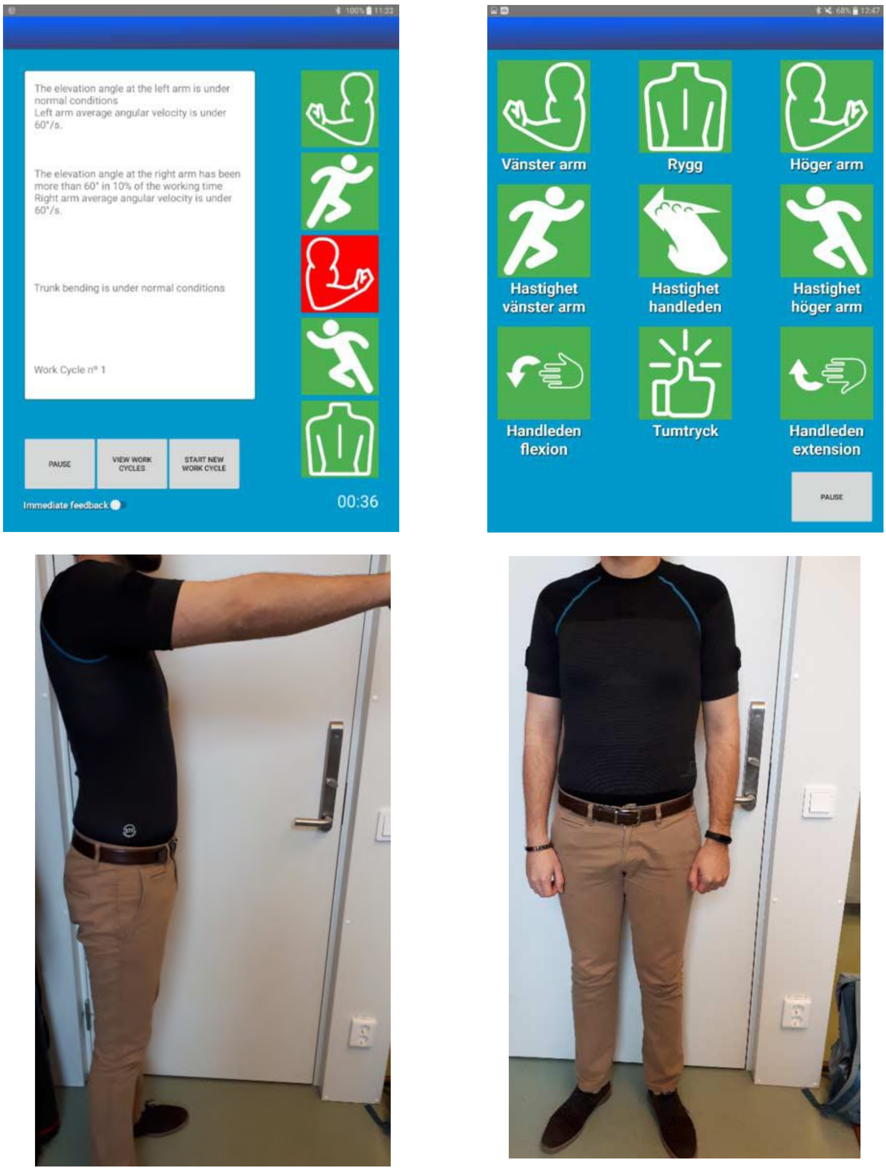

Figure 2. Screenshots of Android Application (under development) and sensorized t-shirt. Visual feedback is showing the limbs risk analysis according to Table 1 criteria. The worn t-shirt in the pictures is sensorized by inertial measurement units for arm, trunk and back.

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Towards Digital and Personalized Healthcare and Well-Being Solutions for the Workplace

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Abstract. Promoting wellbeing at workplaces has the potential to significantly improve the health of workers and to benefit the enterprises and organizations. This multi-factor feat has become a priority in many countries policies, concerning the challenge of active ageing population. Digital transformation enables us to incorporate new technologies in the measurement and analysis of agents in occupational health and the design of schemas to improve employee's wellbeing. Among the different digital solutions that can be implemented to foster a healthy and productive workforce, wearable and environmental sensors together with mobile apps have high levels of acceptance among workers/employees. In this project we have studied how the digital health solution provided by Pocket mHealth conceived and developed by ATOS, can be used to enhance wellbeing and health status in working environments. Pocket mHealth enables patient empowerment in the management of its own medical information, bringing their Electronic Health Record (EHR) and health data coming from different Hospital Information Systems (HIS) to the smartphones. Pocket mHealth solves the need of current healthcare organizations about the adoption of healthcare data openness, following a patient centered design and taking advantage of the potential benefits of this paradigm. Instead of having standardized repositories at the hospital facilities, the patient becomes the driver of the change by means of distributed interoperability.

Keywords. p-Health, m-Health, Digital Ergonomics, Intelligent Workplace

1. Introduction

There is a growing recognition of the need to consider the importance of workplace well-being, which implies a complex blend of people's physical and psychological aspects during their working live, determined both by their tasks and by workplace interventions. The idea goes beyond the concept of wellness or healthy living, considering that making work sustainable over the life course could be a viable solution to face the challenge of ageing populations, as the workers would retain health, engagement, motivation and productivity more time.

The advancement of technologies brings the opportunity to transform current workplaces into digital workplaces, offering services with seamless and secure

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technologies that promise to change user experience and boost the collaboration and productivity[2]. Going further, integrating mobile data acquisition, sensors and wearables with cloud based people-centric services and collaborative and connected digital solutions we can also enhance individual health and increase efficiency and happiness of workforce.

Creating digital workplaces able to enhance healthcare, safety and well-being at workplace [1], and therefore employees performance, entails deployment a holistic approach, starting from analyzing the environmental and work tools [2]. Staff diversity regarding capabilities and needs have to be considered in the implementation of this kind of programs too. There is not a solo solution to fit every person at work [3,4].

We@Work initiative [5] is an example about how to tackle this situation, as it is shown in Figure 1. The project aims to develop a digital tool for workers and employees to ensure well-being, healthy and safe working life. It combines wearable sensors, big data analytics and ergonomics and a compliant cloud-based platform, based on Atos Codex technology[3]. The final outcome is a platform that allows real-time data collection at workplaces that is fed with sensors and questionnaires. Analytics turn gathered data into useful information to prevent work injuries, accidents and in general support healthy working life [6,7].

We@Work leverages the high penetration of mobile technologies in workplaces, which allows employees to be available, work on the go, collaborate easier and have a ubiquitous control on their tasks, agenda and contacts, etc. These possibilities have their appliance in healthcare and well-being services provision too. Time and space barriers limited the classic style of healthcare, where a patient always had to visit a doctor in hospital or clinic. Information and communication technologies (ICT) are a powerful tool to break these barriers [8]. Health data-driven solutions are transforming the way in which healthcare is delivered and also the way in which we work, make sport, and in general, take care of ourselves.

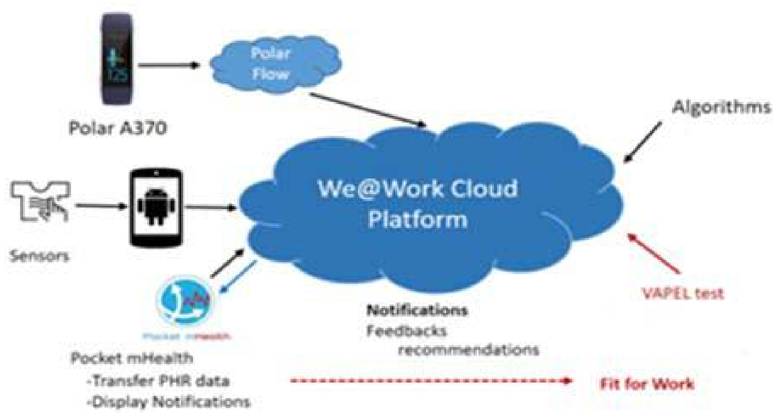

Figure 1. We@Work approach.

[2] https://atos.net/en/solutions/atos-digital-workplace

[3] https://atos.net/en/solutions/atos-codex-insight-driven-outcomes

In the context of We@Work, the gathered data conduct to a definition of the core value of the well-being program, so to enhance individual health, happiness and to build enduringly healthy work.

Physical and psychological health is a basic input for wellbeing, so it is remarkable to consider that expectations around the kind and quality of healthcare services are changing. Users are looking for more personalized services, self-management of their health status and a continue and seamless experience anytime, anywhere [9].

Mobile applications and wearable can boost the necessary change in this direction, giving citizens tools to monitor and manage their health data (as final owners of this information) [10]. Furthermore, the lifestyle, behavioral and health data collected from mobile devices can be used to produce a data model for the individual from several scopes. However, setbacks related to the interoperability with Health Information System (HIS) difficult citizens and healthcare providers to take advantage of this kind of tools [11,12].

The next section presents Pocket mHealth, an application conceived to bring the Electronic Health Record (EHR) to mobile. It consists in the mobile application for smartphones and a set of software tools installed at healthcare systems with access to the HIS using specific designed connectors. Pocket mHealth offers the portability and accessibility that are representative features of its mobile orientation and takes part of the We@Work system thanks to its scalable design, allowing customization and implementation according specific needs. To develop this solution, healthcare standards (e.g. HL7 FHIR) and well-known clinical terminologies (e.g. SNOMED) have been used. The connectors installed at the hospitals allow normalizing the clinical data and transferring data coming from the EHR (or other health systems) to the smartphones. Citizens are empowered within the healthcare loop: the individuals own their health data and it can be combined with data coming from other sources to produce accurate risk assessments at workplace, prompt detection of capacity-loss and self-management of a healthy working life.

2. Pocket mHealth System Description

Pocket mHealth consists of two main elements, an application for smartphone oriented to the interaction with the end user and a set of desktop software components deployed in the systems of clinics and hospitals with access to the connectors that use HIS. This favors the direct communication between the user and the actors involved in the provision of a social health service.

The main objective of the mobile application is to serve the user of means of transport, access point and method of transferring personal clinical information. Interoperability is a key concept to facilitate this task. The clinical information is managed in the form of standardized EHRs following the specifications of widely adopted modern standards of medical care such as openEHR/EN13606 and HL7 FHIR, and well-known terminology such as SNOMED-CT.

Pocket mHealth has been designed following a modular approach based on connectors, as shown in figure 2. These connectors allow processing information and data from different sources. In particular, Pocket mHealth manages information from health systems in the form of EHR, questionnaires on the current state of the user managed by insurance companies and data from wearable devices. These connectors, specific to each information source, transform and formalize this following the known and accepted standards such as the current security and privacy guidelines.

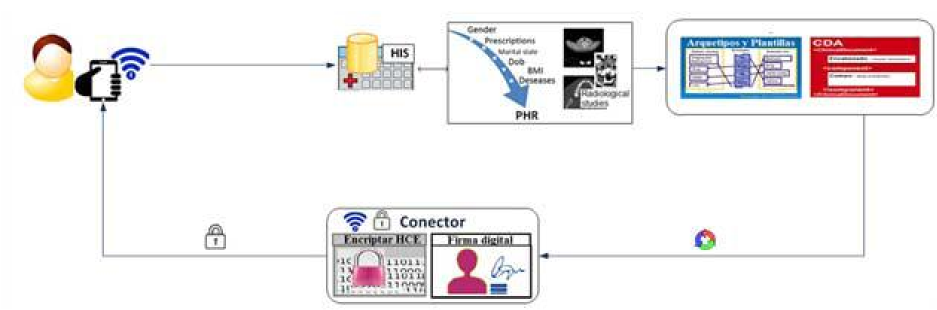

Figure 2. Pocket mHealth interactions and connectors for standardization.

Apart from the management of clinical information, the mobile application makes possible a second objective: to create an interaction method for socio-health services related to the user. In this way, the mobile application offers a channel of direct communication with the user, being able to display interactive alarms or interventions based on the information managed and the activity in which the user is immersed.

Figure 3. Pocket mHealth extension for well-being data.

3. Boosting the Healthcare Transformation

The delivery model of healthcare is transforming from the present hospital and career-centric to the in-home and patient-centric healthcare. Internet of Things (IoT) technology is promising for the ICT industry and for the traditional healthcare as well, because it is ubiquitous and personalized.

The typical functions expected of a Health solution using IoT technology are related to tracking, monitoring, information management, remote service and cross organization integration [13]. These requirements are met in Pocket mHealth with different HISs acting as health information sources in a seamless manner with the tools installed at the hospitals, that allow accessing the HIS using configured templates, normalizing the clinical data and transferring the record to the smartphone using wireless technologies, such as Bluetooth. The mobile application can then store and carry the clinical information coming from different HIS in a totally transparent way. The solution not only provides the benefits of a connected practice or organization such as clinical efficacy improvement, healthcare cost savings and increase of overall care quality, but also supports the care transformation that is enabled by a patient centered design.

In this sense, the advantages and benefits offered by Pocket mHealth focus on the following points:

- Distributed interoperability: thanks to the use of some of the best-known and most widely-used health standards, which allow the interconnection between different systems and promote the exchange of information between the systems directly through the patient from the lowest level and without affecting the clinical information systems and established.
- Information shared, safely, between patient and (occupational) health professionals.
- Continuous care reshaping access to data allows patients.
- Mobility of the user: allows to move and travel with the medical information stored safely in the mobile device; this also favors the possibility of choosing the professional to whom he wishes to go.
- Diagnostic improvement, since Pocket mHealth maintains the patient / citizen's clinical information in a reliable, integrated and updated way. It also facilitates the process of asking for second medical opinions.
- Savings in management costs: allows insurers or private clinics to save costs derived from duplication of tests and errors caused by incomplete or erroneous information. The offered service will be faster and more efficient, and visits to the specialist or primary care can be reduced.

4. Application to the Workplace

Pocket mHealth bridges the communications between the clinical actors and the prevention system (import/export clinical data) and between the end-user and the prevention system (sensors, algorithms, notifications, etc.). The development of more efficient and effective services can be driven by the characteristics of Pocket mHealth, since it is close by the end user in his day to day. In the case of workplaces the services developed to promote occupational health and digital ergonomics can benefit from Pocket mHealth, which favors the supervision of the parameters extracted from user's work activity. This supervision or digital intervention aims to correct or prevent harmful behaviors according to the clinical information of the user, and thus reduce the risk of accidents or damage. In addition, Pocket mHealth may be connected with Hospital Information System and other digital health services, allowing a continuous self-monitoring during the different entire day. This is not only beneficial for the user of the service, but also for the employers and insurance companies, since fostering a safe and careful workspace causes long term effectiveness and minimizes the costs associated with work absences.

By providing feedback, warnings and risk assessments, Pocket mHealth allows employees to get a proactive role in ensuring health at work and organizations to implement effective and personalized health programs at work.

We@Work project implements these previous ideas. Data from wearable sensors are collected in a pervasive manner and processed in conjunction with context information about the daily working tasks being executed. The data stored in the cloud from different job sites and several workers are analyzed with ergonomic algorithms. As a consequence, personalized recommendations are generated, at different stages, automated at first but also made by experts if required, to improve the ergonomics and occupational health of the workers.

Another potential use would involve people with chronic conditions to adapt their daily working routine to their specific capacities in an optimal way. The possibility of the Pocket mHealth to interact with the EHR opens the door for combining the work context information with the actual physiological performance of the worker to accurately detect the work situations that might impact more negatively to the work because of their condition, e.g. hypertension. Pervasive monitoring at work, home and the health care center can be used to detect which work tasks and assignments should be avoided in order to preserve the health of the worker.

Finally, Pocket mHealth can support also the active ageing at work, monitoring older employees performance to adapt their daily activity to their health needs.

5. Future Work

The new Regulation of Global Data Protection (GDPR) is a long and expensive task that will involve numerous changes in the business model of those services that use private and protected data. To face this new horizon, the integration of technologies and tools for identity management and management of access to private data is being studied. In this sense, Pocket mHealth is especially suited to meet the requirements raised by the GDPR since it is integrated with Envidian IAM Suit, enhancing the security and privacy capabilities of the solution.

In addition, Pocket mHealth can offer services for pharmacovigilance, becoming a tool to support semi-automatic reporting of Adverse Drug Reactions (ADRs) to regulatory authorities.

Finally, other potential advances will be targeted to enhance communication among healthcare stakeholders. In this case the integration with other Atos technologies such as Unify[4] will address some of the challenges related to clinical communication and workflow. On the other hand, Pocket mHealth is a patient-centred solution, but we are making advances to offer tools to share specific on-demand health information (e.g. data interesting for public health management or clinical trials) in a secure way to authorize healthcare providers.

6. Conclusions

Health and well-being have an intrinsic value that is strongly associated with job quality. Mobile apps combined with heterogeneous collection of work context

[4] https://www.unify.com/ourpartners/products-services/industry-solutions/healthcare.aspx

information and its analysis can predict risks and identify bad habits and performances at a workplace, covering from wellbeing to individual´s risk prevention of work-related injuries. Protection of workers and adapting the working environment could be achieved with a realistic cost for the main working environment actors and different stakeholders, e.g. occupational health services and companies. Benefits as absenteeism reduction extended working life, motivation and productivity come together with a healthier worker.

Pocket mHealth is based in a paradigm shift needed for person-centric health care: it provides access to EHRs with emphasis on interoperability standards. This way, other types of services or devices with the aim of building more complex applications can be integrated to create a personalized and updated service. As an example, Pocket mHealth takes part in We@Work to target the digitalization of workplaces and developing healthy working habits, giving employees a practical and effective tool to manage their health. Interoperability capabilities of Pocket mHealth allow taking advantage of rapid developments in non-intrusive sensor technology, mobile data acquisition and improved risk assessment methodologies combined with big data. The challenge is to exploit the potential of health mobile apps for the health self-management and integrating health and well-being solutions in the workplaces.

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4th Symposium on Future Intelligent Educational Environments and Learning (SOFIEEe'18)

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4th Int'l Symposium on Future Intelligent Educational Environments and Learning

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As the world moves steadily to become a knowledge-based economy, education and learning have never been more important. Technology is playing an increasingly crucial role in the delivery of education which, in turn, is driving research to discover ever better technological solutions. The age of intelligent environments is bringing such pedagogical advances as smart classrooms, virtual & augmented reality, mobile learning, intelligent campuses, cloud based learning and personalised intelligent tutors. All of which promise to revolutionize current educational practices and to challenge the traditional notion of a university or a school. However, the successful deployment of technology in education is not just a matter for science and engineering. For example, as education is increasingly becoming global, the cultural dimension is important. Likewise, matters relating to commercializing future educational environments have an important role to play in the successful deployment of these technologies. Thus, this is complex but interesting area of research.

To explore this area we have organized a series of academic events starting with the first workshop on *Future Intelligent Educational Environments*, held in Guanajuato (Mexico) as part of the annual Intelligent Environments (IE) conferences. Further editions were held in Athens (Greece) during 2013, Shanghai (China) during 2014, Prague (Czech Republic) during 2015, London (UK) during 2016, and Seoul (Korea) during 2017. The 2014 edition in Shanghai marked a significant step in the growth of the event, becoming a *Symposium on Future Intelligent Educational Environments* (SOFIEE). The Symposium format was very well received and has been repeated to date. We hope that this 2018 edition in Rome as part of IE'18, will continue the successful momentum, by serving as a forum for researchers and practitioners to discuss the latest intelligent technologies that can support the development of teaching and learning around the world.

Papers accepted into this year's Symposium cover a wide variety of topics such as:

a) the use of social media in higher education, b) models for culturally sensitive teaching and learning, c) smart education in K-12 settings, c) research and practice on cultivating children's social adaptability through game-based learning, d) innovative methods for tracking students' progress in mobile learning classrooms, and e) research on innovation and entrepreneurship education systems. Our authors are addressing smart and intelligent learning, learning systems, pedagogies based on a variety of learning settings from formal to informal and from K-12 to higher education. Together these contributions have the potential to greatly advance the research and practice in the multi-disciplines associated with intelligent educational environments and new ways of learning.

As a final note, we wish to express our sincere thanks to the SOFIEE'18 Program Committee for their thorough reviews and continuous support. We will also like to acknowledge our gratitude to the authors who submitted their contributions and to those

who will be there in Italy to enrich the event with their presentations. Special thanks to all our diligent reviewers for their assistance in the organization of this edition of SO-FIEE.

We are looking forward to meeting you all in Rome, which will allow us to build a strong community dedicated to introducing exciting innovations to education.

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Learning Management Systems (LMS) and Social Media in Higher Education

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Abstract. This paper provides a systematic and comprehensive review of social media use in higher education. We reviewed and synthesized relevant studies in the following 5 topics: 1) features of current LMS, 2) LMS gaps and criticisms, 3) social media learning theories, 4) instructional use of social media, and 5) alternative methods of using LMS. Our review reveals that many researchers have investigated these topics and proposed varying methods to integrate social media into teaching and learning. We also present opportunities for future research, including analyzing big data to draw more accurate conclusions on social media needs and usage in higher educational settings.

Keywords. Social Media, Learning Systems, Instructional Design, Personal Learning Environment, Big Data Analysis

1. Introduction

Studies conducted in Western countries have indicated that 93% of millennials spend time online [1], 99% of college students use Facebook [2], and 80% of faculty members use social media [3]. In addition, over half of the faculty members reported that they use social media within their teaching. Given these numbers, it is no surprise that social media's omnipresence is taking the Internet by storm. Furthermore, social media is increasingly becoming a part of educational reform. In 2009, only 10% of surveyed university students had used Facebook to discuss course-related problems with their peers [4]. By 2014, this number jumped to 81% [5]. In five short years, Western university students' use of Facebook for educational purposes skyrocketed.

This ever-increasing popularity of social media use by university students and faculty all over the world requires an investigation as to whether traditional learning platforms in higher education, specifically Learning Management Systems (LMS), are being eclipsed by Web 2.0 tools such as Facebook, Google Drive, Twitter and WeChat. This literature review focuses on what features LMSs should adopt in order to maintain purpose and relevancy for students and instructors, as well as the current Web 2.0 platforms and features students and instructors use for educational purposes.

Due to the fast-changing nature of Web 2.0 platforms, the scope of this review focuses on recent studies. Most of the studies discussed within this literature review were published within the last five years to this present writing in 2017.

2. Defining Social Media and Relevant Concepts

Social media has many different forms and can be divided into six different categories [6]: 1) Collaborative Projects (i.e. Wikipedia), 2) Blogs and Microblogs (i.e. Twitter), 3) Content Communities (i.e. YouTube), 4) Social Networking Sites (i.e. Facebook), 5) Virtual Game Worlds (i.e. World of Warcraft), and 6) Virtual Social Worlds (i.e. Second Life). Although these categories vary greatly, users all seem to be searching for the same functionality when choosing their preferred social media platform. Kietzmann [7] proposes a framework to support this idea and claims that there are seven functionalities that social media platforms may fall into: identity, conversation, sharing, presence, relationship, reputation, and groups (see Figure 1).

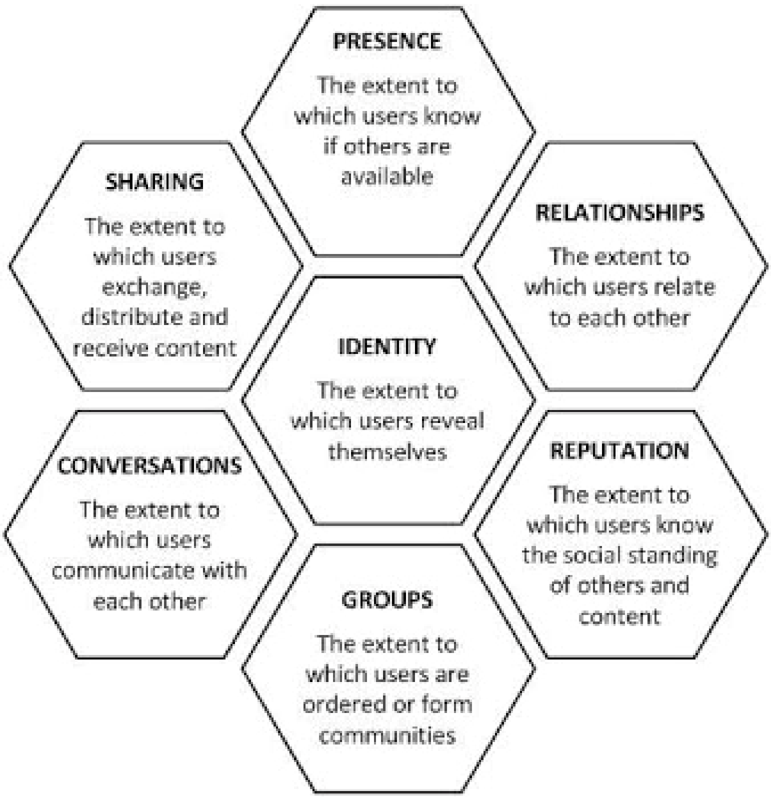

Fig 1. Social Media Functionality [7]

Tools and concepts associated with social media include:

a) Web 2.0: A stage of Web development that is characterized by webpages with user-generated content and the rise in social media. Examples of Web 2.0 websites include Instagram, blogs, wikis, and YouTube.

b) Connectivism: Learning theory that suggests learning is emphasized by roles of social and cultural contexts. It states knowledge is a network, and people learn through pattern recognition.

c) Personal Learning Environment (PLE): Individual learners' spaces that are student centric and are wholly customized by the learner themselves.

3. Features of Current Learning Management Systems (LMS)

Learning Management System (LMS) is a platform used by educational and corporate environments to manage learning—especially for administering, documenting, and tracking courses and training. Examples of a LMS include Blackboard, Moodle, WebCT, Sakai, and Saba Cloud. LMSs have quickly been accepted by higher education institutions as modern-day learning environments for students. These online platforms allow instructors to provide their students with learning materials and activities while tracking participation and progress through data systems and assessments. In the United States, higher education continues to experience an increase in computer and Internet use which necessitates the integration of LMSs in order to bring more instructors and students together.

Despite the substantial use of LMS in higher education, there is a growing awareness that student engagement levels in Web 2.0 environments far exceed their engagement in the LMS used by their institutions. Social media sites, blogs, and wikis offer students exceptional opportunities to create and share content as well as interact with others across the world. LMSs have not evolved enough to keep up with the pace of technology, especially with methods of interaction facilitated by online social networks such as Facebook and Twitter [1]. This discrepancy has challenged instructors to determine whether or not their LMS promotes autonomy or a culture of dependency and how social media might be incorporated to boost and maintain student engagement [8].

3.1 Blackboard, Moodle and Canvas

The widely used LMS in Western countries include Blackboard, Moodle and Canvas. However, Blackboard has been seen as an instructor-centered platform. It is mainly a place for instructor to post course material, to collect assignments, and to track students' learning. Moodle and Canvas emerged as more user-centered platforms. One of the main goals of Moodle and Canvas is to create a community of learners through collaborative tools and activities. According to Moodle, the main power of this activity-based model comes in combining the activities into sequences and groups, which can help guide participants through learning paths. Thus, each activity can build on the outcomes of previous ones (docs.moodle.org/32/en/Pedagogy). The design of Moodle and Canvas are based upon the socio-constructivist learning theory. Both platform encourage instructors and students to interact and to collaborate synchronously in chat rooms or asynchronously in wikis and forums [9].

3.2 Critiques of Current LMS

LMSs currently used in most universities are considered "institutionally-controlled platforms". Social media platforms are largely seen as "student-centric" rather than "institutionally-owned" due to the fact that students are not closely moderated and students are able to post without filtering their thoughts and ideas. LMSs tend to be extremely teacher-centered, affording instructors with an environment for digital content management. In our ever-evolving digital world, LMSs cannot keep up with the current social media paradigm shift [1]. The current design of LMS does not focus on students' social constructivist approach to support lifelong learning.

In addition, there is a lack of connection between formal and informal learning in the current LMS(s). Higher education institutions need to provide more adaptive environments for their students by opening them up to Web 2.0 tools. Furthermore, Personal Learning Environments (PLE) must be redefined in order to allow students to openly choose the tools they want to use without being tied to a specific context or time period, which is often experienced with a LMS [10]. LMSs are limited in their ability to adapt to the shift in preference for user-centric and social learning. As early as 2006, Researchers (e.g., Dalsgaard [11]) have recommended that organizations should move beyond a centralized and integrated LMS and towards the usage of distinct tools used and managed by the students themselves. This perspective illuminates the importance of a Social Connectivist approach to e-learning.

4. Instructional Use of Social Media Tools: Review of Research

Social media has been used, with varying degrees of effectiveness, by instructors throughout the United States. In fact, instructor use of Web 2.0 tools is progressing at a rapid rate. There are numerous experimental studies that analyze how instructors are using social media to enhance their pedagogy. Current social media tools used include: Twitter, Facebook, Linked-In, Blogs, Wikis, WeiBo (microblogging in China), and WeChat, a powerful tool that integrates social media with learning, shopping, banking, paying bills, and Uber-type of car services.

4.1 Western Social Media Tools: Twitter and Facebook

Twitter is a microblogging tool that has been used by higher education in several ways. Instructors can tweet assignments, share links, share conference notes and answer questions. Some instructors have used Twitter as a backchannel for student discourse during a lecture. Instructors join or ask students to participate in real-time discussions via tweet-ups. Studies have shown that Twitter was effective as a back channel during live events to encourage immediate participation—especially at places or events where there may be a lack of feedback due to nervousness or shyness. Microblogging allows for more immediate participation and also invites virtual participation.

Facebook has gained massive popularity among users of all ages. An exploratory study by Wang and colleagues [12] used Facebook for higher education in a Singaporean institute. The study took place in two elective courses over the term of a semester. In the courses, Facebook operated as a tool for announcements, sharing course documents, course tutorials, discussions, and surveys. This interactivity was permitted by the following Facebook features: 1) Facebook wall, 2) Event function, and 3) Feedback space or discussion function. Students agreed that Facebook was successful as their LMS [12]. A study conducted in 2014 explored the potential educational value of Facebook by distributing a survey to 387 subjects [5]. Based on the survey data, platforms were ranked based on four aspects related to education. The survey revealed that E-learning platforms do not rank as the number one choice for any of the four educational aspects. Instead, students preferred to use Facebook and online bulletin board/forums (BBS) for interacting with others, reviewing and sharing resources, and communicating with instructors.

4.2 Eastern social media tools: WeiBo and WeChat

Weibo, similar to Twitter, is a microblogging tool widely used in China. Due to the nature of the Chinese language, the 140-character count allows for more content, as a single Chinese character is representative of a full English word. Weibo's additional features include in-line pictures, video uploads, games, threaded comments, and private chatting. According to a 2012 study on the motivations and usage patterns of Weibo, three of the eight trending topics most related to learning consisted of: 1) professional development, 2) information seeking, and 3) citizenship behavior. The following (Table 1) represents these categories with their sub categories that directly reflect learning behaviors [13].

Table 1. Motivational factors that influence the use of Weibo

Motivational Factors	Subcategories influenced by learning		
Professional Development	Exchange working experience	Exchange learning experience	Updates on industry development
Information Seeking	Search and learn information	Learn about news	Get help from others
Citizenship Behavior	Provide help to others	Provide information to others	Recognition for knowledge

Finally, **WeChat** has quickly become the burgeoning social media platform since its 2011 inception. A study by Bosma, Owsiany, Scharff and Yau [14] examined the usage of WeChat and WeLearn (a learning management platform that takes advantage of the mobile features of WeChat) within a college English curriculum. WeChat as a social platform has become widely popular, especially in China. Its advantages over traditional responsive websites include:

- Accessibility – especially instantaneous accessibility via mobile device
- Popularity – nearly 1 billion users in 2018 according to Tencent
- Flexibility – users can customize the menu and navigation
- Record tracking – WeLearn allows for tracking users' learning paths and progress.

Because of these advantages, WeChat public platforms allow for many possibilities in terms of customizing the app to cater towards instructor and student needs. A study conducted to explore a community college professor's using of WeChat in his class indicates a strong advantage of having a communication record, in addition to instantaneous communication [14].

Taking advantage of the mobile features of WeChat, several leading e-learning companies in China (e.g., Shanghai's Longtime Inc.) developed a learning management platform called WeLearn. Figure 2 shows an exemplary mobile learning course with a WeLearn component (see Figure 3), which is simplistic and mobile-friendly. In comparison, Guo and her colleagues' study [15] find that WeLearn also has the following advantages over a traditional or responsive website:

- Accessibility: once users subscribe to it, they can easily access it from their WeChat account.

- Usability: Users can use WeChat to send instant messages, call, video-conference, transfer files, and form personal and professional groups.
- Flexible menu and navigation: an instructor can customize the menu in WeLearn and encourage students to interact in WeChat.
- Record Tracking: WeLearn is a learning management system light. It has the ability to track every user's learning path and progress.

Fig 2. Interface of An Exemplary WeLearn Course

Fig 3. The Navigation Menu of WeLearn

By analyzing the features of WeChat and WeLearn and examining related studies, Guo and her colleagues [15] provided suggestions on how to integrate WeChat-based mobile learning into the College English curriculum in Higher-Educational Institutions of China. They discovered that the WeChat Open platform can be designed to help to track down, record and manage learning and tutoring as well as the monitoring and management of learning and tutoring. Micro-community organically formed in WeChat can be developed to achieve interactive communication between students and teachers or among students.

5. Alternative Methods of Using LMSs

Stern and Willits [1] assert that no one could have predicted the impact social media trends would have on higher education. The underlying question is whether higher education can bridge the gap between LMS and social media. Higher education is capable of pursuing a balance between the two. Other researchers (e.g., Dabbagh & Kitsantas [16]) note that the learner is responsible for learning in their Personal Learning Environment (PLE). Presently, students utilize Web 2.0 tools concurrently with their institution's LMS.

A study conducted by García-Peñalvo and colleagues [17] proposes three methods for integrating social and Web 2.0 tools with a LMS: (1) Parallel existence which keeps the formal (LMS) and informal (social and web) environments separate, but running side by side; (2) Opening of the LMS, which pushes LMS features to other web services (unidirectional); (3) full integration of external tools into the LMS by coding Web 2.0 tools directly into the LMS. Most methods of LMS utilization we reviewed fall into one of these categories.

5.1 *Parallel existence*

In parallel existence, the formal (LMS) and informal (Web 2.0) learning environments remain separate. PLEs and LMSs simply coexist in this scenario. Students would maintain usage of an LMS while applying another tool, such as Google Drive, in their learning. The benefit for learners is that they are in control of the decision-making process to use their preference of tools efficiently and effectively [10]. As of today, running an LMS concurrently with informal social learning tools is the most discussed and accepted method in the training sphere [15]. One such study by Sclater [8] examines whether or not LMSs, specifically Moodle, are destined to continue as the primary means of organizing the online learning experience for students. Sclater [8] concludes that an LMS's ability to integrate Web 2.0 systems into an LMS is inconsequential. The key concern with integrating is overloading LMSs with too many features that may be better off as separate systems. Sclater [8] proposes that LMSs will become more of a management information system, working in the background. Students can export the information from LMSs and view it in the environments they prefer.

5.2 *Opening the LMS*

This scenario represents a system where Web 2.0 tools are accessible from within the LMS. Conversely, the LMS would not be accessible through those external tools. The biggest critique is the institutional barriers of opening up their LMS. Institutional belief is that the LMS simply serves as information exportation rather than connections with Web 2.0 features [17]. This interoperability initiative allowed the LMS to integrate into external tools as a widget. García-Peñalvo and colleagues [17] postulate that students should use a Personal Learning Environment (PLE) and LMS concurrently, and both systems should be able to interoperate. However, in doing so, they state using web services and interoperability services to open up an LMS has proven very difficult to implement. Their study [17] states the difficulty in building an architecture for exporting to a LMS, which suggests this method may not be worth pursuing due to its complicated implementation.

5.3 Integration of external tools

This scenario emphasizes the idea that the institution chooses the external tools that will be integrated into the LMS. Learners will not have the freedom to choose their preferred platforms. External tools would be integrated as gadgets on the interface [17]. Integrating the LMS and PLE is attainable, but is far from being achieved.

5.4 Dynamic course platform

An alternative framework, named the Dynamic Course Platform (DCP), was proposed by Stern and Willits [1]. A DCP works as an a la carte program where instructors choose appropriate pedagogical tools while preserving the university LMS. Although Stern implemented several different methods within a couple of courses that she taught. Her studies included utilizing a personal blogging site (Wordpress) as the platform for an online course as well as incorporating Twitter into a separate pop culture course. Following her experimentation, Stern and Willits [1] recommend a tri-fold Dynamic Course Platform. The three elements of the platform include: 1) Wordpress, 2) Twitter, and 3) Blackboard (or other LMS). Wordpress serves as a tool for group projects, blogs, pages, and delivery of course content. Twitter serves as a communication and networking tool. Lastly, Blackboard or a similar LMS incorporates gradebook, assessment facilitation and course email.

6. Conclusions

Through this review, we identify several opportunities for future study: First, data need to be obtained that summarize what students and instructors desire in an LMS. Student and instructor non-negotiables need to be outlined (e.g. gradebook, assessment tools, and submission features). Formal surveys need to be conducted to gather conclusive data on student and instructor preferences of the LMS version modifications. A professor's main focus is ensuring organization on a course-to-course level. However, due to this, higher education LMSs are not student-centric, meaning they do not focus on student learning development throughout one's learning career ([11][10][1][8]). Student-centric learning promotes a social connectivist approach, which can include easy communication with fellow classmates, organizing events or study groups, logging personal achievement, and maintaining connections with classmates beyond a course-to-course level. These are all social features that current LMSs do not adequately provide. There is an opportunity to uncover more conclusive analytical data regarding what features students and instructors want in an LMS.

A second avenue for future research regards identifying which LMS integration method is most favorable among university students and instructors. For instance, some studies suggest minimal change – simply running an LMS in parallel with third-party software tools (like Google Docs) to meet instructional needs. Others go as far as to suggest the "tumbling of the LMS ivory tower" [1]. The struggle of determining an appropriate integration method leads to questions such as:

a) What might a dynamic learning platform that incorporates traditional LMS features as well as social media, look like?
b) How can instructors incorporate social media with their LMSs to facilitate learning while ensuring student security and privacy?

c) Additionally, how can instructors determine the efficacy of social media tools in relation to teaching and learning?

There is no definitive consensus on where LMSs stand with new Web 2.0 norms, creating an opportunity for further research in integration methods and their efficacy.

The third route for additional research is further exploring the facets necessary for a new platform that strips away all the unnecessary and outdated features of an LMS. Instead of determining which existing integration method is most favorable, the fundamental features favored for learning should be investigated. This is based on the idea that a large social platform, dedicated to education and life-long learning, does not yet exist.

For instance, there are many large platforms that have been favored in certain pillars of our lives. Facebook has become the dominant fixture in maintaining and keeping track of our interpersonal relationships with friends and family. LinkedIn is the preferred social network for maintaining professional working relationships. However, there is no social platform that adequately encompasses the "learning" pillar of our lives. Through this review, we envision a social platform that performs the administrative duties that instructors and institutions require from an LMS, as well as the user-centric social features that students so direly crave, such as WeLearn. This new social platform could include features that support a world-wide robust social network of academic people and resources and allows for easy communication amongst peers—features not yet available in any mainstream LMS or social media platform. All platforms hosted the big data, which can be analyzed to draw more accurate conclusions on social media needs and usage in higher educational settings.

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Research and Practice on Children's Behavioral Habits Based on Farming Games

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Abstract. Using the "Internet+WeChat+Game+School evaluation+Family" guide, and by aligning the national evaluation system and the curricula of the participating schools in China, this study established a Four-in-One evaluation system consisting of family, school, society, and individuals. Under this system, students, parents, and teachers use the popular fruit tree breeding games to share and communicate their ideas and discoveries, so as to increase students' understanding of self, to witness first-hand the results of putting more effort into tasks, and to experience personal growth. This study shows that game-based learning can enhance students' characters, improve their social adaptability, and promote the healthy growth of their minds.

Keywords. Children's behavioral habits, Internet, farming game, education ecosystems, social media, informal learning

1. Introduction

In recent years, Chinese are living in much richer material lives with phenomenal economic development, but moral education of students in all levels are lacking behind. Bullying in schools, fighting and poisoning incidents in universities have become national news. These events have different attributions, but all have one aspect in common--the deficiency in childhood social adaptation leads to children's social indifference, self-centeredness, and a series of social problems. Therefore, cultivating and enhancing children's social adaptability can help them with a well-rounded healthy growth and this mission should become a top priority for educators in China.

On the connotation of social adaptability, Reber [1] believes that social adaptive behavior is a type of skill that can promote the effective integration of individual and society. Sparron [2] holds that social adaptability is an adaptation to social life environment. It refers to how individuals regulate their own behavior in the form of various psychological activities, thus making their behavior to reach the level appropriate for their age, social requirements and cultural settings. Nie [3] finds that social adaptive behavior reflects the level of individuals' independent living capabilities and their ability to adapt to the social environment.

As to factors influencing children's social adaptation, Shang [4] points to three major ones including the "main role", "symbiotic evolution", and "environmental constraints". As for the way and means to promote children's social adaptation, Zhu and Liu [2] believes that the emotional warmth and the dimension of trust and encouragement in school and parenting pattern can enhance students' social adaptability. Shang [4] further proposes that educators and parents can start from four aspects to build up children's social adaptability:

a) strengthen the interaction between subject and environment and improve practical adaptability;
b) enhance institutional environment to support the development of adaptability;
c) coordinate social organization to enhance p potential adaptability;
d) develop and open up oneself so as to promote regulation and strain capacity.

Existing research (e.g., Nie [3] & Shang [4]) shows that scholars have made considerable achievements in the connotation, structure, influential factors and facilitates way of children's social adaptability, and all these have laid a solid foundation for us to continue to do further research in this field. However, academic circles still have many deficiencies in the research on children social adaptability, which are shown in the following aspects.

a) Although the theoretical basis of children's social adaptability at home and abroad has been relatively rich, how to use these theories to develop a comprehensive and effective training of social adaptability are relatively less;
b) Most of the existing research on children's social adaptability are only concerned with a specific period of time and cannot have a long-term and lasting impact on children's personality cultivation.
c) The main research participants were selected groups of children with special needs, including the descendants of immigrants, suffering from a disease such as autism, children exposed to domestic violence, children of divorced parents, "left-behind" children in the rural countryside, migrant children, etc.

In this research, we tested an innovative way to help children improve their social adaptability. Building on achievements from other researchers, we developed the "Internet+" model and an "Internet+WeChat+Game+School evaluation+Family" guide. By engaging children in playing the farming games, we aim to promote their growth in both mind, morality, and adaptability. By improving the interaction and intimacy between school and parents, parents and children, teacher and children, we pay close attention to and guide the development of children's social adaptability in the long term, thus to provide a new and explanatory support of the theory and practice, and to promote their healthy development in all aspects.

2. Contents of study

Building on findings from previous studies, we established a scale and an appraisal model to measure children's social adaptability in China. Family and social institutions can trace and analyze children's social adaptabilities through our public channel on China's widely used social media tools—WeChat. We also developed a breeding game that can be accessed from our WeChat channel, so as to recruit potential participants. Our study explores the relevant and effective methods in the improvement of relationship in parent-child, peer and teacher-student. The study aims to improve children's social adaptability in comprehensive and continuous ways and to promote their holistic and healthy development.

3. Technology solution

3.1. The Overall Framework

The overall framework of this study is shown in Fig. 1.

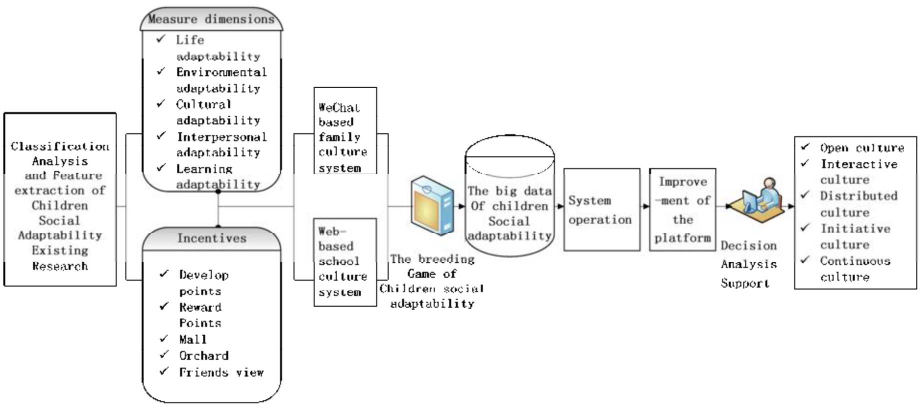

Figure 1. System's overall framework.

3.2. Technology Platform

Front-end use jquery react [5], back-end use spring, springmvc, Mybaits, HTML5 pages to the form of show.

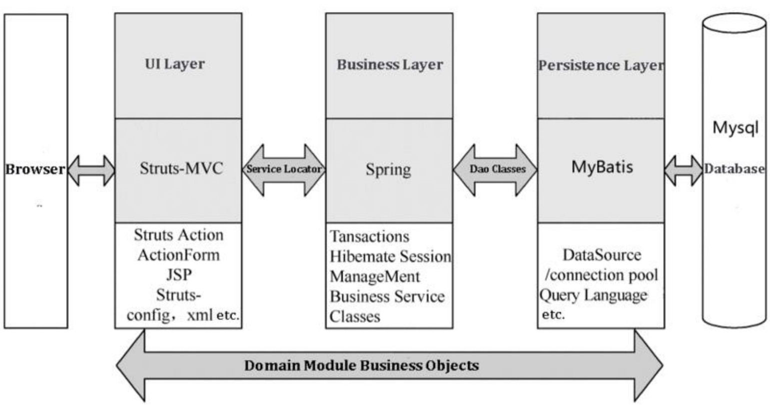

Figure 2. System Technology Platform Architecture.

3.3. Business Platform

This is a four-in-one adaptive evaluation system for students, parents, teachers and schools [6].

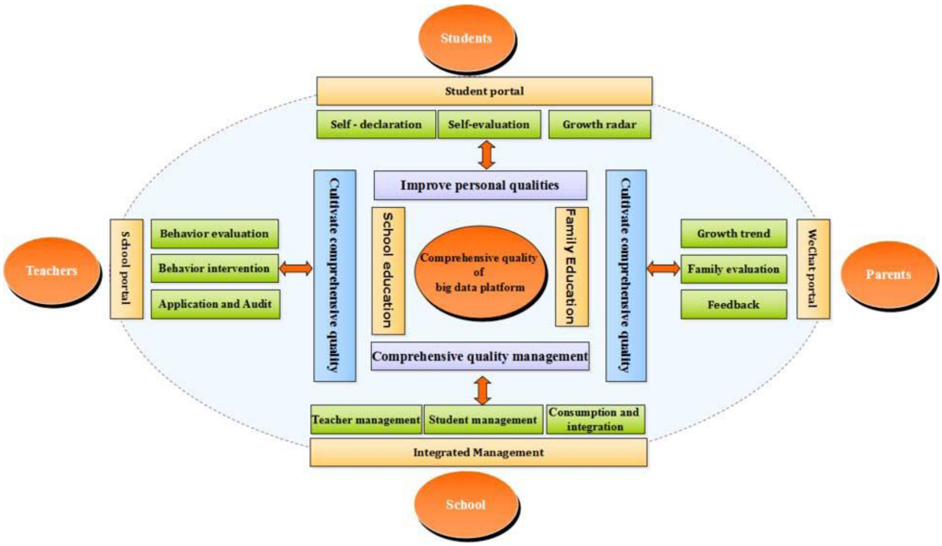

Figure 3. Four-in-one adaptive evaluation system platform.

Taking Zhuhai No.1 Primary School as an example combined with the current emphasis on Children's growth and the need of practical life and teaching, we will finally define the measure of children's social adaptability as five literacy, and classify the subject into literacy. The following is the correspondence and cultivating objectives:

Table 1. Objectives for cultivating Children's social adaptation.

Literacy	Subject	Cultivating objectives
Humanities	Chinese, English	Humanistic basis, Classic reading, Self-confidence expression, International understanding
Scientific	Mathematics, Science	Scientific enlightenment, Imagine guidance, Creative practice
Artistic	Music, Art, Calligraphy	Art appreciation, Aesthetic experience, Artistic imagination, Creative display
Practice	Character education, Practice	Growth ceremony, Security self-protection, Home-school interaction, Conventional autonomy, Evaluation of development, Love and mutual assistance
Health	Sports, Mental health	Health knowledge, Physical fitness, Sports skills, Cooperation and exchanges

3.4. The Design of the Breeding Game

The growth process of children is the same as the process of fruit trees sprouting, blossoming and then gathering fruits. In the students' orchards, teachers and families can add butterflies, bees and other decorations to praise student in time. When the students have wrong behaviors, such as the destruction of school property, caterpillars will used to correct their behaviors.

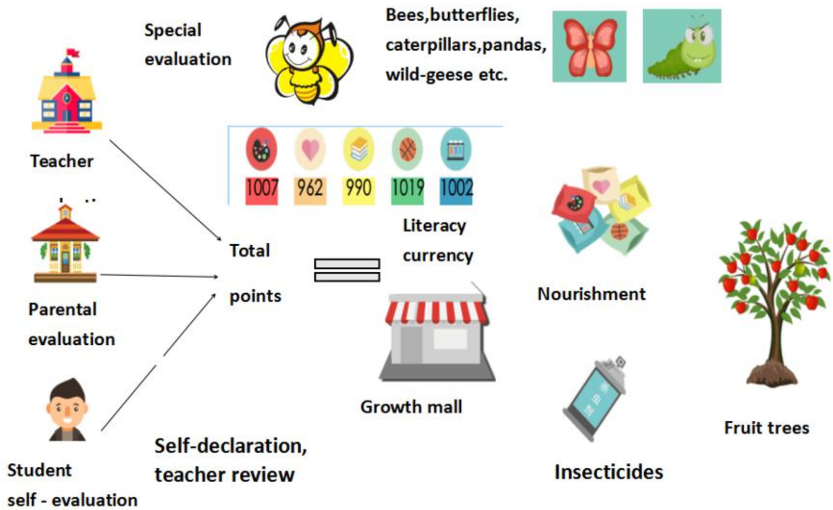

Figure 4. The design of the tre breeding game.

4. Model Design

Child's Growth Development Trend Prediction

a) The data come from the score of school and family. The first evaluating indicator is the five kinds of accomplishment – humanities, practice, science, art, health. Students are scored by weeks.
b) The precondition is the result of the Kolmogorov-Smirnov test fitting normal distribution.
c) For a student, the first week of the humanities score in the sample space to do z-regularization, so as to obtain the first week of regularization humanities score.

$$Xn,i = 1/2((Xi\text{-}u)/2\,\sigma + 1) \tag{1}$$

d) Xn,i approximate to the mean 0.5, the standard deviation 0.25 of the normal distribution.
e) Based on the Xn,i of every week to draw the line chart, it will show a semester of the humanities changing trends. According to these algorithms, we can analysis the specific location of children in the class average (see in Fig. 5).
f) Based on data analysis, through the big data algorithm to predict the future trends.

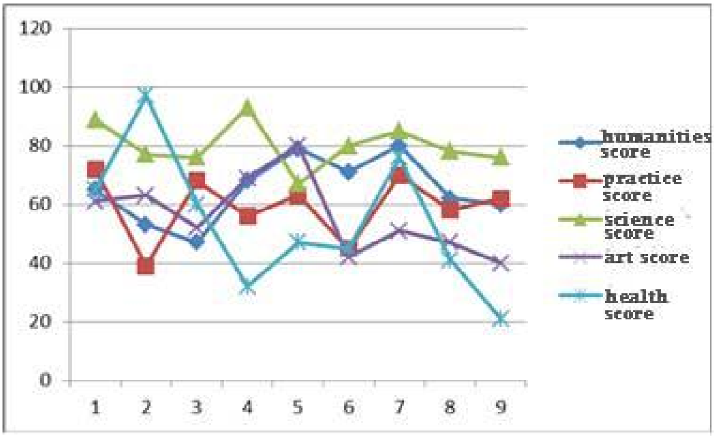

Figure 5. Growth trend statistics.

5. Implementation

The system can be divided into PC subsystem (User: teachers and administrators), mobile terminal family subsystem (User: students and their parents) and mobile terminal teacher subsystem (User: teachers) according to the function.

Table 2. Overview of system functions (PC subsystem).

Operational module	*Functional partitioning*	*Describe*
Log in and personal information	Users log in	Teachers log in the system
	Modify password	Modify password
	Personal information	View personal information and scores
General functions	Constraint condition	Select grade, class and weekend
	Search student	Search student by the student number or student name
	Association model	Evaluate in association model
Student evaluation	Submit evaluation	Select evaluation subjects, evaluation content and submit
	Notice	Send customized content to selected students
	Special reward/punishment	Reward or punishment with special meaning
	Evaluation review	Review the independence declaration
	Export score record	Export score recording (.doc format)
Historical evaluation	Check historical evaluation	Check historical evaluation
	Delete historical evaluation	Delete historical evaluation
Student information	Edit student information	Edit the name and student number of the student and etc.
	Delete student information	Delete a student information
	Add new students	Add a student into selected class
Evaluation statistics	Check evaluation statistics	View the evaluation statistics for the selected class and week
	Sort	Ascending/descending order according to the selected column
	Family performance and self evaluation	View the family performance and selfevaluation
	Charts	View the "star of the week" and "start for the beyond"

Table 3. Overview of system functions (mobile family subsystem).

Operational module	*Functional partitioning*	*Describe*
Log in and personal information	Users log in	Students or parents log in system
	Modify password	Modify password
Comprehensive performance	Comprehensive performance (week)	Current weekly assessment list for all literacy
	Historical performance	A historical assessment list of points
Breeding game	Buy props	Buy items in the store and use
	My friends	Search, add friends and view friend's orchard
Growth trend	Growth status	The overall situation of literacy scores
	Growth trend	The change trend of literacy scores
Interaction	Parents evaluation	Parents evaluate children, give children a message, view the child's message
	Self-evaluation	Self evaluation, leave a message to parents, views the message of parents
	Self-declaration	Parents and children declare their own rating items

Table 4. Overview of system functions (mobile terminal teacher subsystem).

Operational module	*Functional partitioning*	*Describe*
Log in and personal information	Users log in	Teachers log in the system
	Modify password	Modify password
	Personal information	View personal information and sores
General functions	Constraint condition	Select the grade, class and week
	Search students	Search student by student number or student name
Student evaluation	Submit evaluation	Select evaluate subjects and content evaluation to submit
	Notice	Send custom content to selected students
	Special reward/punishment	Reward or punishment with special meaning
	Evaluation review	Review the independence declaration
Student information	Edit student information	Edit student's name, student's number and etc.
	Delete student information	Delete a student information
	Add new students	Add a new student to selected class

Nowadays, there are more than 30 schools and 60 thousands people using our system. Taking Zhuhai No.1 Primary School as an example, it is total number of 2400 students, and it is average 1000 users visit our system every day. The data are shown in Fig. 6.

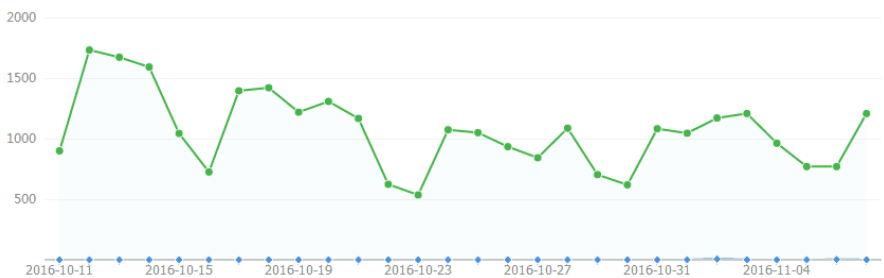

Figure 6. The Daily Visits from Zhuhai No.1 Primary School.

6. Summary

Nowadays, there are more than 30 schools and 60 thousands people using this gaming system. The goal of our system is to build a home-school collaborative evaluation feedback system for schools, teachers, students, and their parents. We persist in the principle of positive encouragement, leading the development of students and encourage their wholesome development. Our system has becoming the starting point of teacher education programs in several universities. The students are particularly fond of and do pay attention to their respective growth gardens. And the parents can learn more about the performance of their children in the learning process. In addition, they also can interact with the teacher and their child in time. This forms a virtuous cycle of education, and it effectively promotes the development of children's social adaptability.

Now that we are building the four in one evaluation system, it can further expand the role of evaluation such as social training agency. This system can enhance the degree of social participation and it can also help children cultivate a positive, open and innovative attitude towards life.

Acknowledgements

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Analysis of Lecturers' Behavior Through the Use of Learning Management Systems: A Case Study in Computer Engineering

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Abstract. This paper shows an alternative vision of teaching evaluation in Learning Management System (LMS) through the analysis of the tool events generated by lecturers. To perform this study, the events recorded in the LMS Sakai are extracted, analyzed and compared with results from students' evaluations of lecturers. The most important dimensions of the teaching process (planning, methodology, resources and monitoring) are thus evaluated in this work. Some remarkable results have been obtained in the study, highlighting two main findings: On the one hand, the use of specific tools may improve student monitoring, and on the other hand, a greater number of resources and personalized supervision does not imply a better student's perception of the applied teaching methodology.

Keywords. Learning Management Systems, e-learning, teaching behavior, evaluation methods, higher education, data analysis

1. Introduction

In the aim of improving the educational process through the use of Learning Management Systems (LMS) in Higher Education, it is necessary to study the user behavior based on the analysis of the data generated by these platforms. New fields of study are created with the common goal of improving the teaching and learning process through LMS. A possible line of research proposed in this paper is to compare the lecturers' actual work within the LMS with the students' assessment on the performance achieved by those lecturers.

This work is based on the case study in the Catholic University of Murcia (UCAM), where several degrees are offered in different modalities (on-campus, blended and online). It is specifically focused on the Degree of Computer Engineering that is offered both on-campus and online. The available data for the academic years 2015/16 and 2016/17 have been taken into account in the study, where the educational methodology is evaluated by means of the use of the LMS Sakai [1], since it is the one adopted in the institution.

The main goal of this work is to discover possible connections between the teaching methodology in LMS adopted by lecturers and the students' perceptions that help to detect possible deficiencies or needs in the teaching process. Hence, the study is structured in the following three stages:

1. Students' evaluations of lecturers in the Degree of Computer Engineering, where four dimensions are evaluated: teaching methodology, available resources, course planning and general overview.
2. Data extracted from Sakai are analyzed to evaluate lecturers' accesses to Sakai, most (and least) used tools and associated events.
3. Finally, the results obtained in the previous stages are compared to detect possible deviations or incidences.

The rest of the paper is structured as follows. Section 2 reviews some previous works related to the analysis of educational data. In section 3 it is explained the development of our proposal. Section 4 shows the case study in the Degree of Computer Engineering using real Sakai data and the results of students' evaluations of lecturers. Finally, conclusion and future work are given in section 5.

2. Related Work

In the field of education there are many alternatives to analyze information and solve problems. Each student has a different methodology for understanding and managing information. It is challenging to know the different styles, methodologies and processes that students and lecturers use in order to find patterns that can help both lecturers to improve the quality of their teaching and students to improve their school performance [1]. To help with this task, the amount of data generated by LMS could be processed and analyzed by techniques capable of extracting behavior patterns. In the literature there are many studies on the students' use and behavior LMS, such as [8,3,6] to mention a few. However, the analysis of lecturers' behaviors on these platforms is not so common.

In [9], an algorithm called CCA (Course Classification Algorithm) is proposed to be incorporated into an e-learning platform to analyze and assess its contents. The algorithm defines a series of metrics that are used to provide suggestions and improvements on contents and their quality. These suggestions are obtained by analyzing the use and quantity of material available as well as the students' use and assessment of such material. With this algorithm lecturers can improve contents and methodologies based on these suggestions. In [4] a study is performed to analyze and understand the perceptions of teachers and students about an LMS. The aim of this research is to anticipate possible problems and help in the improvement and construction of a productive learning system. Another work that takes into account the behavior of lecturers is presented in [7]. In it, the authors carry out a study for 40 blended and online modules to detect behavior patterns and to analyze the design of resources created by lecturers with the aim of improving learning performance.

[1] https://www.sakaiproject.org/features

3. Materials and methods

This study has been performed taking into account the data related to the lecturers belonging to the Degree of Computer Engineering at UCAM during the academic years 2015/16 and 2016/17. Table 1 shows the numbers of lecturers in the two modalities involved in the study, namely on-campus and online. The lecturers belong exclusively to each modality.

Table 1. Numbers of lecturers in each modality and academic year

MODALITY/YEAR	2015/2016	2016/2017
ON-CAMPUS	25	24
ONLINE	24	23

In order to perform this study, two different types of sources of data have been analyzed: (1) LMS events generated by the lecturers and (2) students' evaluations of lecturers belonging to the aforementioned Degree. Firstly, let us explain the LMS tool events to be analyzed in the study. In particular, we have used Sakai as the reference platform for our study, as it is the one adopted in our University. In this work we have classified these tools into two groups, content tools and student monitoring tools:

- Content tools: Lesson Builder and Resources (including audiovisual resources).
- Monitoring tools: Forum, Videoconference, Announcements, Calendar, Private messages, Assignments and Tests.

Note that the Lesson Builder is a tool that allows using web-based templates to distribute the contents of each unit and create a learning methodology (e.g., first it is shown the text resources explaining the whole lesson, then additional and recommended readings, then some audiovisual resources with the most important highlights of that unit, then some related assignments, etc.).

Secondly, the students' evaluations of lecturers are aimed at evaluating four dimensions in the lecturers' performance: Methodology, Planning, Resources and General Overview. These dimensions are graded by the students following a Likert-type scale from 1 (strong negative perception) to 5 (strong positive perception).

Next it is described how the data have been gathered for the study. In the first place, the lecturers' events in the LMS are collected by means of a web application called OnlineData [2]. This application has been developed as part of our previous work, and, in a nuthshell, it enables centralizing and configuring all the interesting metrics related to LMS tools by directly querying the LMS underlying database. These metrics are then presented in different visual forms and with different level of detail. The metrics not only consist on the number of elements created by the lecturer, such as number of uploaded audiovisual resources, number of assignments, number of sessions of videoconference, etc., but also monitoring metrics such as average response time to students' posts in forum, assignments, private messages, etc. The interested reader could refer to [2] for further information on OnlineData. The total number of LMS tool events generated by lecturers involved in this study sums up to 171,412 events. In the second place, the students' evaluations of lecturers was conducted by 32 on-campus students and 38 online students in the academic year 2015/16 and by 42 on-campus students and 49 online students in the academic year 2016/17, respectively.

Finally, the following data analyses have been performed to evaluate lecturers' behaviors:

- Event ranking: This analysis studies the events performed by lecturers to identify not only the most frequent events performed by them, but also the absence of particular events. In this manner it is possible to detect the most (and least) used tools by lecturers and what actions they perform in those tools.
- Time profile of lecturers' log-ins: The intention for this analysis is to evaluate the lecturers' log-in events in order to detect their monthly and weekly connection behavior. In this manner it is possible to identify specific periods with high or low lecturers' activity in the LMS.
- Results of the students' evaluations of lecturers vs. Sakai events: Here it is analyzed the students' perceptions on the lecturers' performance according to the aforementioned four dimensions with respect to the number of events related to content and monitor LMS tools.

These analyses have been performed by means of the OnlineData tool and the visualization of the results has been performed by means of QlikView [5].

4. Results

This section explores the results of the analyses proposed in Section 3. Firstly, a ranking on the generated events is studied both for on-campus and online modalities. Secondly, the lecturers' time profile trends are analyzed on a weekly and monthly basis. Finally, it is presented a comparison of the actual lecturers' performance in the LMS with the students' perception of such performance.

4.1. Event Rankings

Figures 1 and 2 show the rankings for the top 15 types of events generated by lecturers when using the LMS for the online and on-campus modality, respectively. The x-axis shows the event identifier, whereas the y-axis indicates the number of records for each event.

4.1.1. Event ranking for the online modality

Figure 1 shows the event ranking for the online modality in the academic years 2015/16 and 2016/17. The most relevant findings are commented next:

- The number of events related to the Lesson Builder tool (create pages/modify pages/delete pages) in 2015/16 is greater than the number of the same events in 2016/17. This is reasonable due to the fact that in 2016/17 the Lesson Builder pages were already created in the previous academic year and only some content update is necessary.
- A similar fact happens with events related to the Assignment tool, since most of the assignments are reused from one year to the next. It is therefore logical for the event "Assignment saved as a draft" to be one of the most active, since the same tasks are reactivated in the academic year 2016/17 but planned on a new date.

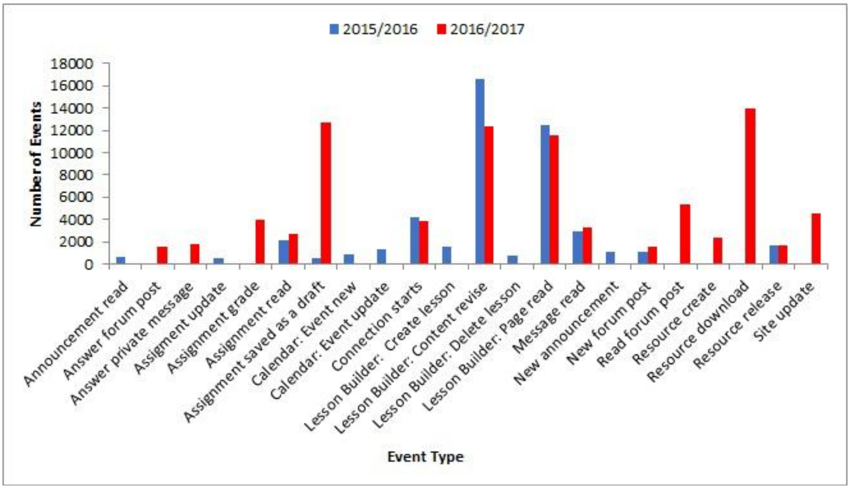


Figure 1. Event rankings related to the online modality for each academic year.

- The number of forums created is similar in both courses, although a bit higher in 2016/17. Some improvement for supervision of students in 2016/17 is detected due to the occurrence of the event "Answer forum post" in the top-15 ranking of that course.
- The customization of the LMS sites is deemed as an important event for the 2016/17 course. This is an indicator of an effort in the improvement in the usability and visual appearance of the virtual campus from the lecturer's side.
- In the 2016/17 course there are no events associated with the Calendar and Announcements tools. It can be assumed that in the case of the online modality this information is reflected in the Lesson Builder pages.

Although not shown in the top 15 event of the Figure 1, the number of videoconferences performed by lecturers in both courses is also worth mentioning, as it is an important parameter to evaluate the supervision of students in the online modality. Thus, in 2015/16 a number of 380 videoconferences were performed, whereas in 2016/17 they increased to 453.

4.1.2. Event ranking for the on-campus modality

Figure 2 shows the event ranking for the on-campus modality in the academic years 2015/16 and 2016/17. The most relevant findings are commented next:

- In 2015/16 lecturers structured their content using the Lesson Builder tool, although it was primarily designed for being used in the online modality.
- In 2016/17 new events related to the Resource tool appear in the ranking, namely "Resource create", "Resource delete", "Resource download", and "Resource revise", which are not present in 2015/16. This behavior suggests an improvement in the content of the teaching material from year to year.
- The most important event in 2016/17 is "Assignment saved as a draft", showing a similar behavior as in the online modality explained already. This hypothesis is validated thanks to the 2015/16 events associated to the creation of assignments

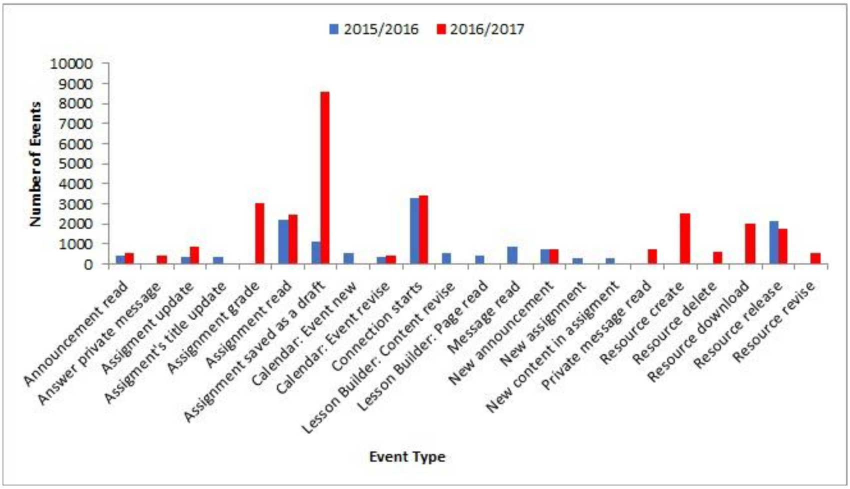


Figure 2. Event rankings related to the on-campus modality for each academic year.

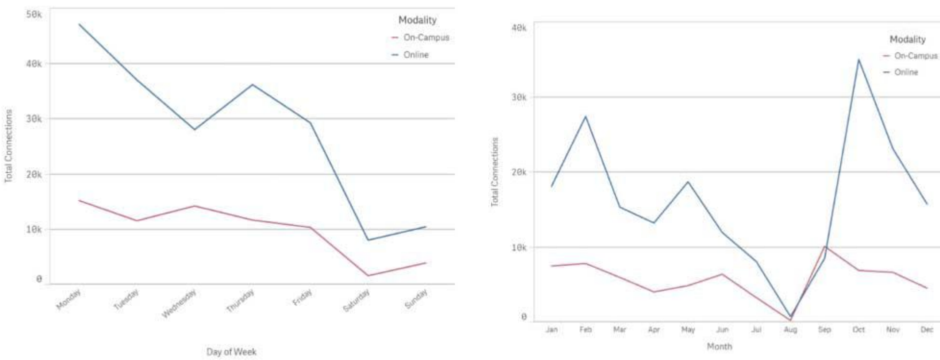
(e.g., "Assignment's title update", "Assignment update", "New assignment" and "New content in assignment"), which do not appear in the 2016/17 ranking.

- For both courses the "Private message read" event appears in the rankings, but it is noteworthy for the supervision of students that the "Answer private message" event only appears in 2016/17, showing an improvement in the number of students' messages answered.
- The events related to announcements are similar in both academic courses; on the contrary, the events related to the Calendar tool have a smaller presence in 2016/17. It may be due to the fact that lecturers prefer now giving notifications by means of announcements instead of listing events in the calendar.

4.2. *Time Profile of Lecturers' Log-Ins*

This section analyzes first the lecturers' log-ins trends according to their teaching modality (see Figure 3). Then it is compared the lecturer's log-in behavior according to the academic year, independently of the teaching modality (see Figure 4).

Figure 3(a) depicts the number of lecturers' connections to Sakai on a weekly basis depending on the teaching modality. Analyzing these data we observe that the differences among the different days of the week and also between the teaching modalities are noticeable. For the online modality, Monday is the most active day; Tuesday and Thursday show similar behavior as the second most active days, and Wednesday and Friday are also similar as the less active weekdays. The activity of the lecturers on weekends is significantly reduced, taking into account that they are marked as days off school in the academic calendar for this modality. In the case of on-campus modality, the behavior on working days does not show significant differences during the weekdays and decreases markedly over the weekend. It is observed that the activity in this modality is always very inferior to the online modality. On the other hand, Figure 3(b) shows the lecturer's log-ins to Sakai according to the months of the year for each modality. In this case, a higher activity for the online modality with respect to the on-campus one is significant again, except for the months of July and August (the latter is the academic holiday month). In the

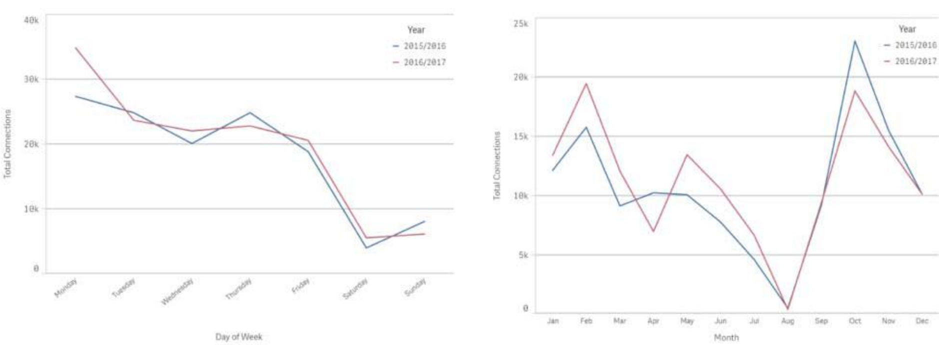


(a)Weekly connection timeline (b) Annual connection timeline

Figure 3. Time profile of lecturers' log-ins grouped by modality.

online modality, the most active months correspond to the beginning of each four-month term (September for the first term, February for the second term), the first term showing more activity than the second one. This same behavior is repeated for the on-campus modality, although with more homogeneous values throughout the year.

Figure 4(a) depicts the comparative of lecturers' log-ins to the Sakai LMS by academic year on different days of the week. It can be seen that the trends in both courses are very similar although the trend in academic year 2016/2017 tends to be more homogeneous. Figure 4(b) shows the comparative of lecturers' log-ins throughout the months of each academic year. The findings obtained from these data indicate that the visits by months are very similar in both courses, highlighting that the number of visits is higher for the first four-month terms (September to January) with respect to the second four-month terms (February to June) in both academic years.



(a)Weekly connection timeline (b) Annual connection timeline

Figure 4. Time profile of lecturers' log-ins grouped by year.

4.3. Results of the students' evaluations of lecturers vs. Sakai Events

This section compares the results of the students' evaluations of lecturers with Sakai events related to the items assessed in the survey. The comparison is shown in Table 2.

This table shows the results for the academic years 2015/16 and 2016/17 and the on-campus and online modalities. The "Method" (methodology), "Planning", "Resources" and "General Overview" columns represent the items graded by the students in the surveys as explained in Section 3. The "Event Resources" column shows the sum of Sakai's events related to the "Resources" and "Lesson Builder" tools that are compared with the "Resources" and "General Overview" items in the survey. Likewise, the "Tracking Events" column shows the sum of events of the Forum, Videoconference, Announcements, Calendar, Private messages, Assignments and Tests tools that are compared to the "Methodology" and "Planning" items in the survey.

Table 2. Comparative between the results of the students' evaluations of lecturers and Sakai events. Dimensions from Method. to Overview Vision are graded by the students following a Likert-type scale from 1 (strong negative perception) to 5 (strong positive perception).

Academic Year	Modality	Events Resources	Tracking Events	Method.	Planning	Resources	Overview Vision
2015/16	Online	33476	11863	4.00	4.18	3.73	4.33
	On-Campus	3854	7767	4.38	4.43	4.26	4.52
2016/17	Online	44855	41413	3.91	4.09	3.61	4.22
	OnCampus	7946	20238	4.11	4.20	3.95	4.27

According to these results, the events associated with content tools in the online modality increase from 2015/16 to 2016/17. However, the most notable increase occurs in the tracking events, where the number of events in 2016/17 is almost fourfold with respect to the previous year. A similar behavior is observed in the on-campus mode. In this case, the events associated with content tools are doubled from one academic year to the next. The behavior for tracking events is also incremental, almost three times more tracking events were generated in 2016/2017 than were in the 2015/16.

It is worth mentioning that although LMS events increase from one academic year to the next, the results for all the different items in the students' evaluations of lecturers drop slightly. It should be noted that the overall results of the surveys are quite satisfactory, but the slight decrease in all aspects is striking, especially when the lecturers' performance in the LMS has augmented with respect to the previous year. In order to determine the reason for this decrease in the the students' evaluations results, several interviews were carried out with a group of students. In these interviews, the students justified the reasons for their scores and the conclusions obtained from these interviews indicate that they feel overfilled with contents and monitoring tasks, suggesting less resources and assignments but of higher quality.

5. Conclusion and Future Work

In this paper a case study has been presented to analyze possible connections between the methodology applied by lecturers in Learning Management Systems (LMS) and the students' perception of such methodology in order to detect possible deficiencies and improve the teaching process. LMS events generated by lecturers during their activity in the platform are analyzed and compared to the results obtained from a lecturer assessment survey conducted by students. The Sakai LMS has been used as the specific learning platform during the academic years 2015/16 and 2016/17 in the Degree of Computer

Engineering offered both in on-campus and online modalities at the Catholic University of Murcia (UCAM).

The analysis of the results indicates that for the academic year 2016/17 lecturers tracked their students more closely than in the previous year 2015/16. This increase in the monitoring process is noticeable as more forums were answered, more resources were uploaded and more videoconferences were performed, between other tasks. Regarding the trend of lecturers' log-ins to the LMS, it is remarkable that the tracking of students in the online modality is always greater than on-campus modality. In addition, lecturers also log-in on weekends even they being school off periods. It is noteworthy that the greatest number of visits occurs at the beginning of each four-month term and during the exam period, with a greater tendency in the first four-month term.

Regarding the students' evaluations of lecturers, it is worth mentioning that despite the positive results and the increased tracking events related to students, the results of this survey in terms of students satisfaction with teaching quality decrease slightly from academic year 2015/16 to academic year 2016/17. This lessening is due in part to the growing demands of the students each year and the fact that the students are overwhelmed with too many contents and assignments for each subject.

Two immediate future lines follow this work. On the one hand, the extension of this study by including lecturers for more than 40 bachelor's and master's degrees offered at UCAM to have a complete view on the analysis proposed in this paper. On the other hand, to perform a detailed study of the students' perception of the quality of each specific content provided by lecturers.

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What Am I Writing: Classification of On-Line Handwritten Sequences

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Abstract. This paper presents a novel approach for classification of online handwritten sequences into text, equations, and plots. This classification helps in identifying the progress of student/learner while attempting different problems in context of classroom equipped with tablets, iPads. Furthermore, it serves as a feedback (for both students and instructors) to analyze the writing behavior and understanding capabilities of the student. The presented approach is based on an ensemble of different machine learning classifiers, where not only the individual sequences are classified but also the contextual information is used to refine the classification results. To train and test the system, a real-world dataset consisting up of 11,601 sequences was collected from 20 participants. Evaluation results on the real dataset shows that the presented system, when tested in person independent settings, is capable of classifying handwritten on-line sequences with an overall accuracy of 92%.

Keywords. sequence classification, feature engineering, machine learning, base classifier, ensemble classifier

1. Introduction

With the evolution of digital world, new opportunities have emerged to interact with our environment and vice-versa. Displays and sensor technologies are the main driving forces behind it. Touch-screen displays have caught the attention of research community for on-line handwriting recognition. Handwriting can be broadly divided into two major categories: (i) Off-line and (ii) On-line. The major difference between the two is the way they are produced and analyzed. Writing produced on normal paper with normal pen is considered as off-line, whereas writing on the touch-screen devices either with finger or digital pen is termed as on-line handwriting. On-line handwriting also includes writing with sensor pens on normal or special paper.

History of handwriting classification goes back to early 20^{th} century, when German police used handwriting as biometric feature before the second world war [1]. After that,

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Nottingham police came up with a handwriting classification system as a result of a decade worth of research. Their presented system was used to classify individuals based on their handwriting, to maintain the record of Nottingham residents.

In 1954, Smith et al. [2] presented six factors for classification of large volumes of handwritings. These factors were speed, size, slant, spacing, pressure and form. Out of these factors, pressure and form were marked as unconscious behaviors and others as developed factors.

Writer and writing style classification approach for on-line handwriting recognition was presented by Bouletreau et al. [3]. Based on velocity, pen-tip displacement data was segmented into strokes. Every stroke was represented by a 1-d feature vector which was then used to train Kohonen network for writer classification. Writing styles were classified using clustering and discriminant analysis techniques. Schomaker et al. [4] presented synthetic parameters for classification of handwriting into different writing families. They termed their approach as preliminary step for handwriting classification.

Most of the work done in handwriting classification domain focuses on person classification and recognition [5,6], word recognition [7,8,9], mathematical expression recognition [10,11,12], and/or sentiment analysis [13,14]. Classification of written data into different classes hasn't been addressed so far, up to best of authors knowledge. Therefore, comparison with existing methods, if any, seems not to be fair. Classification of on-line handwritten data into text and non-text classes using global features, local features, Recurrent Neural Networks (RNNs), LSTM and BLSTM networks has been done in recent past [15,16,17].

Ensemble classifiers are a popular choice for data stream classification [18,19]. The idea behind ensemble classifier is to learn a set of base classifiers and make a prediction based on output of the individual classifiers. This results into reduction of variance and bias, as predictions are now dependent on multiple classifiers trained on the same dataset, instead of a single one.

A wearable sensor-based adaptive system was presented by Pirkl et al. [20]. This system was used to monitor the progress of learner during exercises. It evaluates the learning analytics using multiple on-body sensors and sensor pen. They presented the cognitive analysis of novice and expert users by comparing time taken to perform the exercise to the total number of writing segments produced.

(a) Experimental setup (b) Output after pre-processing

Figure 1. A participant writing on iPad and its digital output

This paper presents a novel, generic approach for classification of handwritten sequences into text, calculation or plot/graph. Experimental setup for data collection is shown in Figure 1a. In addition to classification of individual sequences, contextual information is leveraged in order to further refine the classification results. The rest of paper is structured as follows: Section II elaborates system overview and its modules, followed by detailed analysis of the results and evaluation in section III. Section IV concludes the paper with hints towards future prospects of the presented work.

2. System Overview

We developed a data acquisition module for iPad which helped in collection of the dataset. Acquired data was preprocessed, and fed to the feature extraction module to extract the 26 dimensional feature vector. These feature vectors were then used to train individual classifiers along with an ensemble of them. We also utilized the contextual information for the given sequence while generating the final output. The proposed system is demonstrated in Figure 2.

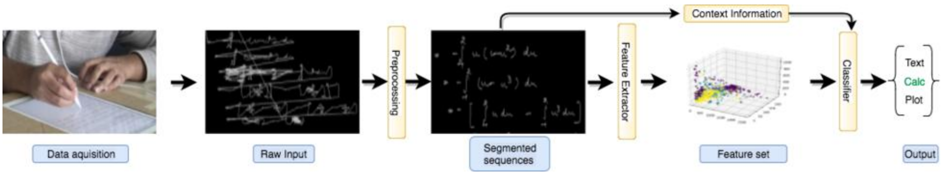


Figure 2. System overview

2.1. Data Acquisition Module

For the purposes of data collection, a dedicated iOS platform was developed. It provided functions for creating, managing and exporting documents. Documents were created on the basis of a template, which predefined the document's structure.

Apple pencil was used for writing on the iPad, which can deliver up to 240 data points per second. These points encapsulates information regarding the location of the pencil on the touchscreen, force of the touch, altitude and azimuth angle, and time[2]. An eraser option was also available in order to be able to make corrections to the written text. Handwriting of the user was rendered in view by linear interpolation between succeeding points. A SQLite database instance was used to store data on the device locally.

2.2. Preprocessing Module

Data acquisition module passed raw continuous data sequences to the preprocessing module. The data also included information regarding the erased sequences. Cleansing of the input data was performed followed by the segmentation into individual sequences. Every segmented sequence represented a single word or expression. The length of the segmented sequences was variable comprising of a single or multiple strokes based on the distance between them. After passing through preprocessing module, the data was visually identical to the one written on the iPad as shown in Figure 1b.

[2]https://developer.apple.com/documentation/uikit/uiview; documentation of the UIView class

2.3. Feature Extraction Module

In the proposed approach, we extracted features regarding the time information, precise and corrected (x,y) co-ordinates of hand-written sequences and the force information. The extracted features also included the commonly used features in on-line handwriting recognition literature [7,5] and signature verification [22,21] .

- Length of the segmented sequence (1): Distance in pixels between start and end point.
- Time of segmented sequence (2): Time in seconds for a single sequence.
- Variance and standard deviation $(3),(4)$ of the rate of change during the segmented sequence Δt.
- Displacement (5): The shortest possible distance in pixels of pencil movement for a given segmented sequence.
- Speed (6): The rate at which the given sequence is produced.
- Velocity (7): Time taken to cover the displacement for a given sequence.
- x, y-range $(8),(9)$: Range is defined by the difference between the maximum and minimum value present in given sequence values.

$$x - range = max[x(t)] - min[x(t)] \tag{1}$$

- x,y-skew $(10),(11)$: Skewness is a measure of the amount and direction of departure from horizontal symmetry for a given sequence.
- x,y-kurtosis $(12),(13)$: Kurtosis is a measure of the height and sharpness of the central peak for a given sequence.
- Variance of Δx, Δy $(14),(15)$: The rate of change of pixels in both horizontal and vertical direction.
- Standard deviation of Δx, Δy $(16),(17)$.
- Variance and standard deviation of direction angles of a segmented sequence (18), (19): Measure of angles between consecutive pixel for a given sequence.
- Variance and standard deviation of gradient of a segmented sequence $(20),(21)$: Gradient or slope of consecutive pixels in a given sequence. Gradient is measure of steepness and direction of line.
- Vicinity aspect (22): The aspect of the trajectory of a given sequence [7]

$$\frac{(y - range) - (x - range)}{(y - range) + (x - range)} \tag{2}$$

- Vicinity curliness (23): The length of given sequence divided by $max(\Delta x, \Delta y)$ [7].
- Range of force (24): The difference between the maximum and minimum force value for a given sequence.
- Mean force (25): Average force applied for a given sequence.
- Variance of force (26).

2.4. Classification Module

Classification module comprised of a combination of the baseline machine learning algorithms, which were fused together as an ensemble classifier. In the presented approach, we utilized K-nearest neighbors, Random Forests and Decision Trees as the base classifiers. Classification module is demonstrated in Figure 3.

2.4.1. *K-Nearest Neighbors (KNN)*

K-nearest neighbors [23] is one of the simplest machine learning algorithms for pattern recognition. KNN classification decision is made on the basis of majority votes of the nearby data points. The target object is assigned to most common class present in the K-nearest neighboring data points.

2.4.2. *Decision Tree (DT)*

Decision tree classifiers [24] have been successfully used in a wide range of classification problems because of their flexibility, simplicity and computational efficiency. Decision trees recursively partitions the dataset into smaller subsets and defines a decision framework consisting of a set of tests defined at each branch in the tree.

2.4.3. *Random Forest (RF)*

Random forest classifier [25] is a combination of the tree predictors, and is considered as a very effective machine learning algorithm for prediction. Each individual tree within the forest optimizes over a randomly selected set of features which significantly reduces correlation between the different trees contributing towards the diversity of the ensemble classifier.

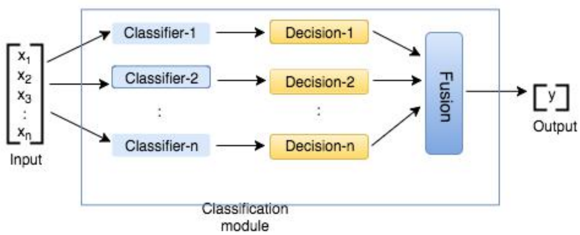


Figure 3. Classification module

2.4.4. *Ensemble Classifier*

The performance of the base classifier is mainly dependent on the successful learning of patterns present in training data. Learning patterns of every base classifier may vary from each other despite of being trained on the same dataset. To improve the performance, an ensemble of classifiers was used, which fused outputs of the individual base classifiers to generate an improved and stable single output. Ensemble classifiers have been successfully leveraged in the past to improve the classification results.

3. Experiments and Evaluation

3.1. *Data Collection*

A group of 20 participants (14 males, 6 females) were selected for the experiments. All participants were students from different disciplines belonging to different regions, i.e Pakistan, India, Cuba, Venezuela, USA, etc. 18 participants were right handed and 17 participants (12 males, 5 females) had their first writing experience on digital devices (iPad in our case).

During the experiment, participants were asked to solve different exercises based on the instruction manual provided to them. Exercises comprised of text reproduction, creative writing, copying equations, solutions to basic calculus problems and drawing some easy graphs.

3.2. Dataset and Evaluation Protocol

The dataset consisted of $11,601$ segmented writing sequences. 54% sequences belonged to text, 24% to calculation and rest of the 22% belonged to the plot/graph class. We used 70% of data for training and the rest of the 30% for testing. Small subsets of consecutive sequences belonging to a single class were used to provide context information. Taking the contextual information into account, a single final decision was produced for the given subset.

We used scikit library [26] to train the machine learning models. We also evaluated our system when contextual information with individual sequence was provided. We evaluated K-nearest neighbors, random forest and decision tree classifier. We carried out 10-fold cross-validation during the training. The obtained results are reported using the average accuracy and confusion matrices.

3.3. Results and Discussion

Detailed analysis of the presented approach considering performance of the base classifiers and their ensemble combination with and without information of the neighboring sequences is elaborated below.

We start our discussion with the selection of optimal parameters for individual base classifiers. To extract the optimal parameters for every base classifier, a grid-search was performed along with a 10-fold cross validation on the train set. The best number of nearest neighbors $k = 11$ was estimated, which is the key parameter to train a KNN classifier. Parameters for the random forest classifier are the number of estimators, $est = 99$ and splitting criteria is $entropy$.

3.3.1. Person dependent results

Person dependent classification refers to organization of train and test set in a way that both contains a percentage of every user's data. We trained a KNN classifier with $k = 11$, number of nearest neighbor configuration. After 10-fold cross-validation, we achieved the overall accuracy of 73% as summarized in Table 1. The KNN model was particularly effective for classification of the text class, predicting 92% of the total sequences correctly . Results for calculation class and plot/graph class were 64% and 65% respectively.

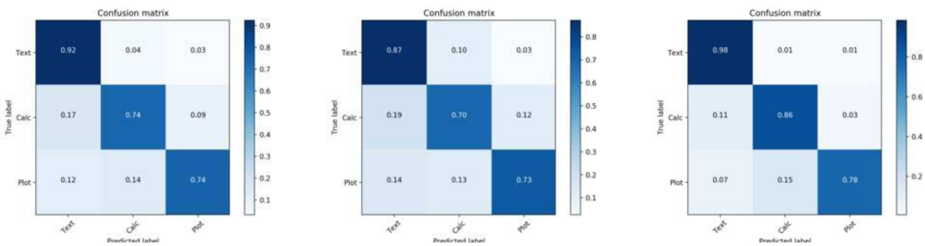
Overall results accomplished by the decision tree classifier were 72.3%. Individual class results were found to be 81%, 67% and 69% for text, calculation and graph/plot class, respectively.

The employed random forest classifier was able to outperform other base classifiers. Individual results achieved by training random forest classifier were found to be $90\%, 79\%$, and 77% for text, calculation and plot/graph class, respectively.

Table 1. Person dependent performance analysis of base classifiers

Classifier	Overall Accuracy(%)	Text (%)	Calculation (%)	Graph (%)
KNN	73	92	64	65
Random Forest	80	90	79	77
Decision Tree	72.3	81	67	69
Ensemble Classifier	83.2	92	74	74

We tried different combinations for ensemble classifier. Best results were observed by an ensemble of random forest, decision tree and k-nearest neighbor classifier, when 83% of the input sequences were correctly classified. Success rate for the text class prediction was found to be 92% and 74% for the calculation and plot/graph class.



(a) Person dependent results (b) Person independent results without context information (c) Person independent results with context information

Figure 4. Normalized confusion matrices for ensemble classifier

3.3.2. Person independent results

In the person independent evaluation, train and test sets were split based on the users. It means that for a particular user, his data can either be used in training or testing phase, but not in both. We used the same base and ensemble classifiers with the same configuration to establish a strong comparison with the person dependent setting.

KNN achieved an overall accuracy of 75.1% for person independent configuration with the class-base accuracy of 95%, 52% and 59% for text, calculation and plot/graph, respectively, as shown in Table 2. Decision tree classifier produced an overall prediction accuracy of 69.3%, by predicting 83%, 62% and 68% of the sequences from text, calculation and plot/graph class correctly.

Random forest classifier again surpassed the performance of the other base classifiers when evaluated in a person independent setting. Overall correct prediction rate for random forest classifier was found to be 80.8%. Random forest classified 83% of the text sequences, 75% of the calculation sequences and 77% of the plots/graphs correctly as highlighted in Table 2.

By evaluating an ensemble classifier, we achieved an overall accuracy of 80%. For person independent setting, our presented approach correctly classified 87% of the text, 70% of the calculation and 73% of the plots/graphs sequences, as shown in Table 2.

Table 2. Person independent performance analysis of base classifiers

Classifier	Overall Accuracy(%)	Text (%)	Calculation (%)	Graph (%)
KNN	75.1	95	52	59
Random Forest	80.8	83	75	77
Decision Tree	69.3	83	62	68
Ensemble Classifier	80	87	70	73
Ensemble+Context	92	98	86	78

We also tested the presented approach, to produce single result for consecutive sequences by retaining the contextual information. Multiple sequences belonging to the same class were fed to the classifier. These sequences were first classified individually. Based on the individual results, a single final prediction was made by the system utilizing the contextual information. Confusion matrix in Figure 4c highlights the classification results for the ensemble classifier when contextual information is used. By using the contextual information, the overall accuracy improved to 92%, where about 98% of the text sequences were classified successfully. Classification rate of calculation and graph/plot class was found to be 86% and 78%, respectively as shown in Table 2.

3.4. Discussions

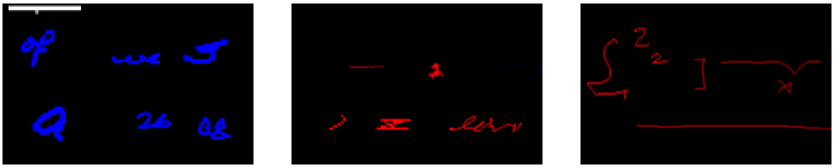
Written text is easy to distinguish since it follows clear pattern. Therefore, sequences belonging to text class are classified correctly with highest accuracy, both in base classifiers and ensemble classifiers as shown in Figure 4. Small sequences comprising of a single or couple of letters were often confused with the calculations. Therefore, the presented approach faces difficulty while distinguishing between text and calculation, when input sequence is a single stroke number or letter.

Similarly, some punctuation marks were misclassified as plot/graph. Misclassification from the text class are shown in Figure 5a and 5b.

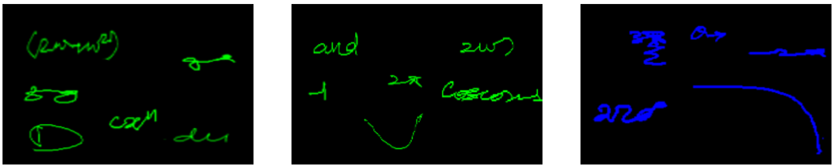
As a derivation or a calculation has a close resemblance to text production, our presented approach struggles in differentiating between calculation and text, shown as confusion matrices in figs. 4a to 4c. Individual strokes for calculation carries high resemblance with a single or two letter stroke of the text class. Improvements can be achieved by providing contextual information, as discussed later in this section. Long horizontal lines drawn to format the fractions into nominator and denominators along with square bracket signs are often confused with plot/graph class. Few misclassified sequences from calculation class are shown in Figure 5c and 5d.

Graph/plot sequences indicates clear patterns, features and structure. These patterns are significantly different from that of textual writing and calculations in visualization. In the given scenario, we consider all strokes present in the graph as plot/graph sequences including axis markers, plot legends, and/or axis labels. Therefore, some sequences were confused with text and calculation class, as shown in Figure 5e and 5f.

Considering that the segmented sequences composed of a single or double characters, it was quite difficult to identify whether they belonged to text or the calculation class, unless carrying specific symbols associated to a particular class. Most of the sequences in calculation were composed of characters which were very similar to text, but when combined with mathematical symbols, demonstrated significant difference be-



(a) Text misclassified as calculation
(b) Text misclassified as plot/graph
(c) Calculations misclassified as plot/graph



(d) Calculations misclassified as text
(e) Plot/graph misclassified as text
(f) Plot/graph misclassified as calculation

Figure 5. Misclassified sequences using ensemble classifier

tween text and calculation. The classifier could be improved by incorporating information regarding the neighboring individuals, which means if preceding and following sequences of input sequence belong to same class, then its more probable input sequence belongs to the same class. Therefore, contextual information was leveraged to improve the overall results by 12%. Results for text class were further improved to 98%, while for the calculation class, an increment of 16% was noticed, which was quite significant. The presented approach requires only about $1/3^{rd}$ of a second to classify a given sequence using contextual information, which makes it suitable for real-time settings. Results with and without contextual information are reported in Table 2.

4. Conclusion and future work

In this paper, we presented an approach capable of classifying on-line handwritten sequences without any prior conditions. The presented approach is generic, as it does not put any constraints on end user while attempting exercises, thus can be used in any setup.

The proposed system was evaluated on the handwriting of 20 participants and achieved a successful classification rate of 92%. Every data class was correctly predicted in a fraction of a second 78% of the time, as shown in Figure 4c. We believe that the presented approach will help instructors to oversee the performance of the students during writing, solving exercises, and/or plotting graphs.

We aim to tackle the problem of differentiating between copying text, creative writing and attempting solutions in the future work. We also plan to release the dataset publicly with multi-labeled sequences, i.e. current classification labels and copy or creative writing labels. We also propose a cognitive analysis system by incorporating gaze information in our presented approach which quantifies the stress level and difficulty of the exercises for an individual learner.

5. Acknowledgment

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Identifying Cultural Learning Preferences: A Cross-Cultural Comparison of Korean and Chinese Students

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Abstract. This study aims to examine, identify, and compare the learning preferences between students in China and South Korea. Previous published studies (e.g., Wang et al., 2016; Liu et al., 2017) have laid the groundwork for this study by providing the theoretical lens for which we could conduct the current research. The Framework for Culturally Adaptive Teaching and Learning (FCATL) (Snow & Wang, 2017), building on related studies, uses three dimensions to gather data on learning preferences: Social Relationships, Epistemological Beliefs, and Temporal Perceptions. In this study, we tested the model with 126 undergraduate students from Korea and 61 undergraduate students from China using a survey instrument that is associated with the FCATL. The survey instrument derived from it was then administered to see if it can help instructors and students to reflect on their cultural preferences and learning habits. The results of our survey indicated its potential use in aligning expectations between learners and teachers, and between learners themselves.

Keywords. Culture, Korea, China, learning preferences, cross-cultural teaching

1. Introduction

With the emergence of online resources for education, learners from all over the world are becoming more connected. This evolution of learning makes understanding cultural expectations and learning styles very important since any online class could contain students from increasingly diverse backgrounds—not only different nationalities but also differences in generation and region (e.g. people from metropolitan centers and those from more rural communities).

Knowing which types of teacher behaviors and student expectations are preferred can create a more inviting and enriching environment for all students, regardless of cultural background. Negative opinions of a class can hinder student learning [1], so a data-based understanding of what can cause negative opinions and gaps in expectation is needed. Yet, if an instructor adjusts rules and behavior, and then learners feel they are being negatively stereotyped, this can lead to a reduction in working memory capacity and academic performance [2].

This study will help modify and test a survey instrument which can help instructors identify student expectations and preferences. Quantitative and qualitative data from undergraduate students at institutions across South Korea and China was gathered and analyzed, and future research will be conducted at other postsecondary institutions.

The results of this study can help instructors to identify gaps in expectations, and then meet and/or align those expectations through adjustments in classroom management, communication strategies, and instructional design. It can also help individual students understand how their individual approaches to learning may differ from other students they are interacting or collaborating with, thus avoiding or ameliorating conflict which could negatively affect learning outcomes.

2. Background: Previous Studies

In 2010, Parrish and Linder-VanBerschot [3] developed the cultural dimensions of learning framework (CDLF) which they said was based on the work of other cultural researchers like Hofstede (2005) and Nisbett (2003). They then used the CDLF to create a survey on culturally based learning preferences that used a 1–10 point bipolar scale. Other researchers (Liu et al., 2017) have conducted studies using the CDLF, with a focus on teaching and learning differences in global education between Chinese and American learners in a corporate training program [4].

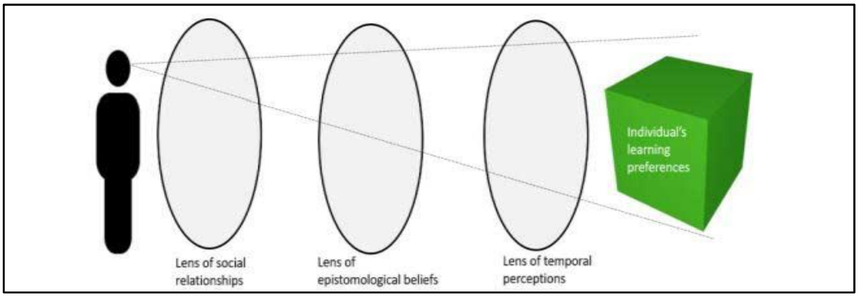

Figure 1. Framework for Culturally Adaptive Teaching and Learning (FFCATL).

Hunt and Tickner [5] used the CDLF survey instrument education majors at University of Auckland but noted that a 1–10 point scale creates two middle values (respondents cannot select 5.5), and those middle values could be seen as agreement with both statements, agreement with neither, or an opinion that both statements are irrelevant.

3. Methodology

In this study, we modified the CDLF after some user testing and a literature review, ultimately settling on a nine-point scale to avoid having two middle values. We also added a brief qualitative section asking for experiences and comments on related issues. Researchers with native language skills translated the survey into Korean and Chinese, and the tri-lingual survey was distributed to undergraduate English as a Foreign Language (EFL) learners and instructors at one university in South Korea and another university in China. The researchers also helped translate the narrative data provided by participants from both countries.

Like the aforementioned Parish and Linder-VanBerschot study [3], the FCATL framework examines the cultural component of learning through three lenses: social relationships, epistemological beliefs, and temporal perceptions. Data collected helped us to determine learning preferences and cultural factors that can improve or hinder the learning experience of undergraduate students in South Korea and China.

The survey was distributed through a learning management system for each participating class. Sixty-one Chinese students and 126 Korean students completed the electronic survey, along with approximately 10 students from a variety of other countries. The first part of the survey presented respondents with two statements and a bipolar scale to select. This survey is adapted from a survey used in a similar study by Deinzer and his colleagues [6] but with thoroughly revised questions and scale. To answer each "question", respondents would indicate which statement they most agreed with and how much they agreed with it. Statements dealt with social relationships, epistemological beliefs and temporal perceptions (This will be elaborated on in the Results section of this paper). At the end of the survey, qualitative data about respondent demographics were collected. This included, but was not limited to, questions about age, gender, school setting, and nationality.

When answering questions with the bipolar scale, selecting one of the first four bubbles showed agreement with the left-hand statement and selecting bubbles 6 to 9 were for the right-hand statement. In terms of strength of agreement, bubble 1 indicated strong agreement with the left-hand statement and bubble 9 indicated strong agreement with the right-hand statement. A selection of 5 meant no choice or neither statement was applicable to the class. It is important to note that the bipolar statements are not necessarily mutually exclusive; it is possible to agree with both without being hypocritical. The point is (a) which statement do respondents agree with more, and (b) how strongly do the respondents agree.

Selecting this bubble indicates that you agree with the right-hand statement, but only to a moderate degree.		
Students should feel comfortable asking a relevant question any time during the class. This helps ensure students understand the class material.		Students should mostly listen and observe during class, and not interact unless asked to do so. This helps ensure the class will be orderly.

Figure 2. Sample survey statements and the measurement scale.

4. Results

The data revealed many similarities in the preferences of these Korean and Chinese students, but statistically significant differences on four topics. When performing descriptive analyses on the survey results, the team began by finding four questions with average mean differences of greater than one. When performing T-tests on these four questions, the P(t) values to determine statistical significance needed to be less than 0.05. The results of our T-tests were showing results of <0.0005 or smaller. The following table shows which questions were highlighted for further analysis, found by difference in mean scores >1.

4.1. Results: Lens of Social Relationships

The lens of social relationships section pertains to strategies and values in motivation and communication. It examines how respondents view the relationship: between the teacher and the student; between individual students; and between a student and the class as a whole. Whether respondents believe students perform better when being nurtured or challenged is also investigated here.

Out of the ten questions in this section, the results were very similar in eight of them, showing little significant difference in the answers between the Korean and Chinese students. In short, the mean scores indicated that overall, both groups:

- Moderately agreed that class topics can be requested by students and not solely left up to the discretion of the teacher
- Moderately agreed that students should feel comfortable expressing disagreement with statements in class materials or statements made by the teacher
- Strongly agreed that students perform better when praised for their effort rather than for their improvement
- Moderately agreed that learning how to develop and express their own thoughts or vision is more important than learning how to develop and express the thoughts or vision of experts
- Moderately agreed that students should be assessed based on how much they improve instead of whether they have reached established standards of performance
- Moderately agreed that students learn more when feeling comfortable and relaxed during activities and discussions instead of when expectations are high and they are pushed to excel
- Were undecided or ambivalent about whether it was more important for students to (a) not show up other students in the class, or (b) to perform to the best of their ability no matter how that looked to the other students
- Slightly agreed that making mistakes is common and acceptable and does not necessarily indicate that teacher expectations are too high

However, two of the questions in this section of the survey yielded significant different mean responses (Fig. 3). Since the survey sample size between both countries varied vastly with the number of participants, we ran a t-Test for two unequal variances between both sets of raw data. This confirmed the significance (Fig. 4).

Table 1. Mean response values showing significant disagreement between Korean and Chinese respondents: Lens of Social Relationships.

Question		**Korea**	**China**
1	In Class Behavior: Comfortable Asking Questions (1) v. Just Listen and Observe (9)	4.56	3.02
2	Understanding: Students should ask questions to check their understanding (1) vs. Students should have no need to ask questions (9)	5.56	2.92

QUESTION 1: t-Test: Two-Sample Assuming Unequal Variances between Korea and China		
	Variable 1	*Variable 2*
Mean	4.555555556	3.015625
Variance	6.328888889	4.142609127
Observations	126	64
Hypothesized Mean Diffe	0	
df	152	
t Stat	4.541845922	
P(T<=t) one-tail	5.64189E-06	
t Critical one-tail	1.654940175	
P(T<=t) two-tail	1.12838E-05	
t Critical two-tail	1.975693928	

Figure 3. Results of t-Test for Unequal Variances: Question 1.

DS Q1	Korea	China
Mean	4.555555556	3.015625
Standard Error	0.22411889	0.254417506
Median	4	2
Mode	7	2
Standard Deviation	2.515728302	2.035340052
Sample Variance	6.328888889	4.142609127
Kurtosis	-1.41442028	1.02007124
Skewness	0.0009509	1.22579173
Range	8	8
Minimum	1	1
Maximum	9	9
Sum	574	193
Count	126	64
Confidence Level (95.0%)	0.443559099	0.508412818

Figure 4. Question 1 Descriptive Statistics.

While the responses for questions 1 and 2 tell us something on their own, it is more useful to look at them together. Question 1 asked whether students prefer (a) a class where the teacher allows them to ask questions at any time, or (b) a class where students do not speak up unless asked by the teacher. Almost 80% of the Chinese responses were between 1 and 4, indicating Chinese students are more likely to prefer a class where the students can ask the teacher questions at any time. The mode score for Chinese respondents was 2, indicating strong agreement. The Korean students were less unified in their answers. Only 52% of the Korean respondents indicated they preferred a class where students ask questions at any time, which is significantly fewer than the 80% of Chinese respondents. Furthermore, the mode for Korean respondents was 7. Answers from 6–9 indicate a preference for a more orderly, teacher-centered class so according to our results, a random Korean student from our sample is 28% more likely to prefer this than a random Chinese student is.

Question 2 asked respondents whether students (a) should test their understanding of class content by asking questions during class, or (b) should have no need to ask questions if they have prepared and paid attention to the teacher. Sixty percent of Korean respondents agreed with the latter, choosing responses between 6–9. As with Question 1, the mean for Korean respondents on Question 2 is 5.56 the mode is 7 (Fig. 4).

In contrast, 84% of Chinese respondents indicated students should ask questions. The Chinese respondent mode was 2, as 19 of the 64 respondents indicated strong agreement. Their mean value of responses is 2.92, a two-and-a-half-point difference from the mean Korean response. A total of 54 Chinese respondents indicated that they believed students should ask questions during class (i.e. they chose options 1–4).

When compared to Korean students, do Chinese students see more value in asking questions, and taking more responsibility for what is discussed during class time? The data indicates this could be true, but the survey results may be skewed due to sample size variance, so more investigation of this difference is needed.

DS Q2	Korea	China
Mean	**5.555555556**	**2.920634921**
Standard Error	0.217505499	0.225489838
Median	6	3
Mode	7	2
Standard Deviation	2.441493168	1.7897701
Sample Variance	5.960888889	3.20327701
Kurtosis	-0.97126245	1.639028416
Skewness	-0.4621869	1.378151154
Range	8	7
Minimum	1	1
Maximum	9	8
Sum	700	184
Count	126	63
Confidence Level (95.0%)	0.430470376	0.450747763

Figure 5. Question 2 Descriptive Statistics.

Question 2: t-Test: Two-Sample Assuming Unequal Variances between Korea and China		
	Variable 1	*Variable 2*
Mean	5.555555556	2.920634921
Variance	5.960888889	3.20327701
Observations	126	63
Hypothesized Mean Diffe	0	
df	162	
t Stat	8.410326462	
P(T<=t) one-tail	1.00777E-14	
t Critical one-tail	1.654313957	
P(T<=t) two-tail	2.01554E-14	
t Critical two-tail	1.974715786	

Figure 6. Results of t-Test for Unequal Variances: Question 2.

4.2. Epistemological Beliefs

The epistemological beliefs section of the survey assessed how students prefer to create and disseminate knowledge. Upon reviewing the raw data for questions in this section, it was apparent that most of the Korean and Chinese respondents' answers were very similar in epistemological beliefs. For example, respondents from both countries:

- Showed no preference between doing work that produces objectively correct answers, and work where thought process is emphasized over "being correct"
- Showed no strong opinion on whether students perform better when the teacher gives students a fixed procedure to follow versus when the teacher gives students more freedom to complete a task (the Korean respondents chose slightly more freedom and the Chinese chose slightly more structure, but not by enough to warrant an investigation since the mean difference was only 0.54)
- Strongly to moderately agreed that debates improve understanding of course material; Respondents did not agree that debates be avoided out of concerns over how they could affect class atmosphere
- Attributed student success to an equal balance of student effort and motivation on the one hand and teaching style, lesson quality and learning environment on the other; In other words, neither one mattered more than the other in their opinion.

However, descriptive analysis performed on the raw data showed responses for question 14 had a mean difference of greater than one (see Fig. 7) and a nonparametric t-test showed that this was, in fact, a significant result (see Fig. 8).

Table 2. Mean response values showing significant disagreement between Korean and Chinese respondents: Lens of Social Relationships.

Question		Korea	China
14	Students Learn More: working quietly and efficiently (1) v. socializing and discussing (9)	5.98	4.64

DS Q14	Korea	China
Mean	**5.984126984**	**4.639344262**
Standard Error	0.189228719	0.2844156
Median	7	5
Mode	7	5
Standard Deviation	2.124087105	2.221356844
Sample Variance	4.511746032	4.93442623
Kurtosis	-0.59380767	-0.7095136
Skewness	-0.61001099	0.29428319
Range	8	8
Minimum	1	1
Maximum	9	9
Sum	754	283
Count	126	61
Confidence Level (95.0%)	0.37450712	0.568915904

Figure 7. Descriptive Statistics for Question 14.

t-Test: Two-Sample Assuming Unequal Variances		
	Variable 1	*Variable 2*
Mean	4.639344262	5.984126984
Variance	4.93442623	4.511746032
Observations	61	126
Hypothesized Mean Diffe	0	
df	114	
t Stat	-3.936562704	
P(T<=t) one-tail	7.13172E-05	
t Critical one-tail	1.658329969	
P(T<=t) two-tail	0.000142634	
t Critical two-tail	1.980992298	

Figure 8. T-Test on Question 14 Results.

Question 14 asked whether respondents believe that students learn more when they (a) work quietly and efficiently versus (b) socialize and discuss class concepts with others in the class. Working quietly was on the left side of the scale, which means that numbers 1, 2, 3, and 4 indicated a preference for this statement, and the "discussing material with peers" statement was on the right side of the scale, meaning students who preferred that would have chosen 6, 7, 8, or 9. Again, a choice of 5 indicates no preference or no relevance to the respondent's class.

The mean for Korean students on this question was 5.98. Koreans preferred more discussion, in general, with two thirds choosing responses of 6-9, which indicates a preference for more social environments. The mode of 7 indicates that the most popular answer indicated this preference to a moderate degree. On the other hand, of the 61 Chinese respondents, 30 of them preferred quiet learning environments (i.e. selected bubbles between 1 and 4). This is slightly less than 50% of them, but it is important to note that 15 of the 61 Chinese respondents selected bubble 5, showing no preference. That means only 46 Chinese respondents made a choice of one statement over the other, and nearly two thirds of those with an opinion (65%) preferred a quieter classroom. The mean Chinese answer was 4.64 which shows a strong preference.

4.3. Temporal Perceptions

The temporal perceptions section of the survey looks at student's preferences regarding time. The two main emphases are clock time vs. event time, and linear time vs. cyclical time. The former refers to focusing on prompt beginning and ending times vs. letting an event last as long or short as is necessary or satisfactory. Linear time vs. cyclical time is less intuitive. Nisbett [7] framed it as believing time is a line vs. a circle, and reported a conversation with a Chinese student who said, "The Chinese believe in constant change, but with things always moving back to some prior state." [xiii in the book]. Tam and Dholakia described the cyclical framework as focusing on habits and the linear framework as focusing on goals [8].

After reviewing the raw data for temporal perceptions, it was clear that the Korean and Chinese students felt mostly the same about time. As with the other sections, most of the questions yielded a mean difference of less than one. There were five questions about temporal perceptions, and four questions were too close to infer any cultural differences.

Table 3. Mean response values showing significant disagreement between Korean and Chinese respondents: Temporal perceptions.

Question		**Korea**	**China**
20	Changing Schedules: means class time not used effectively/poor planning (1) v. schedule should change based off students' needs (9)	6.65	5.48

DS Q20	Korea	China
Mean	**6.650793651**	**5.475409836**
Standard Error	0.176137558	0.270201865
Median	7	6
Mode	7	7
Standard Deviation	1.977139187	7
Sample Variance	3.909079365	4.453551913
Kurtosis	0.173603835	4
Skewness	-0.99786154	-0.37156806
Range	7	8
Minimum	2	1
Maximum	9	9
Sum	838	334
Count	126	61
Confidence Level (95.0%)	0.348598088	0.540484202

Figure 9. Descriptive Statistics for Question 20.

t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	*Variable 2*
Mean	6.650793651	5.475409836
Variance	3.909079365	4.453551913
Observations	126	61
Hypothesized Mean Diffe	0	
df	112	
t Stat	3.644123846	
P(T<=t) one-tail	0.000204112	
t Critical one-tail	1.658572629	
P(T<=t) two-tail	0.000408225	
t Critical two-tail	1.981371815	

Figure 10. T-Test on Question 20 Results.

In short, both Korean and Chinese respondents:

- Indicated it is slightly better for teachers to be flexible with time according to student needs rather than stick to a schedule.
- Strongly agreed it is preferable for teachers to punish students who don't meet deadlines rather than setting flexible deadlines and focusing on the quality of the work
- Agreed to a minimum extent that students should be patient because improvement may come slowly, so they should not expect immediate improvements or gains
- Indicated that a teacher moving too quickly or slowly through class material may impede student performance, but moving too slowly is marginally preferable

The question with the biggest difference in mean averages is question 20. This question asked undergraduate students about changing the class schedule. Does a change in class schedule likely mean the teacher did not plan or manage time well? Perhaps a class schedule should be permitted to change if the teacher and/or the students feel that more or less attention is required on a topic or skill? Respondents could indicate agreement with the statement on poor planning/time management (choices 1, 2, 3, 4) or the statement saying that schedules can be flexible (choices 6, 7, 8, 9). Again, a choice of 5 indicates shows no preference or irrelevance to the present class.

According to descriptive statistics for question 20, the mean for Korean students was 6.65, with a mode of 7. The Korean respondents preferred the schedule to be adjusted to their needs, in general, with about 79% of the respondents choosing responses of 6-9. On the other hand, only 59% of the Chinese students leaned towards adjusting the class schedule based on need. Thirty-three percent picked choices on the other side of the spectrum, meaning that a third of the Chinese respondents thought that changing the class schedule indicates poor planning by the instructor.

Looking at the percentage comparisons above, it's clear that a majority of the students in both cultures show a preference for changing schedules to follow student's and teacher's progression, rather than it just being poor planning by the teacher. That being said, approximately 30% of the Chinese respondents believed to a moderate to strong extent that a teacher changing the schedule indicates said teacher did not plan or manage the class well.

5. Conclusions

When considered as a whole, the data indicate that a Chinese respondent in these classes is significantly more likely to prefer asking the teacher questions (see Table 1 and Fig. 3) and value an environment that encourages this (see Fig. 5). The issues raised in Question 1 represented the biggest difference of opinion between the Korean and Chinese students, with a difference in mean value of 2.64 (5.56 –vs. 2.92). Since the Korean respondents indicated strong agreement with the statement, "Students should have no need to ask questions", they likely place more onus on themselves to pay attention in class and do the necessary preview and review work outside of class time. Or perhaps they feel questions are better asked outside of class time.

Regardless, during a one-way lecture or presentation, one of these Chinese participants would more likely feel stifled, while one of our Korean participants would more likely feel this was more orderly and an efficient use of time. Overall, we might infer that the Korean respondents were more trusting of the teaching figure to explain things clearly, or just simply feel that asking questions would be best done outside of class time. Unfortunately, the qualitative data we collected did not provide any insight into this.

While the preferences expressed regarding questions may make it tempting to conclude that the Chinese students were less shy or more talkative by nature, the data from Question 14 may contradict this. A Chinese student from one of these classes would be less likely to want to discuss class content with classmates (see Table 2 and Fig. 7). Perhaps the Chinese participants felt that knowledge should come from the teacher and the Korean participants would be more open to constructivist activities aiming at the co-creation of meaning, or even a Vygotskian strategy of having strong learners helping weaker learners. In the class with the Korean students, having the teacher present material while the students attentively watch and listen before discussing content in pairs or small groups Trying these strategies with the Chinese students we surveyed might be less successful or at least require more explanation of intent and value.

Finally, the Chinese respondents indicated that the learning schedule should be set before the first class by the teacher, whom should also closely manage use of class time (see Table 3 and Fig. 10). Changes were believed to be evidence of teacher error. The Korean respondents disagreed with this overall and thought schedules should change according to student needs. Paying close attention to formative assessments would be wise here so the teacher could make quick adjustments to planned learning activities and lectures based on the results. Instructors with these Chinese students would also be wise to clearly explain the reasons for any changes to the class schedule to avoid losing the trust of the learners.

Due to the small sample size, we cannot draw broad conclusions about Korean and Chinese populations. However, for teachers charged with educating these particular students, and for the students themselves, it is useful to know student preferences and expectations. When gaps exist, a teacher could group students with similar answers together during activities and projects. Alternatively, sometimes it be wise for the teacher to simply give warnings or short explanations (to groups or individuals as needed) to create alignment. Teachers need not always alter curriculum, teaching style, or planned learning activities. When learners have to interact with each other to complete homework or in-class activities, it could be beneficial to realize that others have different conceptions of how students should be taught, and how social relationships and time should be managed. Recognizing potential stress points is a necessary step to avoiding or addressing them. In conclusion, we recommend that this model and its corresponding instrument be used to draw conclusions about learners in a specific setting.

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6th International Workshop on Smart Offices and Other Workplaces (SOOW'18)

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Introduction to the Proceedings of SOOW'18

In recent years we have experienced an unprecedented grows of digital devices that form a parallel digital universe. This rapidly expanding digital universe fed by increasing number of sensory devices recasts the way we live and work. The concept of smart office capitalizes on the digital universe and empowers the contemporary worker with more confident decisions and greater support for new ideas while undisturbed by the workplace environment. Today, the concept of smart office has grown to embrace seamless and continuous experience regardless of shifting between devices that bridge augmented and virtual reality with the physical world. The importance of smart office concepts is evidenced by countless low cost sensors and miniature computers available on the market and also with major IT companies investing into projects with more natural way of interacting with digital devices. Yet, the effective orchestration of all the digital devices still remains a major challenge. Also, little is known about the long term psychological and social implications. These should be addressed in the continuing research on smart offices and other kinds of smart workplaces.

The 6th International Workshop on Smart Offices and Other Workplaces (SOOW'18) constitutes a platform for discussions on advancements in smart office concepts and related aspects both in academia and in practice. This year SOOW will focus on more general workplaces settings and smart automation scenarios. In an industrial environment, temperature behaviour can be considered as a challenge for analysis and inspection. In this direction, Bautista – Sánchez et al. present a process for environment partition by clustering that uses analysis of historical measures of temperature to obtain at first, the best statistical value for making partitions. Miraoui describes the development and implementation of a fuzzy based context-aware services adaptation for a smart office that is able of improving inhabitants comfort and contributing to energy savings. Paz Hernandez et al. present a system combining modern 3D reconstruction technologies with a wireless sensor network for remote monitoring and information management of construction sites. Mesquita et al. presents an agent-based architecture of a recommender system for travel agencies, based on two original algorithms, one that aggregates preferences and one that makes the group formation. Last, but not least, Mikulecky focuses on possibilities and circumstances enabling to view smart workplaces as a kind of smart learning environments. All this year contributions to SOOW represent interesting research endeavours and results from around the Europe.

The workshop Smart Office and Other Workplaces was organized mostly bi-annually as a satellite event along the International Conference on Intelligence Environments. The previous workshops were organized in remarkable cities such as Barcelona, Nottingham, Athens, Prague, and London. This year SOOW is held in Rome, the famed city of the Roman Empire, with its more than 2800 years of monumental cultural history, full of wonderful palaces, millennium-old churches, grand romantic ruins, monuments, statues and fountains. We are honoured that the 6th workshop on Smart Office and Other Workplaces takes place in this outstanding city.

Pavel Čech, Goreti Marreiros, Peter Mikulecký

(SOOW'18 co-chairs)

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Agent-Based Architecture for Travel Agency

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Abstract. In recent years there has been an increase in tourist demand in Portugal, mainly in the north. When a tourist arrives the first time to a new place, he needs to do an exhaustive research on the region or receive recommendations through applications that exist in the market. TheRoute has as an objective the development of a recommender system of touristic routes, with special focus on the northern region of Portugal, but it can be used in other regions of Portugal or in other countries. It's an investigation project that has as an innovator aspect the recommendation of routes based in the personality traits os the tourist, and also takes into account the information of the context of the tourist and the surrounding environment. To accomplish these objectives where implemented two algorithms, one that aggregates preferences and one that makes the group formation. The proposed objectives were accomplished with the development of the preference aggregation algorithm and with the group formation algorithm.

Keywords. Recommender System, Preference Aggregation Algorithm, Multiagent System, Tourism, Group Formation Algorithm

1. Introduction

Nowadays people prefer when their job gets simplified, or by getting access to more information or by some software that automates the processes they are working on, and smart workplaces have the objective to do both. It is a type of Ambient Intelligence.

Tourism is when someone travels to a location other than the one she lives in and does it by the means of pleasure or work. This work focus on the tourists that travel by pleasure and when tourists are looking for a vacation programs, they go to Tourism Agencies to seek help in finding one suitable to the individual/group. What Smart Tourism Agencies aim, is that tourists may be able to get recommendations without leaving the house and simplifying the options to the ones they really like.

There are several systems that make tourism recommendations, like INTRIGUE [1], the Travel Decision Forum [2], the Generalist Recommender System Kernel (GRSK) [3] or the Collaborative Advisory Travel System (CATS) [4], but these systems do not incorporate the personality traits in the recommendation process [5]. And this is where this project enters the scenes. The project TheRoute was developed with the objectives to bring the recommendation of routes and the group formation of

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tourists to a new level. Those recommendations are based on the personality traits of the tourists, and also takes into account the information of the context of the tourist and the surrounding environment. The system has two types of end users, and so two types of platforms, the tourists, that will use one of the platforms to obtain routes to visit and the other platform will be used by tourism agency agents, with the purpose of making thematic routes, or forming group of tourists to organize visits.

The work this paper focus is the multiagent system that is used to aggregate the preferences of a group of tourists with the assistance of an algorithm of preferences aggregation. There is an algorithm that is oriented to groups formation in the way that each member of the generated groups has similar preferences with the other members, thus enabling better visit experiences to a city or location. In this paper it is explained what architecture the multiagent system has, and the behaviors of each agent in the system, followed by the explanation of the algorithms used to solve the problem.

The proposed objectives were accomplished with the development of the preference aggregation algorithm and with two versions of a group formation algorithm in which each of the versions are explained in the paper.

2. Group Formation Algorithms

For the group forming problem there were studied some algorithms that are common in group forming problems. The first being studied was the k-means clustering algorithm [6], that works by generating clusters and then forms groups based on the clusters, the algorithm generates the best solution to the problem but takes a great toll in computing time. Other algorithm studied to the case is the genetics algorithm [7], where it generates a starting population of solutions and with an evaluation method it testes the solutions and crosses them to generate another generation of population, until the termination condition is met, the algorithm will generate more generations. When the generations stagnate, there is a mutation in the next generate so the stagnation doesn't continue. The last studied algorithm was the Greedy [8], the algorithm operates by forming groups through the evaluation of the Points of Interest, then groups the users by the ones that have higher evaluations for the same top-k set of Points of Interest.

3. Preferences Aggregation Algorithms

The algorithms that are design to make aggregation of the preferences of the members of a group were found mostly in systems that already exist in the market, systems like CATS where the evaluations of each Point of Interest by the users are joined using an arithmetic mean [4] or in the case of Travel Decision Forum, that each user specify their preferences, the system generates and presents the recommendations and then the users discuss between them which recommendation to take and if consensus is missing they can choose no alternative [2].

These systems weren't a solution that fits this project, this project needs an algorithm that is autonomous, where the users don't have to interact with the system to get a valid solution, and it is needed an algorithm that goes beside an arithmetic mean. For this problem was found an algorithm that fits these two conditions, the Negotiable Alternative Identifier, that selects the most preferred alternative of the group by using the evaluations each user has of the Points of Interest that exist [9].

4. Developed Method

4.1. Problem Definition

When the analysis and the design of the software was created, the first that was made, was the modeling of the tourists and of the points of interest. So, these two are composed as the Table 1 describes.

Table 1 – Modeling of the Tourist and the Point of Interest

Tourist	Point of Interest
Name	Name
Date of Birth	Description
Categories	Categories
Personality	Latitude
Agreeableness	Longitude
Conscientiousness	Average Visit Time
Neuroticism	Rating
Openness	Limitations
Extraversion	Opening Hour
Limitations	

After this modeling, we reached a conclusion, that these problems were multicriteria problems, where for the preferences aggregation problem (Table 2), the criteria are the Categories that the tourists like and their personality and as for alternatives, the evaluation of each Point of Interest.

Table 2 - Preference Aggregation Multicriteria Problem Definition

Preference Aggregation Problem	
Criteria	Alternatives
Categories Likes	Points of Interest
Personality	Evaluation

And as for the group formation problem (Table 3), the criteria are the Categories that the tourists like and their personality and as for alternatives, the evaluation of each Point of Interest and the Thematic Routes, that are composed by a set of Points of Interest.

Table 3 - Group Formation Multicriteria Problem Definition

Group Formation Problem	
Criteria	Alternatives
Categories Likes	Points of Interest Evaluation
Personality	Thematic Routes Evaluation

4.2. Multiagent System Proposed Architecture

The multiagent system follows a simple architecture (Figure 1), where there is an agent that is always running and that is responsible to create the other agents. This agent, the Receiver agent, behaviour starts by receiving a request to generate a route to a group of tourists. Then the agent will request all the data of the tourists and the Points of Interest available in the region. Then he will create a number of Tourist agents equal to the number of tourists in the group and each agent will represent one tourist of the group. The next agent to be created is the Tourist Agency agent, that will generate the solution to the group problems, this agent to obtain the solutions, it uses the preference aggregation algorithm and the route generation algorithm that is an ongoing part of our system.

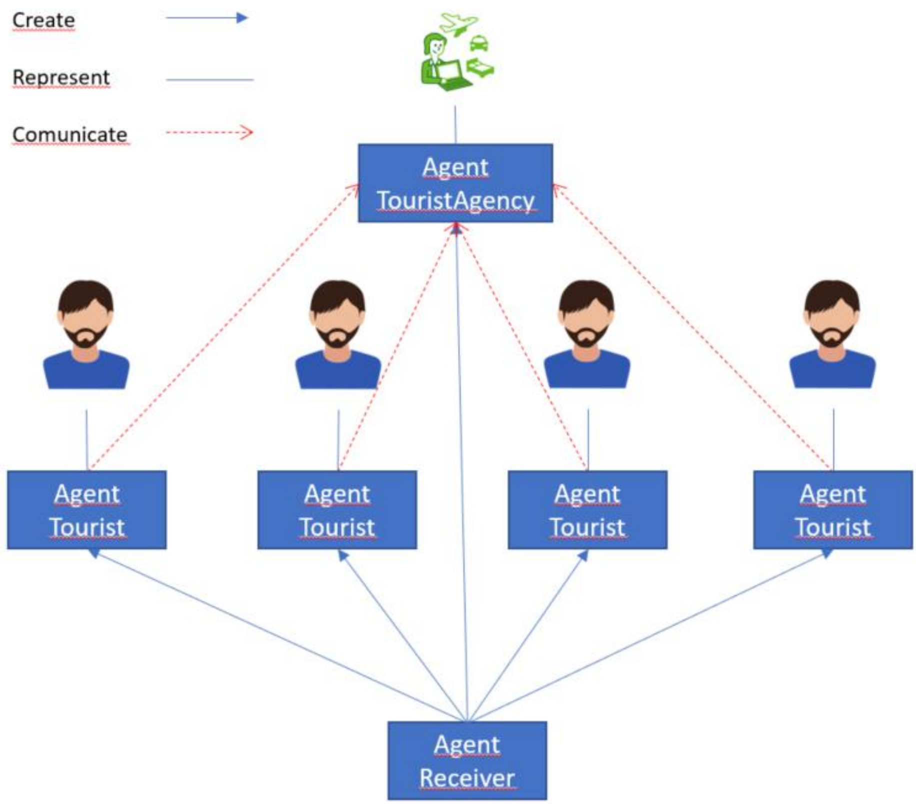

Figure 1 – Multiagent System Architecture

4.3. Proposed Algorithms

Before choosing the algorithms that would be implemented, there was a need to define the Use Cases the system needed to implement, so we made and analysis of the problem. The defined solution, as described in Figure 2, is (1) Route generation for a group of tourists, (2) Group formation for two or more thematic routes, (3) Group formation with generation of dynamic routes and (4) Group formation for one thematic route.

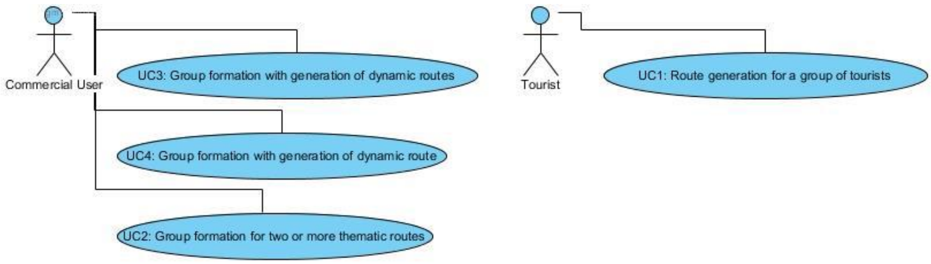

Figure 2 – Use Case Diagram

For the development of this project we chose one preference aggregation algorithm that based on the existent Points of Interest evaluations, it could give a set of Points of Interest that the group members have preference in visit. After the analysis of the systems or algorithms detailed in section 3, it was chosen the Negotiable Alternative Identifier. But the algorithm had to be adapted to our problem and it had to suffer changes. Those changes happened in the algorithm's third phase, where the solution had to return a set of alternatives instead of one alternative. Besides the preferences aggregation algorithm there is the need for a group formation algorithm that can be easily adapted to different types of sets. The case where there is a group formation for thematic routes is different from the one that after the group formation there will be a route generation, and so after the analysis, in section 2, the best algorithm that fits the parameters is the Greedy Algorithm. Since this algorithm uses a matrix of evaluation to form the groups, it is adaptable to what is being evaluated in the matrix, if it is Points of Interest or thematic routes.

4.4. Development

The software that is being developed to the project TheRoute follows a module based architecture where there is a Front-Office for the clients, a Data Access Layer that manages all the communications, the Data Base to store the data, the Decision Support Module where all the algorithms and software business is located and the Back-Office where the administrator, the content managers and other non-tourist users access to manage all kinds of information.

The algorithms mentioned in 4.2 and the multiagent system are implemented in the Decision Support Module. There is a service for each use case in the module, and next it is explained the flow of the use cases.

The first use case starts by receiving a request of the Data Access Layer, the receiver of this request is the first agent of the multiagent systems. The message is sent in JSON and carries some of the needed information for the case to function, the IDs of the users in the group, the latitude and longitude of the starting point, the weekday when the route will be executed, the starting hour and its duration and the mode it will be executed (by foot, car or public transportation). Therefore, the agent will request all the tourists received information and the Points of Interest of the location. After all the information is gathered, the agent will create all the Tourist agents with the information of the assigned tourist and start executing the tourists, and in the end creates the Tourist Agency agent, that will give the set of Points of Interest that the group most prefer by using the preference aggregation algorithm. This algorithm is one adaptation of the Negotiable Alternative Identifier [9] with an alteration in the phase 3, which the original algorithm selects only the alternative the group most prefer and it was changed to a set of the most preferred. The last step is to generate the route using the route generation algorithm and send it to the Data Access Layer.

The next use case, the group formation for two or more thematic routes, the way it receives information is similar to the previous one but the information that comes with it is different, besides the list of the users IDs it comes with the thematic routes IDs. After requesting and gathering the remaining information, it is executed the group formation algorithm the algorithm is one adaptation of the Greedy algorithm that is described in [8], the changed that was need to make is that the alternative, instead of being one Point of Interest, it is a route, and a route has multiple Points of Interest, so it is used to the formation, the average of the evaluations of the Points of Interest in each route.

The third use case, the group formation with generation of routes, it starts, like the others, by receiving a request of the Data Access Layer, and then requesting the remaining information to the Data Access Layer. After that it executes the group formation algorithm but a different version, that receives a list of Points of Interest that the tourists will evaluate and then will form the groups according to those evaluations. After the group formation it will start for each formed group a process similar to the first use case, where first will be executed the preferences aggregation algorithm and then the route generation algorithm.

The last use case is, the group formation for one thematic route, is similar to the previous use case with the difference that instead of a list of Points of Interest of the location, it will use the list of Points of Interest of one route.

5. Conclusions and Further Work

The proposed objectives in the beginning of this paper were accomplished, where the multiagent system is functional and works, besides that, the proposed algorithms were successfully implemented and properly tested so they would give the better possible solution to the end user. Despite these functional tests, it is still necessary to carry out testes/study of satisfaction on the tourists that will use his software. This project has a prosperous future in the area, if after making case studies with end users, the feedback is positive. As for future work, there are still some areas that can be explored and that need investigation, the next step is improving the multiagent system, so it implements a negotiation mechanism that makes the preferences aggregation more automatic, where each agent represents a tourist and its preferences and defend his interests, negotiating with the other agents. One of the other future objectives is to make a virtual visit of the planning route that is generated for the tourist, where the tourist can have a trailer of the route he is going to make, and if he doesn't like the visit he can always make changes.

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Smart Workplaces as Smart Learning Environments

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Abstract. This paper is focused on possibilities and circumstances enabling to view smart workplaces as a kind of smart learning environments. When we wish to increase the smartness of a workplace also its smart learning abilities must be increased accordingly. When designing a workplace that should be smart, we have to take into account, that it is necessary to respect different areas and professions, different working cultures, and the fact, that learners in the workplace come from different age groups with different educational and professional backgrounds. They also have different positions in organizations, so the particular workplace must be, if we really want to have it smart, tailored in accord with all these circumstances and requirements.

Keywords. Smart workplaces; Smart learning environments; Ambient intelligence; Workplace learning

1. Introduction

Smart learning environments, intensively developed as a result of focused research in the area of *Ambient Intelligence* (*AmI*), deserve also attention of the large community oriented on intelligent workplaces and technology enhanced learning at workplaces. Smart learning environments are considered a new degree of computer enhanced learning, with a considerable number of interesting facilities.

An intelligent workplace can be, among its other positive features, helpful in managing knowledge, which can be usefully needed by the users working in the workplace. Such knowledge can be used not only for solving various problems requiring some expert knowledge to be properly solved, but also for learning related knowledge at the workplace when creating sophisticated decisions or looking for solutions of complicated tasks. In that sense, any smart workplace could be considered and used as a smart learning environment, because any real smart workplace should be enhanced with learning facilities related to the workplace's purpose.

In the paper, we intend to map the recent state of the art in the area of smart environments oriented on learning with a focus on those their features that could be beneficial for workplaces. Our idea is that design of smart workplaces can be positively influenced with a number of features that are typically used is smart learning environments, and that both approaches can be combined aiming to reach a new quality of smart workplaces. Based on our recent research, we shall focus on smart learning

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possibilities on workplaces enabled by the recent results of smart workplaces area research.

2. Smart Workplaces

A manager, or any worker, working in a smart workplace, in order to be able of producing the best possible working decisions, should have the right information in the right time, as it is nowadays naturally understood. However, without having the appropriate knowledge the production of good decisions would not be easy, if not impossible.

Such a decision making should involve the following steps [17]:

- Identifying and defining the problem (a decision situation: an opportunity or trouble).
- Classifying the problem into a standard category.
- Constructing an abstract model that describes the real-world problem.
- Finding potential alternative solutions to the modelled problem and evaluating them.
- Selecting and recommending a good enough and appropriate solution to the problem.

The nowadays decision making environment is changing very rapidly, because business and its environment are more complex today in the global market. The decision making function has become more complex than in the past.

Factors causing complexity of managerial decision making are mainly as follows [27]:

- More alternatives of managerial decisions because of growth and advancement in ICT, as well as advancement and diversity in technology in general.
- Larger error cost because of increased competition, as well as increased structural complexity.
- More uncertainty because of increased consumerism, as well as decreased and fluctuating political stability.
- It is a need for quick responses because of decreased and fluctuating political stability, as well as growing, complicating and fluctuating market economy.

As a result of such complexity, managers must either become more sophisticated or must have the tools to overcome increased complexity. In our opinion, the latter case is the promising direction that should be expected from the ambient intelligence (AmI) approach as a collection of sophisticated intelligent tools for managerial decision support (cf. [1], [3], [7], or [13]). These tools could be a basis for a significant increase of the workplace smartness, making the workplace very close to the concept of smart learning environments.

The central design element of a smart learning environment is usually a dynamic learner profile, which includes learning history, learner specific information and learning goals. However, this is just a small (yet important) part of a really usable learning environment based on ambient intelligence principles. We do believe that the AmI principles can be considered as being very suitable for creating smart environments for learning in organizations, as a part of more general intelligent environment for managerial support. Usage of the AmI principles is in this case concentrated not only on solving managers' profiling problem, but it is more complex, with a number of equally important issues (e.g. customization, context-based services, privacy issues, applications of AmI algorithms, intelligent interfaces, smart learning objects, etc.).

3. Smart Learning Environments

Maybe the best specification of smart learning environments can be found in the seminal paper [12] by Kinshuk and his colleagues. Their opinion is that *"a learning environment can be considered smart when the learner is supported through the use of adaptive and innovative technologies from childhood all the way through formal education, and continued during work and adult life where non-formal and informal learning approaches become primary means for learning".* That is, Kinshuk and his colleagues support the meaning of smart learning environments as neither pure technology-based systems nor a particular pedagogical approach, but a mixture of both. Nevertheless, this is just a conceptual specification, telling us very few about real smart learning environments.

According to [29], a smart environment for learning (or a smart learning environment) can be defined as any space where ubiquitous technology influences the learning process in an unobtrusive, social, or collaborative manner. It means, that a smart environment can be also an 'aware' workplace, capable of understanding something about the context of its inhabitants or workers. These ideas are very close to that of original ISTAG Scenario 4 *Annette and Solomon in the Ambient for Social Learning* (ASL).

The ISTAG Scenario 4 [4] was a vision of a learning environment, based on a position that learning is a social process. The scenario certainly was a nice incentive for a number of new initiatives focused on more or less successful attempts to design and introduce various types of smart environments capable to support different aspects of learning process. In our paper [21] we intended to suggest conceptually a new multi-agent architecture aiming at achievement of the "ideal" architecture inspired by the ISTAG Report [4].

Hwang [9] published an important idea about smart learning environments that have to be taken always into account: "*A smart learning environment not only enables learners to access digital resources and interact with learning systems in any place and at any time, but also actively provides the necessary learning guidance, hints, supportive tools or learning suggestions…in the right place,…right time and… right form".*

Hwang [9] also summarized the following potential criteria for a learning environment being considered as smart:

(1) A smart learning environment is *context-aware*; that is, the learner's contexts in the real-world environment are taken into account by the smart learning environment, therefore the system is able to provide learning support based on the learner's online and real-world status.

(2) A smart learning environment is able to offer *instant and adaptive support* to learners by immediate analyses of their needs from different perspectives (e.g., learning performance, learning behaviours, profiles, personal factors) as well as contexts in which they are situated. Moreover, it can actively provide various personalized support to the learners, including learning guidance, feedback, hints and learning tools, based on their needs.

(3) A smart learning environment is able to adapt the user interface and the subject contents *to meet the personal factors* (e.g., learning styles and preferences) and learning status (e.g., learning performance) of individual learners. Learners can interact with the learning environment also via mobile devices (e.g., smartphones or tablet computers), wearable devices (e.g., Google Glass or a digital wristwatch), or even via ubiquitous computing systems embedded in everyday objects.

The context aware and ubiquitous learning as being naturally close to the educational perspective of Ambient Intelligence as well as to the idea of smart learning environments, was defined and studied by many authors. In one of our previous papers [20] we pointed out that ubiquitous computing has tremendous potential for framing learning, particularly in informal and socially constructed contexts. To reach this potential it is necessary designing, developing, and testing of new ubiquitous prototypes for learning systems. A more general overview of the AmI possibilities in education brings the paper [2], or earlier [19]. The aim of both papers was to present selected ideas supporting the vision of smart environments for higher education in the Czech university settings. Related ideas can be found also in our papers [18], [22], or [23].

4. Conditions and Possibilities for Workplace Learning

Without any doubts, learning is nowadays taken into account as an even more strategic factor for global competitiveness. Workplace learning is a key part of this process, driven by the impact of changes in demographics, skills demands, technologies, and people's relationships and roles within various institutions, organizations and communities. Learning is no longer confined to occasional formal activities in classroom environments. Work and career are no longer static and predetermined entities [16].

It is well known that one essential aspect of professional work is continuously developing competence and that one key aspect of professional work is that the professions drive their own knowledge development. Parding [25] describes workplace learning as intentional, in that it goes hand-in-hand with organisational development; it is also supposedly affecting both employees, employers and "customers" positively. The learning can take place within ordinary daily operations; it can be integrated in regular work activities often on a more informal basis, even though some external courses on a formal basis may constitute parts of this.

Previously, learning and development in various professions focused usually on formal learning taking place outside of everyday work, considering those professionals as passive content receivers [25]. The focus then shifted towards learning and development in everyday work, highlighting the importance of work organisation in such a form that enables time and place for learning. The terms *professional learning* and *continuous professional learning* are sometimes used to signal this shift in perspective.

As Manuti with colleagues pointed out in an interesting paper [16], already Stern and Sommerlad [26] proposed to re-define the term *workplace learning* by arguing different degrees of separation between *learning* and *work.* They suggested three broad approaches:

(1) *the workplace as a site for learning*; here the spatial separation of learning from work is supposed, learning activities are typically in the form of in-company training and usually take place outside of the immediate working environment – *off the job*;
(2) *the workplace as a learning environment*; here learning is planned and organized but takes place within the working environment and is largely *on the job*;
(3) *learning and working as inextricably linked*; here the best characterization is *continuous learning*; the workplace is structured to maximize processes of learning where employees learn how to learn as well as learn skills related to their own jobs and those of other workers [26].

Following Manuti and colleagues [16] and a couple of other authors (cf. [3], [14], [15], or [24]), the concept of workplace learning has acquired a broad array of meanings within the last decades. One of the commonly recognized result is that the efficacy of workplace learning is deeply linked to the efficacy of the types of learning that it can be referred to (see [28]). The types of learning can be specified as *formal* and *informal* learning, the informal learning is sometimes called also *non-formal* learning.

Formal learning is defined as structured learning that takes place *off the job* and outside of the working environment, typically in classroom-based educational settings. In the workplace, formal learning is composed of planned learning activities that are intended to help individuals acquire specific areas of knowledge, awareness and skills useful to perform their job well [16].

Informal learning recognizes that the acquisition of knowledge and skills in the work setting does not occur only from organized programmes, but learning also occurs during critical moments of need embedded in the context of practice. In contrast to formal learning, informal learning occurs frequently in situations that are usually not intended for learning, most notably in the actual work setting. Informal learning arises in situations where learning may not be the primary aim of the activity but is activated by some anticipated or existing problem situation that requires resolution. Informal learning may occur because of evolving activities including group problem solving, hypothesis testing, mentoring, coaching and job shadowing [16].

Smart learning environment approach can be naturally used in designing smart workplaces according the point (2) above, in the case, when the workplace is understood as a learning environment, as well as the point (3), when learning and working are inextricably linked. To design a smart workplace in such a way that intelligent learning facilities are its integral part is a challenge that certainly could increase the smartness of the workplace substantially. Here the novel methodology for designing smart workplace environments utilizing fuzzy relations can be used, as an working example [1], or suitable pervasive technologies, as described in [10]. In any case, the smart learning part of the workplace environment should be linked closely with the workplace purpose, approaches, and necessary knowledge behind the job. Knowledge management approaches could be helpful here, too.

5. Conclusions

According to [3], information and communication technologies has not only reshaped the traditional practices of formal education and work, but also our view of valuable knowledge and competence. This was reflected in discussions about new kinds of complexities in work tasks and the need to identify new kinds of competencies to deal with an increased information flow. Another significant change provided by digital technologies is that learning activities such as workplace training and education can take place in the digital world. The use of intelligent technologies, such as cloud computing, learning analytics or big data, focuses on how learning data can be captured, analysed and directed towards improving learning and teaching, and supporting the development of personalised and adaptive learning.

This paper is focused on possibilities and circumstances enabling us to view smart workplaces as a kind of smart learning environments. Indeed, by increasing the smartness of a workplace also its smart learning abilities must be inevitably increased, in order to keep its smartness in the sense as understood commonly. Using new technologies, new approaches, new methodologies, as described e.g. in [1], [5], [6], [10], [11], or [30] certainly will contribute to higher smartness of smart environments in general, and particularly of smart workplaces, having in the future many of the positive features of smart learning environments [8]. However, as Tynjälä [28] pointed out, we should not to make the mistake of assuming that the workplace is a unified environment for all learners. Instead, we should recognize that people's situations and organisational positions with respect to working and learning in the workplace differ. Workplaces designed for different areas and professions have different working cultures and learners in the workplace come from different age groups, different educational and professional backgrounds and different positions in organizations. As Tynjälä [28] stressed as well, that important challenge for workplace learning is the tendency to design workplaces in such a way that they can provide a learning environment not only for their regular employees but also for students coming from institutions of vocational and higher education. That all should be taken into account when a smart workplace is going to be designed. We hope that some new methodologies or new approaches will be helpful in that.

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A Context-Aware Smart Office for Improved Comfort and Energy Saving

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Abstract. Smart spaces are defined as a physical space rich in equipment and software services that can interact with people to provide intelligent services to them. The main aim of such spaces is improving inhabitants comfort and contributing to energy saving. Examples of smart spaces include smart offices which are equipped with a set of appliances to improve employee's comfort and contributes to energy saving. However, many employees become frustrated with the difficulty of using the complex functions of their appliances by spending a non-negligible time in configuring and setting these appliances which prevent them from focusing on their main tasks and therefore affect their productivity. One major requirement for smart spaces is context-awareness which allows them to provide the accurate service according to the current context with minimum intervention and in an unobtrusive manner. Previous works did not deal in depth with the context-awareness factor and are limited to a simple automation of appliances inside a smart space. In this paper, we develop and implement a fuzzy based context-aware services adaptation for a smart office where we base our approach on a clear definition of context and methodology for extracting context information.

Keywords. Smart office, context, Context-awareness, Service, Adaptation, Sensor, Fuzzy Logic.

1. Introduction

Embedding computer products into people' s everyday lives have driven research into the paradigm of both ubiquitous computing and smart spaces. So far, there is no explicit or common definition of smart spaces, which are also known as Ambient Intelligence or Ambient Assisted Living. Research on smart spaces tries to move from spaces filled with smart devices and appliances to smart spaces where communication and harmony are imposed (resp. synchronization). Such spaces should personalize themselves in responses to current context changes including user presence, behavior and environment. The most useful definition of smart spaces was proposed by D. J. Cook and S. Das [1]: "Smart space is able to acquire and apply knowledge about its environment and to adapt to its inhabitants in order to improve their experience in that environment". The main goal of smart spaces consists of effectively fulfil the needs of the user and control the environment on behalf of him by configure the devices and appliances present in their environments in a seamless, unobtrusive and non-intrusive way. intelligence in smart spaces reside on the effect that technology can recognize the user's current contexts and providing services accordingly. Context-awareness is a key

enabling factor for the development of smart spaces. In Previous works, each component usually performs a single function and there is no synchronization with other components of the space. In addition, they suffer from not dealing in depth with context-awareness by not relying on a clear definition of context or a clear method for extracting context information. Our aim is to develop and implement a context-aware smart office using fuzzy logic for services adaptation which improve both employee's comfort and energy consumption. We base our approach on both a clear definition of context and a simple method for extracting context elements.
The rest of this paper is organized as follows: In Section (2), we provide some background information about related work. In Section (3), we present context recognition, its extraction and acquisition inside a smart office. In section (4) we detail the development and the implementation of our approach of context-aware services adaptation using fuzzy logic technique. Section (5) provides some concluding remarks and future research directions.

2. Related Work

Considerable effort has been spent for enabling home automation in the last years and several interesting systems for services adaptation in a smart space have been proposed. Different techniques of artificial intelligence (resp. machine learning) have been used to achieve the automatic adaptation task such as bays network, neural network, case-based reasoning, rule-based systems genetic algorithms, KNN, etc. [2-21]. [22] Highlighted research projects employing multi-agent system, action prediction, artificial neural network, fuzzy logic and reinforcement learning. It is found that the combination of tools and techniques are crucial for successful implementation. Some of the previous works used the fuzzy logic technique for services adaptation, we focus on them in this section. [23] Proposed to extract fuzzy membership functions and rules that represent the user's particularized behaviors in an environment. Their proposed technique is an unsupervised data-driven one-pass approach for extracting fuzzy rules and membership functions from data to learn a fuzzy controller that will model the user' s behaviors. The intelligent learning mechanism used would learn and predict the needs of the user and automatically adjust the agent controller. They performed experiments on the Essex intelligent Dormitory (iDorm)[24] during a stay of five consecutive days. [25] designed and implemented an intelligent home environment made-up of intelligent appliance agents performing distributed and adaptive "transparent" fuzzy control. The agents interact and coordinate their activities using the Fuzzy Mark-up Language. [26] proposed a fuzzy logic system for recognizing activities in home environment using a set of sensors. Their approach allows to recognize several Activities of Daily Living (ADLs) for Ubiquitous Healthcare. [27] Used a context sensitive and proactive fuzzy control system for controlling the home environment. Their implementation consists of a lighting control system that is implemented into a smart home which learn its rule table without any predefined information and didn't need any training prior to use. Inhabitants' actions would have to be monitored, and system would have to learn through these observations. The learning process would need to be continuous, because our habits and routines change over time. The used fuzzy values are: time, outdoor light and person activity (present, absent). [28] proposed an Energy Management System (EMS) which tries to find effective and efficient energy consumption. It has two parts, the first one is a fuzzy system which its inputs can be external events like price signal, environment condition data and renewable resources or can be human behavior and preferences. This part has some fuzzy rules along with their membership functions which makes appropriate output for the second part which is an intelligent lookup table. [29] presented an approach to automated light control using fuzzy logic rules. Their system controls the number of lamplights as for the number of people inside room. [30] developed a fuzzy controller for HVAC (Heating, Ventilating and Air Conditioning) systems which maintain comfort conditions in a living environment based on the standard predicted mean vote (PMV) index. Their system takes into account the outdoor weather conditions as well as the time response of the system. [31] demonstrated that a fuzzy logic approach is able to optimize the level of energy performance and comfort taking advantage of solar energy and BAS (Building automation systems) in an office space developed a virtual model of a smart office room (SOR), equipped with dynamic shading, lighting and air conditioning control system. [32] proposed an adaptive fuzzy mechanism for heating control in smart houses. The fuzzy system is connected with an expert system and considers various input data which can enter the system. The proposed adaptive mechanism adjusts the thermal comfort rate based on the input data and IF-THEN rules.

Most of previous works were oriented to energy saving and few of them were oriented to the real comfort of users. There are few works that apply adaptation to the full set of appliances inside a smart space which make their approach lose synchronization and harmony between appliances. The most remarkable drawback of previous works is that they do not deal in depth with context-awareness which is a basic element for the intelligence of considered spaces.

3. Context Recognition in a Smart Office

3.1. Smart office description

Employees spend a considerable amount of time working in their offices. The general objective of research on smart office is to fulfill the office employee's requirements for comfort while reducing energy which enables them to work in a more efficient way. C. Le Gal [33] defined a smart office as an environment that is able to help its inhabitants to perform everyday tasks by automating some of them and making the communication between user and machine simpler and effective. Marsa-Maestre et al. [34,35] defined smart offices as an environment that is able to adapt itself to the user needs, release the users from routine tasks they should perform, to change the environment to suit to their preferences and to access services available at each moment by customized interfaces.

An exemplary office contains a set of basic appliances and furniture. The principal furniture are a desk and a chair for the office employee. Appliances could be a cooler, a heater, a set of light bulbs and a window blinds. The whole set of equipment could be classified into two categories: a) light system composed of window blinds and light bulbs, b) climate system composed of the cooler and the heater. All this equipment should provide a set of services through different forms (or modes) to the worker occupying the office. These services should be triggered according to the current context collected from different sensors installed in the office. (Figure. 1).

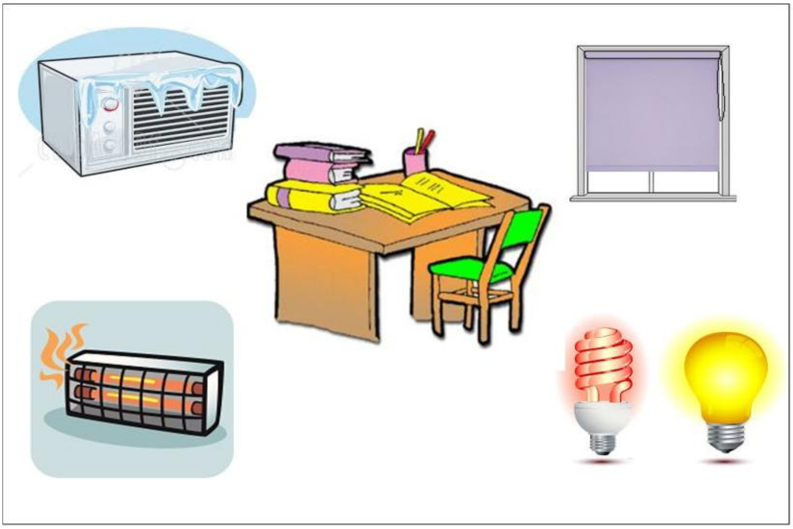


Figure 1. Components of a typical office

3.2. Context definition and extraction

Context-awareness could considerably improve the ease of use of a smart space appliances and devices without imposing undue technological complexity, effort, or inconvenience which reduces user's supervision of smart space facility control and management. A clear and complete definition of context is the cornerstone of a context-aware systems. A clear and complete definition of context is the cornerstone of a context-aware systems. So far, there is no common understanding what 'context' exactly means. Several definitions of context have been proposed since the 1990's, some of them were based on enumerating contextual information (localization, nearby people, time, date, etc.) like those proposed by [36-41]. Chen and Kotz [42] showed that general context definitions remain vague and inadequate in a computing environment. Other definitions were based on providing more formal definitions to abstract the term, like those proposed by [43, 44]. They were very general and do not help to limit the set of contextual information. In addition, most of proposed definitions were specific to a particular domain, such as human-computer interaction and localization systems. Ameyed et al [45] proposed a prediction-oriented definition of context which promotes three axes: 1) Time, 2) Space, and 3) Purpose (finality) of its use as follows: "Any entity undergoing a spatiotemporal variation and that may lead to a change in the service or the quality of service in the short or long term". In our previous work [46, 47, 48], have made a survey of existing definitions of context and proposed a service-oriented definition of context for a pervasive and ubiquitous computing environment as follows: "Any information that triggers a service or changes the quality (form or mode) of a service if its value changes.". We strongly believe that our definition is sufficiently abstract and helps to limit the set of contextual information. Based on our previous definition of context, the process of context elements extraction starts (first step) by specifying for each appliance of the smart office the set of services that can be provided. In addition, for each service we should specify also the set of information which their change of values will trigger the service. There are two basic information which their change of value will trigger appliances services: a) employee presence or entrance to the office will trigger the light system composed of window blinds and light bulbs set and b) seated employee which will trigger the climate system composed of the cooler and the heater (Table 1).

The second step consists of specifying for each service the set of forms through which the services can be provided. We should also specify for each form of service the set of information which their change of values will change the form of a service (Table 2).

The last step consists of making the union of the two previous sets to get the final list of contextual information. This information will compose the global context and, in our case,, will be composed of the following elements with their possible values (Table 3).

Table1: Service triggers

Appliance	Service	Trigger
Window blinds	Lighting	Employee presence
Light bulbs set	Lighting	Employee presence
Cooler	Cooling	Seated employee
Heater	Heating	Seated employee

Table2: Services forms changing information

Appliance	Service	Trigger
Window blinds	Closed, mostly closed, half opened, mostly opened, totally opened	Employee presence, outdoor light, indoor light
Light bulbs set	Off, low, average, high	Employee presence, outdoor light, indoor light
Cooler	Off, very low, low, average, high, very high	Seated employee, indoor temperature
Heater	Off, very low, low, average, high, very high	Seated employee, indoor temperature

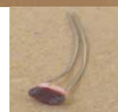
Table 3: Context elements possible values

Context element	Possible values
Employee presence	Present, absent
Seated employee	Yes, no
Indoor light	Dark, low, average, high
Outdoor light	Dark, low, average, high
Indoor temperature	Very low, low, almost low, medium, almost high, high, very high
Employee presence	Present, absent

3.3. Context acquisition

Context values are gathered using a set of sensors which are mainly from the Libelium company. It manufactures hardware and a complete software development kit (SDK) for wireless sensor network. Table 4 summarize the set of sensors used in our system by showing for each context element the sensor (s) used to gather its value.

Table4: Used sensors for context gathering

Context	Sensor	Picture
Employee presence	Libelium PIR sensor	
Seated employee	Libelium force and pressure sensor (on chair)	
Indoor and outdoor light	Libelium LDR (light dependent resistor)	
Indoor Temperature	Libelium temperature sensor	

All these sensors were embedded on a Libelium waspmote module which in turn was equipped with a Wi-Fi module to ensure communication with the controlling computer. Figure 2 shows both the waspmote and Wi-Fi modules.

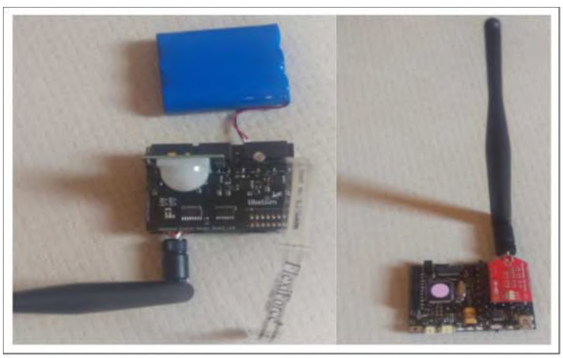


Figure 2. Sensors board and Wi-Fi module

4. Context-aware Services Adaptation

The main goal of context-aware services adaptation in a smart office is to provide the required comfort to an employee in an unobtrusive manner keeping him focusing on his main work tasks instead of losing time in setting and configuring the appliances according to the current context. For the adaptation task, we used the fuzzy logic technique. Fuzzy systems are well suited for dealing with imprecise quantities used by humans. It is often used to help make humanlike decisions. Control systems using fuzzy logic are generally fast, user friendly, cheap and they don’t need much memory [49]. As mentioned before, we have two fuzzy control systems: a) light control system which responsible for adjusting the ambient light of the office and triggered when it perceives the employee presence and b) the climate control system which is triggered when it perceives the sitting of the employee. The climate system will not trigger if it does not perceive the sitting of the employee because in some cases there is no need for that if the employee makes a simple entry/exit to the office without staying there. Figure. 3 shows the two fuzzy control systems.

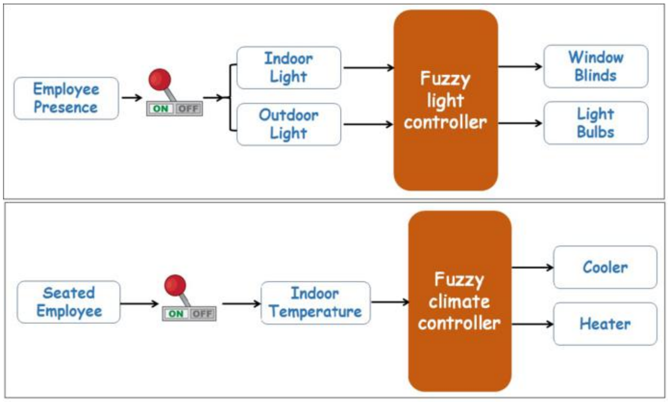


Figure 3. The two basic fuzzy control systems

The operation of the climate controller depends on only one context information namely indoor temperature and triggered when the sensor system perceives a seated employee. The set of possible fuzzy rules are as shown in Figure 4. The operation of the light controller is similar to the climate controller; however, the set of fuzzy rules is bigger and contains twenty rules. For each pair of values of indoor and outdoor light correspond a pair of values for the window blinds position and the level of luminosity of light bulbs.

For the implementation of our system, we have used the fuzzylite which is a free and open-source fuzzy logic control library [50]. Figure 5 shows the implementation of the climate controller using the fuzzylite tool. The implementation of the light controller is alike.

- *IF indoor temperature is very low THEN cooler is off AND heater is high*
- *IF indoor temperature is low THEN cooler is off AND heater is average*
- *IF indoor temperature is almost low THEN cooler is off AND heater low*
- *IF indoor temperature is very medium THEN cooler is off AND heater is off*
- *IF indoor temperature is very almost high THEN cooler is low AND heater is off*
- *IF indoor temperature is very high THEN cooler is average AND heater is off*
- *IF indoor temperature is very high THEN cooler is high AND heater is off*

Figure 4. Set of fuzzy rules for the climate system

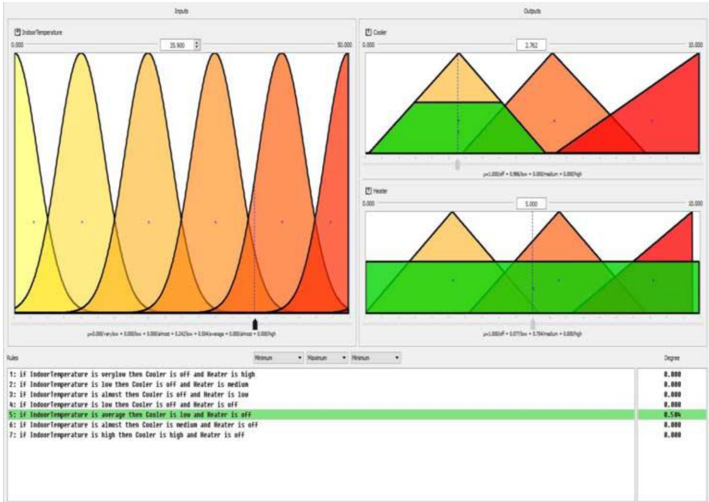


Figure 5. Implementation of the climate system using FuzzyLite tool

We have made a series of tests to evaluate our system, each Serie includes ten tests. The overall evaluation shows that the climate system has 90% of satisfactory results. We have obtained almost the same satisfaction with the light system. All the appliances of the smart office came with a remote-control device. We have used the USB-UIRT (Universal Infrared Receiver/Transmitter) which allows any USB-equipped PC to Transmit and Receive Infrared signals to common appliances of the office. To learn the infrared code of some useful button of each appliance remote control device. We have used the promixis software application (Girder) which allow us to learn different infra-red codes for each appliance remote control device. An example of Infrared code learning is shown in Figure 6.

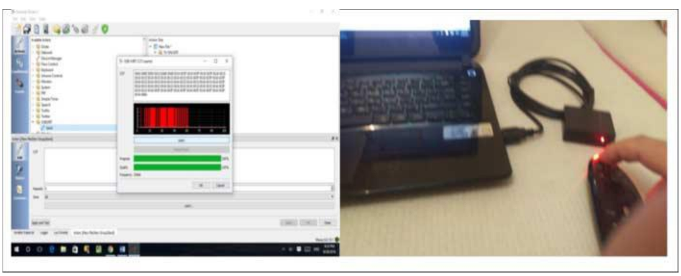


Figure 6. Learning an infra-red code of a remote-control device.

5. Conclusion and Future Work

The aim of smart spaces is to increase inhabitants comfort, help them to save energy and automating their daily interaction routines with appliances of the smart space. Automation should be done in an unobtrusive manner with minimum interaction with appliances. Office employees should work comfortably and focus on their main task not spending time in configuring appliances. Smart offices can offer these benefits for employees. Context-awareness could considerably help on the development of smart offices by making appliances providing their services automatically according the current context. In this paper, we have presented an approach for context-aware services adaption for a smart office using fuzzy logic technique. We have developed our system based on a clear definition of context and a simple and easy method for extraction context elements. We have also implemented the whole system composed of typical office appliances, network sensors for context acquisition and the command system. The evaluation of the developed system has led to satisfactory results. Our future work will focus on applying our approach on other smart spaces such as classrooms, hospital rooms, hotel rooms, etc.

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Towards Real-Time Monitoring and Remote Management of Construction Sites

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Abstract.
In this work, we present a system combining modern 3D reconstruction technologies with a wireless sensor network for remote monitoring and information management of construction sites. After describing the most important requirements, we compare available technologies and present our implementation of a prototype system and its capabilities as a baseline for future applications.

For on-site data transmission (e.g. sensor data), we implemented a sub-1-GHz wireless network utilizing the CC1350 Simplelink, an ultra-low-power wireless micro controller manufactured by Texas Instruments. Offline local data access is supported and demonstrated by our Android application for reading and modifying data on each node via direct Bluetooth connection. Additionally, information among nodes, connected devices, and a remote server, is transmitted via a gateway over the Internet. We leverage the capabilities of the Microsoft HoloLens to provide augmented information and to create an up-to-date 3D scan of the environment on-site. The 3D model and node data is provided to remote observers in real time using our visualization client.

Keywords. Wireless Sensor Networks, Augmented Reality, 3D Reconstruction, HoloLens, Sub-1GHz

1. Introduction

Construction sites are still a mostly unexplored area for digitalization. In practice, reporting is still often done in handwritten form, information is not propagated to decision makers at all or is propagated with significant delay. The typical life-cycle of bigger projects includes a wide range of steps such as identification of requirements, project planning, design and engineering, logistics, building construction, operations and maintenance. One general issue is the lack of an accurate information flow in real time between all steps. Hence, the first part of the life-cycle

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(design and planning) is decoupled from the second part, making appropriate and in-time reaction to events or problems during construction phase difficult. As a result, delays in project completion are common.

We argue that a system capable of monitoring real time state and progress of a construction site can significantly improve the quality and effectiveness of a project by providing useful information both on-site, and for remote experts. Therefore, as a first step towards a real world application and evaluation of such a system, we investigated the following questions:

1. What are the most important requirements and challenges the proposed system has to meet?
2. Which technologies have to be considered for the system design?
3. Is it possible to design and implement a prototype system using mostly off-the-shelve technologies?

2. Related Work

Different applications for construction site automation have been proposed in recent literature. Lu et al. in [1] implemented an architecture for localization of resources using wireless networks and radio signal strength. Structural damage detection and prediction using wireless sensors and machine learning was studied by Alavi et al. in [2]. There is also work done by Cheng et al. with sensor deployment for fire prevention in [3]. Pirkl et al. propose a wearable sensor system which supports construction site workers in work documentation by integrating a standard safety helmet self localization, room dimension estimation, and material detection [4].

In [5] and [6], the authors propose autonomous mobile robots to monitor different locations. Similarly, automated machine control and simulations are presented in [7].

Regarding information distribution, Kim et al. propose a mobile application to aid workers log information in their daily tasks ([8]). Chae et al. explore implementations of structural behavior observation using Zigbee compliant sensors ([9]). The authors implemented a wireless sensor network to collect this information and visualize it remotely. Jang et al. in [10] developed a protocol for wireless sensor network information collection and web-based visualization.

Finally, 3D reconstruction is a very recent approach to construction sites. 3D thermal reconstruction for fire brigade operations by Schonauer et al. in[11], and reconstruction of spaces with sensor towers by Wang et al. in [12] are among these studies. Mobile 3D reconstruction are explored by Laine et al. in [13]. They developed an smartphone-based image collection to reconstruct structures for later viewing. Katz et al. developed an application for camera networks scattered around the compound to get information in [14].

3. Requirements & Application Scenario

3.1. Requirements

One of the major challenges for any technical system operating on construction sites is the always changing, sometimes even chaotic, environment. However, our goal is exactly to capture and track those changes and provide them to decision makers in real time. This includes essential information such as the physical and functional characteristics of a facility: geometry, spatial relationships, quantities and properties of building components.

On a practical level, we have to keep in mind the lack of available infrastructure. This means that in some phases of the construction, there is limited access to a reliable power supply and in many cases, little to no access to landline Internet or to mobile networks. Depending on the type of the construction, the site's area can also be very large, extending over kilometers in a direction.

Based on those factors and discussions with construction professionals, we identified the most important requirements of the system as follows.

3.1.1. Autonomous Operation

- Essential parts of the system need to be battery powered to be independent from the local power grid's state.
- The System needs to provide its own network communication in case of unavailability of on-site infrastructure.

3.1.2. Robust Operation

- Power consumption for any component needs to be low to minimize maintenance times and support long term monitoring.
- A robust and scalable communication infrastructure is needed which can be accessed locally in case of network outages.

3.1.3. Easy Deployment and Remote Monitoring

- Simple deployment and localization of all components need to be featured to minimize training and application overhead.
- Information exchange should be possible between the system's components and a remote site in real time.

3.2. Scenario

In the initial phase, a member of the crew would place several nodes throughout the site. These nodes are able to carry distinct types of sensors that fill the particular needs of the location (e.g. humidity, temperature, movement detector). They can also store other types of information such as a log of events or tasks. Any authorized member of the crew is able to access the information of each node and is also able to send information through the network. The nodes can be relocated at any time easily, in which case the position should be updated automatically (e.g. through tracking) or manually.

Parallel to the placement of the nodes, an initial scan of the construction site is created with the aid of a 3D reconstruction capable device. This initial scan forms the basis for future reconstructions. The 3D model can be fully or partially updated on a regular basis, if new scans are made.

We also need a central node capable of concentrating the information coming from all other nodes available at the site. Its main functionality is to relay the collected information to a remote location over the internet. It is also capable of transmitting incoming information to each node.

Through the remote server's interface the personnel is able to oversee the information stored or collected by each of the nodes on site. Additionally, one is capable of browsing the most recent 3D model of the construction or looking up the recent changes. Lastly, the remote connection enables the dispatch of messages to any and all individual nodes currently connected.

4. Technology Overview

For the use-case scenario described in section 3, we identified two core components: 1) On-site network communication and 2) 3D reconstruction. In this section, we provide an overview of possible technologies the system can be build upon.

4.1. Network Communication

A study made by Jang et al [10] revealed that for a group of sensors to be placed at constructions, the cost of wired networks is a definite disadvantage of the approach. Also the mobility of the components would be compromised. For these reasons, we decided not to consider wired networks. WiFi, Bluetooth, and other radio frequency (RF) data exchange standards are the most common technologies found in wireless networks.

A WiFi based solution could be suitable for smaller construction sites, where a small number of access points (AP) can cover the whole area. WiFi communication has typically a higher power consumption compared to other alternatives, but also allows higher data rates.

Bluetooth is a good alternative for peer-to-peer networks, where only two devices connect to each other. It also supports low power modes. Smartphones and other modern devices usually support discovery and connection of Bluetooth devices. To our knowledge Bluetooth-based mesh networks are still in the experimental phase.

Today many sensor network systems use radio frequency (RF) communication. RF links can provide optimized power consumption characteristics. The actual frequency band chosen plays a significant role in the performance of the network (e.g. data rates and range). Thus, RF nodes are usually able to function autonomously and are also able to be placed freely throughout the environment.

For RF networks, an important choice is the network topology. In a star network topology, each node transmits its data through single central node, whereas in a mesh network topology each node is also able to exchange information with other neighboring nodes. While a mesh configuration delivers a more robust and flexible solution regarding node placement and interference, the implementation is also more complex and demands more power consumption per node.

4.2. 3D Reconstruction

For creating accurate 3D measurements on construction sites, the standard technology is the Lidar based 3D-scanner. They are usually very expensive and require stationary measurements at multiple locations. On the other hand, they produce a very accurate model.

In our vision, we want a solution which does not require any dedicated measurement session, but the model gets generated as the workers do their daily activities. One possible approach is the camera based 3D reconstruction, with monocular or stereo camera systems (e.g. StereoLabs' ZED stereo camera). In this scenario, normal workers could carry cameras and record images over the day. Based on the collected image sequences, the visited areas could be reconstructed by specialized algorithms. To achieve this, SLAM (Simultaneous Location and Mapping) algorithms were a focus of our experimentation.

For comparing different available technologies, we performed a practical evaluation in indoor environments. Since the systems relay on image quality and lighting conditions, the assessment was carried out in the same place and at the same time of day. Furthermore, the speed at which the cameras were moved was taken from natural human motion. Figure 1 part A depicts the room dimensions and trajectory chosen. We tested implementations based on the ORB-SLAM algorithm, as well as implementations using ZED stereo camera, and HoloLens.

ORB-SLAM [15] is among the most recognized mapping algorithms for real time applications. It has shown promising results in autonomous robotics for its ability to extract trajectories efficiently, and for its portability among systems. To record the environment in our application, we calibrated the algorithm using a GoPro Hero4 Session camera; a device that is suited due to its high quality recording and battery life. Figure 1 part B shows the trajectory recorded by the algorithm. The main disadvantage found during the evaluation is the lack of accurate distance units, resulting in a scaled version of the trajectory taken. The scale generated depends on the motion speed during the initialization phase, resulting in inconsistencies when the trajectory is repeated.

The result of the evaluation also shows a decrease in accuracy during abrupt turns. Due to the scaling difference, small changes in the translation of the camera can produce big differences in the resulting trajectory. Finally, due to open sections in the construction, the lighting conditions are susceptible to sudden change. These unexpected changes cause an abrupt loss of location for the algorithm during the experiment.

The ZED camera is a stereo device fabricated by StereoLabs and has extensive software support for its use. This product is able to reconstruct the environment and deliver a 3D model in a post-processing procedure. We evaluated the accuracy of the results following the same base scenario, trajectory and lighting conditions as before. The main disadvantage of the camera is the reduced portability of the system due to its dependency on specialized hardware. The recommended specifications for optimal performance of the ZED camera are a NVIDIA

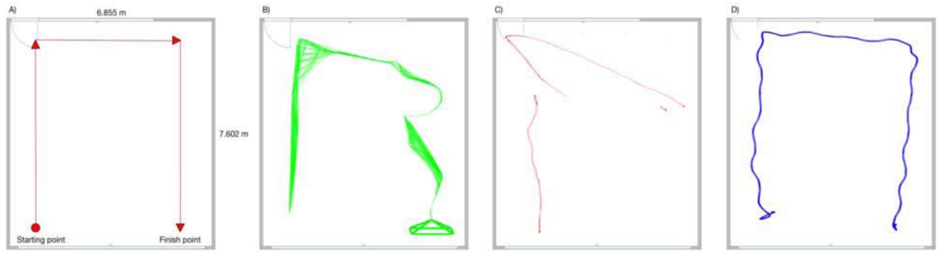

Figure 1. A) Path taken whilst carrying the recording device. B) Path recorded by monocular OrbSLAM (scaled) C) Path recorded using ZED camera (scaled) D) Recorded HoloLens trajectory

GTX1060 graphics card or higher, along with USB 3.0, 8 GB RAM, and a quad-core processor. In this evaluation, we used a NVIDIA Jetson TX2 along with a special version of ZED's software designed for this embedded module. The Jetson platform increases the mobility of the camera, offering the possibility of building a portable device for our application. Figure 1 part C shows the trajectory recorded by the camera during the experiment.

The results show a well reconstructed portion of the environment during a linear trajectory, but decreases accuracy during turns. It also shows a decrease in quality when faced with empty portions of walls (i.e. windows), resulting in brief but significant loss of tracking. Finally, the distance measured by the device presents a significant scale difference, going up to 100000% larger than the actual size.

As previously stated, we want a solution capable of being portable and easy to use for the construction personnel. Furthermore, for our application, we relay on the quality of the reconstruction and expect it to be able to capture the environment as good as possible. However, the 3D model of these feature-based methods was not detailed enough for our purposes. These methods are also sensitive against poor lighting conditions and sudden rotational movements, two things we can not control in this application.

4.2.1. HoloLens

As a third option, we evaluated the 3D mapping capabilities of the Microsoft HoloLens. The device creates and updates the 3D model of the environment by walking and looking around the scene, which makes the process extremely easy. Additionally, the HoloLens, currently available in it's developer edition, already provides an interface to this 3D model.

The main disadvantage of the device is its short measurement range, having a maximum of 3.1 meters. Consequently, the reconstruction is limited to rooms and halls. Figure 1 part D shows the recorded trajectory of the device, and Figure 2 shows a 3D model of the reconstruction. The evaluation shows a high quality reconstruction and a robust trajectory calculation in the presence of turns, sudden camera movements, and unexpected lighting condition changes.

To extend the evaluation of this reconstruction, we assessed the accuracy of the map by comparing the dimensions measured on the created model to the real size of the room. Table 1 shows the results under different lighting conditions.

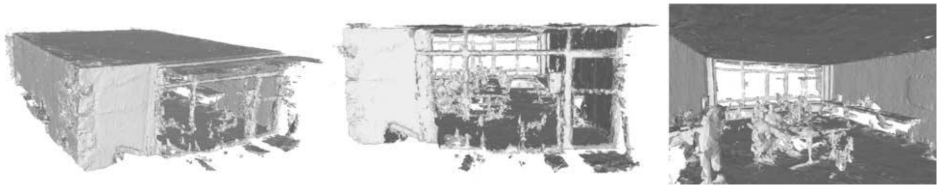

Figure 2. HoloLens 3D reconstruction of a single room from different angles

Dimension	Natural Light	Light Bulb Day	Light Bulb Night	Ground Truth
Width	6.897 m	6.912 m	6.931 m	6.850 m
Height	2.733 m	2.804 m	2.712 m	2.737 m
Length	7.815 m	7.737 m	7.932 m	7.602 m

Table 1. HoloLens accuracy measurements under different lighting conditions

Dimension	Natural Light	Light Bulb Day	Light Bulb Night
Width	0.686131%	0.905109%	1.18248%
Height	0.146145%	2.44794%	0.91341%
Length	2.80189%	1.77585%	4.34096%

Table 2. Error percentage of the measurements

Table 2 contains the error analysis for the measurements using the values from Table 1.

The best results are achieved in natural light environments where there was a difference of 47 mm in width, 4 mm in height, and 213 mm in length. On the other hand, the worst results are perceived in artificial light environments at night, where the difference was 81 mm in width, 25 mm in height, and 330 mm in length. Throughout the experiments, the height of the evaluated room was surprisingly inaccurate when light bulbs were on and in the presence of natural light, showing a 67 mm difference. These variations can be explained by reflections on glass windows present in the environment. Such reflections occur more prominently with the use of light bulbs, and they are a major obstacle in modern computer vision, as algorithms cannot distinguish between reflections and real objects.

5. System Prototype

An overview of our proposed system architecture is presented on Figure 3.

5.1. Wireless Network

As described in section 3, the size variability of the construction sites and the need for long autonomous operation were the main determining factors for the on-site communication network. State of the art hardware components using sub-1-GHz frequency bands usually operate over long ranges and support low power consumption, which make them the perfect choice for our system.

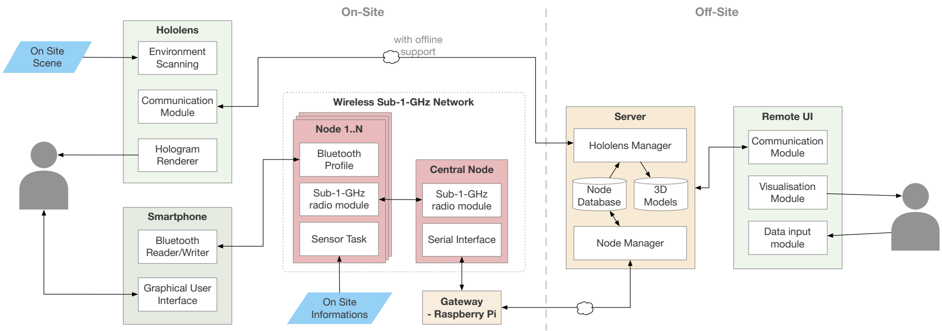

Figure 3. Architecture of our prototype implementation highlighting the major system-components and their connections.

Hardware For our hardware implementation, we applied a board using the CC1350 SimpleLink Ultra-Low-Power Dual-Band Wireless Microcontroller developed by Texas Instruments. For long range communication, the nodes operate on the 868 MHz radio frequency, using a star network topology. It can also operate using the 2.4 GHz Bluetooth Low Energy (BLE) standard, which we used to provide a close range interface for mobile devices such as smartphones. The board is capable of managing a wide variety of sensors. In this prototype implementation however, no particular sensor was used, instead we stored simulated data on the nodes. The central node and the sensor nodes are implemented using the same hardware design, but running different firmwares.

Central Node The main functionality of the central node is to act as an information transceiver, collecting and distributing data from and to the nodes. It also implements a serial interface to the gateway, a device connected to the Internet for communicating with the remote server.

Nodes The nodes are responsible for storing information and, if a sensor is connected, reading its values. These can be published over two interfaces: 1) the 868MHz channel to the central node, which relays to the remote server or 2) locally over a Bluetooth connection. However, the board is capable of using only one frequency band at the same time, so the node has to switch operating modes regularly. In our implementation, it works as follows: 1) If available, read sensor values 2) Bluetooth mode is activated 3) When a Bluetooth connection is requested during that time, the node exposes a generic attribute profile (GATT) containing the stored information 4) If no Bluetooth connection is established during a set period of time, the node adapts its frequency to 868 MHz to communicate with the central node. 5) After the exchange is completed the loop starts over.

5.2. Android Application

For testing and demonstrating the direct Bluetooth interface feature, we implemented an Android application and utilizing the Board's operating system built-in Bluetooth API and protocol stack. Via an initial, basic interface on their smartphones, users can obtain and modify information of the connected node.

5.3. 3D Scanning

After evaluating different 3D reconstruction technologies, we decided to integrate the Microsoft HoloLens into the system. The HoloLens not only ensures accurate spatial reconstruction but also provides a portable and easy-to-use interface. Furthermore, its augmented reality features open up new ways of interaction and visualization of information. To leverage the device's capabilities, we implemented a custom application.

Figure 4. Visualization of a 3D scanned mesh for remote view (left) and augmented node information during deployment (right).

Currently the main feature of the application is the scanning. During scanning the system draws a 3D representation of the surroundings, creating a superimposed hologram over all surfaces and objects (Figure 4). If the current area contains a node from our network, a hologram will also indicate its position. The device can also recognize sensor nodes using image processing on its camera stream. Once a node is detected, its position will be updated. After finishing the scan process, the 3D model and the location of all detected nodes are transmitted to the central server. This can happen in a post processing step, if there is no network connection available for the HoloLens. 3D models can also be stored locally in object-file format (.obj) compatible with modern 3D model viewers.

5.4. Remote Monitoring

3D scans and node data from the construction site are transmitted to a remote server. In the prototype version, this was implemented without data security features, using the Unity frameworks networking capabilities. This server unit works as a central source and storage of node data. It also stores the 3D models extracted from the site.

Additionally, we designed a prototype user interface application to work alongside the server. Since it was created in Unity, it can be compiled to a broad range of desktop and mobile environments. This UI includes a 3D visualization based on the most recent on-site scans and can present each node's information in the 3D model. Changes submitted to the server are instantly displayed in the visualization.

6. Conclusions and Future Work

Construction sites are generally a challenging environment for digitalization. In this work, we have discussed the most important requirements a system for real time monitoring and information distribution must fulfill. We have explored different existing possibilities for developing and implementing such systems and we argue the advantages and disadvantages of each approach. And finally, we presented a system prototype implementation that enables construction professionals the ability to monitor real time progress as well as relay information to the site from anywhere as fast and as reliable as possible with off-the-shelve technology.

We aim to build up the system even further, improving the user experience in remote displays, in the augmented reality realm, and finally in our smart phone application. Encouraged by our initial results, we also wish to expand the capabilities of our 3D reconstruction model to provide a history log. This will provide an intuitive visualization about progression of the project. Lastly, we will evaluate our system in the construction context in order to gain necessary feedback from the final users.

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Using Statistical Analysis for Environment Partition by Clustering Using Historical Temperature Behavior

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Abstract: Temperature behavior is considered in the industrial environment as a challenge for analysis and inspection. The use of smart technologies is essential in different industrial environments when exists multi-stages. It is a challenge when the goal is the prediction of events through time. In this paper, we present a process for environment partition by clustering that uses analysis of historical measures of temperature to obtain at first, the best statistical value for making partitions. The experimental results demonstrate that our approach has good results.

Keywords. Intelligent, inspection, industrial security, clustering partition, smart environment, environment behavior, prediction.

1. Introduction

The use of a large number of sensors in an environment allows having more precision for detecting abnormal phenomena or sense the environment. It is hard work with many dimensions into Machine Learning techniques for Smart Environments. The application of reduction techniques is an excellent option, but there are areas in an environment that behave in a very similar way, and they can be in different locations, so, the reduction could generate the loss of a variable that can be critical in the area where it is located. In this work, a proposal was made for the partition of different regions in an environment, analyzing the behavior of the same and sectioning the context by K-Means technique. A reduction of dimensions is applied to identify those variables that describe in the best way the behavior of each area where the temperature is a critical factor. The dataset used to model this process is the information of 53 sensors of Intel Berkeley Research Lab dataset, it seeks to analyze the behavior of a sample of sensors. The first part describes the concepts surrounding smart environments, technical considerations, approaches and

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some applications. The second part shows the description of dataset, the behavior in statistical terms and the search for a parameter that, in the third, was used for the identification of areas by clustering and dimensional reduction.

2. Related work

In this section, we describe some approaches and considerations taken by some authors; context factors, and techniques for solving it some of them. We describe some features of environment-behavior in statistics terms.

2.1. Computational intelligent approaches

A smart environment, in terms of capacity, it will depend on the context requirements [1], Turgut performs a compilation of different techniques that they are used for implementation of technologies in buildings; he highlights factors such as signals interference, economic cost, speed, and issues in the environmental analysis. One of the main factors that Turgut consider critical is the environment instability like noise and signal reflections, highlights the use of deterministic algorithms and correction algorithms like Artificial Neural Networks, Bayesian Decision Trees, Support Vector Machines, and Bayesian Classification [2]. Ben Letaifa [3], in much more significant dimensions, studied three cities (London, Stockholm Montreal) and emphasized factors such as the economy, population, governments system, geography. All those factors are part of knowing the scale to deploy smart technologies and how much is the need according to the above factors. In the studied variable of this work, Morgan describes that statistical distribution of temperature depends on the primary way by climatic variation of the environment, among other factors and that, in statistical terms, it is common to find a bi-modal distribution because of there day and night [4]. Besides, with multi-stage environments, there are multimodal distributions, where is difficult to know the data-behavior in an environment [5].

Mayer [6] describes that one of the leading challenges in the Internet of Things is the adaptation of smart technologies in the environments or industrial environment using the services provided by the same context. Mayer presents a proposal for use semantic and reasoning with visual modeling tools to generate a model with the ease of adapting to many environments.

2.2. Application scenarios

The application of smart techniques to generate a smart environment will depend on the problem in question, and it is also required for the correct management when we want to have accurate information of different elements within it [7] since it facilitates the life of users [8]. There is no exact model to follow, but there are cases in which information can be extracted to solve these situations.

One of the most common examples is smart offices; work carried out by Le [9] where his team developed an architecture for work offices. They distributed microphones and cameras in a couple of offices with the purpose of recognizing the user activity, interpret gestures and perform operations on a blackboard, where they project an application developed by themselves and that allows working in conjunction with another office. The location of the microphones and the cameras are based on different jobs although the distribution depends on the dimensions of the environment too. The challenge is directed towards multi-stage environments, where the number and location of monitoring modules are varied and then comes the need to select which of them are the best for describing the local stage [10].

Aiming at maximizing comfort, minimizing costs to the environment, it must make use of artificial intelligence techniques. An example of this [11] is the use of prediction techniques and construction of autonomous decisions where the prediction plays the most crucial role, and this will generate out of the specificity of the environment, learning from observation to predict behaviors in the future.

There are proposals for sensors placement in smart environments, but with this, also confers a challenge to know those critical points that give more information about the environment. The use of more sensors in vast spaces is beneficial but increases the dimension analysis of the environment-behavior. When the monitoring stations already exist in the environment, the use of the prediction techniques becomes a challenge by the number of variables to be used, therefore the need of a rigorous selection of the most representative stage modules.

On the other hand, Diane and Salaj [11] propose the use of learning techniques which can anticipate events and deploy actions or alerts to users, they describe that location plays one of the primary roles for prediction. It is hard to take *n* elements for prediction, and is necessary to take only those that describe the behavior when there are different stages in the environment. Therefore a smart environment must be able to determine when and where an event will happen. With this, the system autonomous decision that was previously done by a reaction, it can anticipate and deploy a stage stabilization process.

Concerning a variable to study, as is the temperature, it is not a variable that changes quickly, traditional systems of automatic response react when the threshold defined is exceeded, and restore the variable level it has an energy cost and requires an effort of the same system or human resource.

3. Preliminary experiments

In this section, we deploy the process that we use to obtain the best value that describes the behavior of each sensor. At first we calculate statistics values, and we applied normality tests to discover if the distributions follow a normal standard distribution, then, with all those results we applied an adjusted curve to know the distribution curve.

3.1. Dataset features for the process (An environment sample)

The original dataset [12] it has 2,313,682 independent records from 54 sensors, not all data is used for this work, and the data was adjusted and performed for this purpose as we can see in Table 1.

Table 1. Dataset features

	Original dataset	**Reduced dataset**
Number of records	2,313,682	2,098,980
Sensors	54	53
Period	28/02/2004 - 02/04/2004	28/02/2004 - 20/03/2004
Time between each records	31 seconds	31 seconds

Some arrangements have been made, including the removal of sensor 5 and his data because it has incomplete data. The period of days was cut, and a low pass filter was applied to eliminate outliers, to recover lost information, it was used Principal Component Analysis (PCA) and Alternating Least Squares(ALS) [13].

Concerning the variable to study, the temperature was chosen, given that, for our objective, it is a critical variable to monitor. The primary purpose of reviewing the environment-behavior in different ways can give us an idea of the context variability, besides that, generate a methodology that allows being applied in similar environments.

To realize what is the environment-behave, is necessary to know aspects of the data behavior, what is shown in Figure 1 is the thermal map of the average temperature in one day of our dataset.

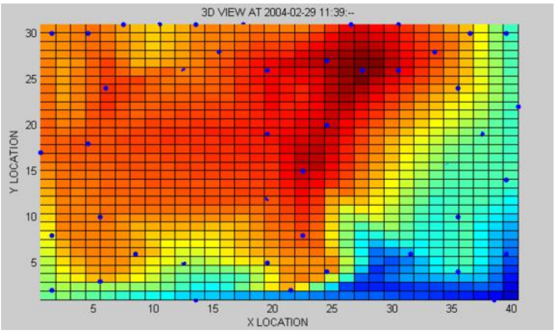

Figure 1. Temperature behavior: 29-02-2004

3.2. Statistical analysis

For the statistical tests to known the behavior, the original data were used without applying PCA-ALS, and the samples were on the last value recorded per minute by each sensor, this allowed no significant losses, besides it was done in this way because there are no intervals of high significance between each period. Nine of the 53 sensors were randomly taken uniformly; in Table 2 we describe their behavior over one day.

Table 2. Statistical values

Sensor	Mean	Standard Deviation	Variance	Mean Absolute Deviation	Median
1	19.26574641	1.221135492	1.491171891	1.039864989	18.979
7	19.2352306	0.891045575	0.793962217	0.736589383	19.1652
13	18.40604599	1.181935172	1.396970752	1.001240287	18.6311
18	19.04658256	1.586366196	2.516557708	1.321563967	19.2534
25	19.02939732	2.485106163	6.175752643	2.104231653	18.587
30	18.58663052	2.099529497	4.408024109	1.761434334	17.8226
40	19.15883712	1.662755253	2.764755032	1.448910723	18.7634
45	18.16285474	1.374222652	1.888487896	1.164730721	18.1068
52	17.97068889	1.103766094	1.218299591	0.918193457	17.9059

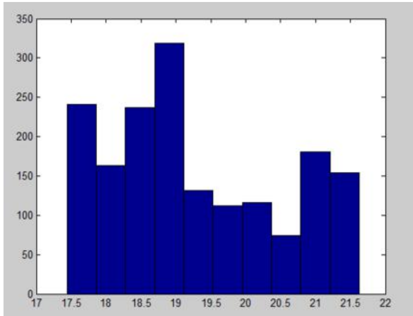

Figure 2. Temperature behavior: One sensor histogram.

Taking the histogram of one of the sensors we can realize that does not show a defined distribution as we show in Figure 2, so we can not choose any statistic value when we do not know the distribution of our data.

A normality test was performed to know if data to one day have behavior that fits to normal standard distribution. For this we used two separated criteria, one of them was Kolmogorov-Smirnov test, and the other was Anderson-Darling test, we use a significance level of 5% [14], some considerations of the model proposed by Jiashun were taken; Influential features PCA [15], the results are described in Table 3.

Table 3. Normality test

Sensor	K. S.	P-Value	A. D.	P-Value
1	1	9.232962881516412e-20	1	5.00e-04
7	1	5.802408110556665e-08	1	5.00e-04
13	1	3.264777358469370e-07	1	5.00e-04
18	1	4.199077468453737e-18	1	5.00e-04
25	1	5.807580467287169e-22	1	5.00e-04
30	1	2.224544606398663e-32	1	5.00e-04
40	1	5.076627560843064e-24	1	5.00e-04
45	1	1.149932384764373e-07	1	5.00e-04
52	1	0.001052009391966	1	5.00e-04

H_0 is the premise that the data follow a normal standard distribution, H_1 has to be the premise that data does not follow a normal standard distribution.
Where:

- S.D = Standard Deviation.
- K.S = Kolmogorov-Smirnov.
- A.D = Anderson-Darling.
- 1 = Null hypothesis is rejected.
- 0 = Null hypotheses is not rejected.

By the previous tests, is concluded that in windows of one day, there is no statistical evidence to accept H_0, therefore, the data do not follow a normal standard distribution.

Finally, the average of all sensors in one day, three days and the average temperature per minute during a day and three days, giving the following results that show Table 4.

Only one case it was approximate to normal standard distribution, but it is not sufficient to justify the behavior.

Table 4. Normality test: Sensors and environment behavior

Type	Mean	S. D.	K. S.	P-Value	A. D.	P-Value
Sensors in 1 day	18.7718	0.6685	1	0.03948	1	5.00E-04
Sensors in 3 days	20.5316	1.6773	1	0.00283	1	5.00E-04
Ambient in 1 day	18.8061	1.5593	1	1.79E-07	1	5.00E-04
Ambient in 3 days	20.4850	3.0821	1	3.17E-31	1	5.00E-04

3.3. The distribution behavior

By not having a data behavior in terms of the distribution that follows, it is necessary to search for another way, to get the best feature to give weight to the clustering technique. In statistic terms, with more reason in environments with multi-stages, there are multi-modal distributions [5], which may not have a known function and is essential to identify the measures that represent the data in the best way. Reimann [5] comments that separating the data in N-distributions and estimating each central value of each distribution is not practical because it must be found a single value that approximates to the central distribution value and is the best representative value for the same which we do not know. He says that the median is a value that allows dividing the total distribution results into two parts, and that can be the closest measure to the central value and as such, the best distribution representative.

When we make the adjustment curve, we found that data follows a multimodal distribution; therefore, the data can contain different distributions, similar what Morgan says when works with temperatures in 1-day windows that include day and night. Now what we require is the approximation to the center value so, as Reimann reports, the median is a good candidate, although there is not much difference between our best candidate and the average (Figure 3).

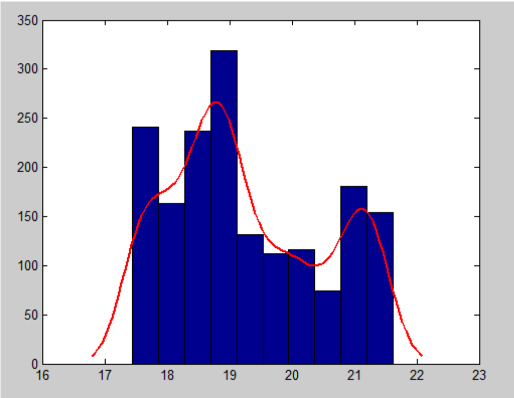

Figure 3. Fit curve distribution.

Before we select our best candidate, we will increase the sensor sampling on a range of 3 days; Table 5 shows statistical values:

Table 5. Measures on 3 days

Sensor	Mean	Standar Deviation	Variance	Mean Absolute Deviation	Median
1	20.74429061	2.516489775	6.332720786	2.092689229	20.5176
7	20.61146012	2.310284493	5.33741444	1.902998913	20.0962
13	19.8144863	2.878298954	8.284604866	2.339397322	19.1358
18	20.57168902	2.61564189	6.841582497	2.263529714	20.5764
25	21.81054223	5.1655706	26.68311962	4.262883536	20.5764
30	20.65717037	4.131053679	17.0656045	3.469639286	19.7238
40	20.72176609	3.222287164	10.38313457	2.628378039	20.4196
45	19.80043369	3.110624802	9.67598666	2.595615625	19.4886
52	19.13410303	2.51007835	6.300493325	2.182016725	18.7928

With the results of the previous table, we can see that two features: the mean and the median are very close to the central distribution point; therefore, we can select one or both of them as features vectors.

4. Experiments

As could be seen previously, the data, in statistical terms of the sensors may be similar, but with a multimodal distribution, before starting a dimensional reduction, with the purpose of making predictions, a reconstruction was made to get the missing data using PCA and ALS.

4.1. Dimensional reduction with PCA

After PCA-ALS was applied, our goal was to discover those features vectors that describe the environment-behavior, to interpret that non-observable information [16,17] we use PCA over 53 vector features of the data segment as Table 6 shows, after applied PCA we obtained 13 features.

Table 6. Features vectors

1	6	8	12	16	20	24	28	32	36	40	44	48

However, since is a context that has multi-stages, see Figure 1, there is greater uncertainty that the information provided by PCA mentioned above can describe the environment, taking into account also that the data do not follow a normal distribution and exist multi-stages.

4.2. Clustering by multi-stages behavior

To be able to solve the previous issue, we use the previously statistical results, and it can be established that the average does not move away from the median in our multimodal distributions, so it is an excellent candidate to be a feature vector for clustering with the other features. Therefore, the parameters used for sensor clustering were the location by their coordinate pairs and the average of the temperature per day, so the third parameter it weights the grouping.

K-Means was used for clustering all those elements that have similar features [18], but it must be considered that there is also a risk when we want to select a value number of clusters incorrectly. Therefore, it makes use of DBSCAN[19] at first to identify in relative terms, how many groups can be generated.

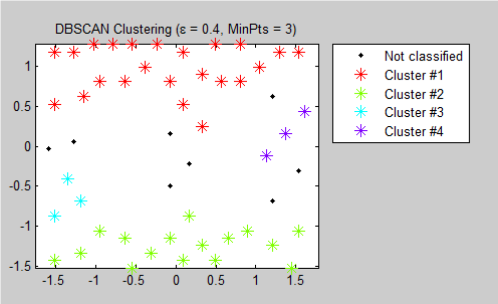

Figure 4. Unsupervised clustering by DBSCAN.

It can be showed in Figure 4, DBSCAN generates 4 clusters, but left some elements out of groups, at least it gives an idea of the approximation to the number of clusters to produce with K-Means. Figure 5 shows K-Means application, and it has excellent results [20] when is commonly used with PCA [21], it should be mentioned that the use of clustering is to obtain minimal loss of variables where the location is also a critical part of the environment.

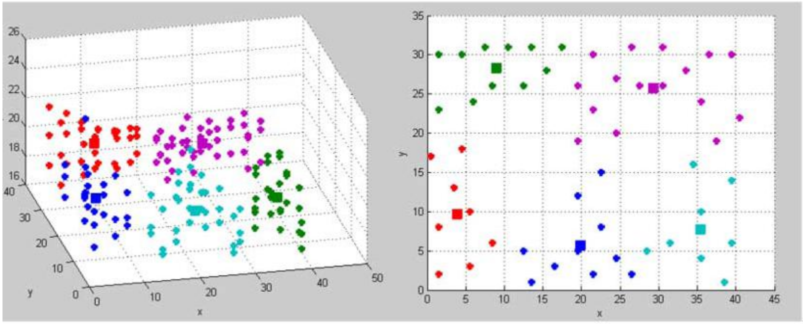

Figure 5. K-Means Clustering.

5. Preliminary results

As we mention in the previous sections, at first, we analyze the data for selecting the best representative value of each distribution. Then we applied PCA for dimensional reduction for select best sensors that describes the whole environment. Next, we use the best representative value of each sensor concerning the statistical distribution of temperature, we applied DBSCAN and K-Means to discover multi-stages, and finally, we applied PCA.

5.1. Dimensional reductions for each cluster

After we applied K-Means, and apply PCA for each cluster, we obtain the following results showed it in Table 7.

Table 7. Clustering results

Cluster	Sensors
1	11, 15
2	6, 10, 51
3	20, 24, 28
4	1, 31, 35
5	38,42,46

It could be verified in Table 8 that the results of both reductions are not so different:

Table 8. Comparative results

PCA	Vectors													
Direct application	1	6	8	12	16	20	24	28	32	36	40	44	48	–
By clustering	1	6	10	11	15	20	24	28	31	35	38	42	46	51

Now we can describe the environment-behavior by each cluster or in a general way. However, it is necessary to emphasize again that in multi-stage environments is required to know the location of events to support prediction techniques, so, a better environment response can be obtained by the system.

6. Conclusions and future work

The analysis in an environment that already has historical information is vital for the implementation of smart techniques. If not have done the statistical analysis before to know the environment, could have fallen into a drastic reduction in dimensions when the information could be bimodal or multimodal and the information show an apparent relationship between them.

It is necessary to understand the environment-behavior before the transition to smart environments. As a future work we are planning to deploy this strategy in a real communication room in an oil pumping station from PEMEX (Mexican Petroleum).

This work is in progress, and we hope to report our results in future publications.

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9th Workshop on Intelligent Environments Supporting Healthcare and Well-Being (WISHWell'18)

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8th International Workshop on Intelligent Environments Supporting Healthcare and Well-Being (WISHWell'18)

June 25, 2018, Rome, Italy

Chairs: Juan C. Augusto[a] and Wei Chen[b]
[a]*Department of Computer Science, Middlesex University, London*
[b]*Department of Electronic Engineering, Fudan University, Shanghai*

Introduction

The workshop will bring together researchers from both industry and academia from the various disciplines to contribute to this new edition of the International Workshop on Intelligent Environments Supporting Healthcare and Well-Being. This event previously joined forces with the International Workshop "PervaSense – Situation recognition and medical data analysis in Pervasive Health environments" and the workshop on "Smart Healthcare and Healing Environments". Healthcare environments (within the hospital and the home) are extremely complex and challenging to manage from an IT and IS perspective, as they are required to cope with an assortment of patient conditions under various circumstances with a number of resource constraints. Pervasive healthcare technologies seek to respond to a variety of these pressures by integrating them within existing healthcare services. It is essential that intelligent pervasive healthcare solutions are developed and correctly integrated to assist health care professionals in delivering high levels of patient care. It is equally important that these pervasive solutions are used to empower patients and relatives for self-care and management of their health to provide seamless access for health care services.

The technical program will be composed of an invited Keynote: "The role of Reinforcement Learning technologies in realizing innovative eHealth applications" by *Dr. Antonio Coronato.*

This will be supplemented with discussions and panel-type activities and the presentation of the following selected papers:

An Agent Based Approach to Monitor the Behaviors of People Living Alone *by Carlos F. Pfeiffer, Badreddine Cherradi and Nils Olav Skeie*

A Reinforcement-Learning-based Approach for the Planning of Safety Strategies in AAL Applications *by Giovanni Paragliola and Antonio Coronato*

Identification and Analysis of Emotions in a Game Based Therapy for Patients with Cognitive Impairment by *Pedro Cruz-Parada, Victor Zamudio, Javier Navarro, Faiyaz Doctor, Carlos Lino, David Gutierrez and Maria Del Rosario Baltazar Flores*

Towards an Innovative Architecture to Monitor and Handle Emotions in Work Scenarios by *Victor Zamudio, Juan Jose Manriquez Santos, Francisco Javier Navarro Barron, Carlos Lino, Faiyaz Doctor, David Asael Gutierrez Hernandez and Rosario Baltazar*

INLIFE - Independent living support functions for the elderly: Technology and pilot overview by *Arlene J. Astell, Anton Gradišek, Jani Bizjak, Hristijan Gjoreski, Matjaz Gams, Karmen Goljuf, Maria Fernanda Cabrera-Umpierrez, Juan Bautista Montalva, Youla Karavidopoulou, Maria Panou, Aikaterini Touliou, Nikolaos Kaklanis, Stefanos Stavrotheodoros, Dimitrios Tzovaras, Evangelos Kaimakamis, Katja Laakso, Margret Buchholz, Sandra Derbring, Christina Samuelsson, Anna Ekström, Alvaro Garcia, Javier Chamorro Mata, Sarah Kate Smith, S Potter, Monique Tabak, Marit Dekker-van Weering, Fatma Cossu-Ergecer and Belinda Black*

We deeply appreciate the Intelligent Environment 2018 conference organizers for their help on hosting this event. As a final note, we wish to express our sincere thanks to the Program Committee for their thorough reviews and support along this year and the previous editions.

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An Agent Based Approach to Monitor the Behaviors of People Living Alone

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Abstract. A method to monitor and detect unusual or atypical behaviors compared to previous stored data is presented, as part of a system to automatically monitor the behaviors of people living alone. The system uses a discrete event oriented framework, where data from cameras and other sensors is automatically analyzed to get information about the status of the person (defined by his location inside the house, his position, and the intensity of movement), information about the room status, (the number of persons in the room, the status of windows, doors, lights and other appliances, the room temperature and humidity, etc.) and information about external status (external humidity, external temperature). Every two seconds all the information is mapped to discrete set variables that take a reduced number of values, and stored in a system state database . An agent based approach is used to define agents that use the information from this data base, and build models to characterize the person typical behavior. Monitor agents that use this characterization to detect atypical behaviors when the system state is updated, are also defined. The approach is demonstrated with a simple prototype to monitor the time spent in each of the rooms of a small apartment.

Keywords. behavior modeling, agent based monitoring, health care monitoring system

1. Introduction

This article presents an extension of a previous work published in [1], where a discrete framework to develop a system to monitor people living alone was introduced. We use the definitions for *system state*, *activity* and *behavior* provided in the referenced article, where an activity is defined by a given combination of system state variables values, including the person status, the room and room section status, and the external status. Activities can be extracted by queries in the system state database. Several combinations of variables values on the system state can be mapped to the same activity, and labeled with a description meaningful for the users and system designers. For example, all combinations that include the person sitting or lying in the sofa section of the main hall, while the

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TV is on, could be labeled as the activity Watching TV. The accuracy of the statement is not important (the person may be reading or sleeping with the TV on) in order to detect if a pattern is typical (common) or not. More specific activities can be defined by including more system state variables on the activity definition, for example system states where the position of the person is sitting, the room section is sofa, the TV state is ON, and the light is OFF, could be mapped to an activity labeled "Watching TV sitting on the sofa with lights off". Of course, it is also possible to label activities just with code numbers without giving them meaningful names. A simple behavior is defined as a single activity during a time span, for example watching TV for some time. More complex behaviors can be described by sequences of activities and their duration over a time span, indicated by changes on specific system state variables, for example when a person gets up of bed and goes to the bathroom, several variables of the system state change depending on the trajectory the person follows, the actions the person takes (as long as these actions produce changes on the state variables), and the time the person spends in each section of the apartment.

2. System architecture

An expansion of the basic system architecture given in [1] is presented in figure2. In this article we focus on the behavior monitoring components: behavior monitoring agents, behaviors models agent, and the behaviors models database. This architecture has the advantage of collecting the models in a single database that is populated dynamically as more agents are added, as it is explained in subsequent sections, in comparison with architectures that require the agents to include the models in their definition [2].

2.1. Behaviors monitoring and behavior models agents

We define an agent as a physical or virtual entity able to perceive and act on its environment in a limited way. It has its own objectives, resources, skills and services, and may communicate with other agents to achieve its objectives [3]. A well designed agent-based monitoring system, should allow the addition of new agents as needed, without requiring the modification of existing ones.

The proposed framework allows the incremental adding of agents designed to monitor specific behaviors, or a specific class of behaviors. To test the framework, we chose to monitor the time the person spends in each one of the rooms of the small apartment depicted in figure 3. The usefulness of monitoring this specific class of behaviors (time spent in a determined area) is evident, since it can detect possible dangerous situations, for instance if the person does not leave the bedroom in the morning, or if the person takes an unusual amount of time in the bathroom.

Three similar agents were defined, each one with the task to monitor a different room section: the main hall monitor agent, the bedroom monitor agent, and the bathroom monitor agent. The agents get a notification when there is a change on the system state that matches the activity corresponding to the behavior they monitor, in this case, the room where the person is. An additional agent was defined to handle model requests, as explained below.

2.2. Agents operation

When the person enters a given room (detected by a variable change in the system state), the corresponding monitoring agent starts a timer, and sends a request to the behaviors model agent asking for the average time the person spends on the room *during that part of the day*. The behaviors model agent check the behaviors models database for a corresponding entry, and if it does not exists, it triggers a procedure to query the system state database to extract the required information, and it calculates the average time spent on the room within a continuous time bracket including the time the monitoring agent was triggered. This information is stored creating a new entry on the behaviors models database. Once a behavior model entry is created, the behaviors model agent updates the statistics regularly, keeping history of the changes.

For instance, when the person enters the bedroom, the system state reflects it by changing the location of the person to "bedroom". The agent in charge of monitoring the bedroom is triggered and sends a request for the average time a person spends in the bedroom to the behaviors models agent, sending the combination of state variables that define the activity to monitor (in this case, person_location = bedroom) and the time stamp when the agent was triggered. If there is not a valid entry in the model database (i.e., there are not entries valid over a time bracket including the time when the agent was triggered), a procedure is called that access the historical database, calculates the required statistics, and creates a new entry on the model database with information that can now be sent to the agent monitoring the bedroom. This allows the creation of different models describing the room occupancy at different times of the day (i.e., the model corresponding to the morning may be different than the model corresponding to the afternoon, for the same activity; since the activity occurs in different time brackets, it represents different behaviors, and the average staying times may be different). Similar procedures are used to define the agents in charge of monitoring the kitchen and the bathroom.

Notice that it is straightforward to define agents to monitor the time a room is not occupied, following the same procedure. For instance, to monitor the time the bathroom has not been used, an agent with the state variable person_location $\neq$ bathroom can be easily added.

3. Behavior modeling and classification

The agents monitoring the behaviors attempt to classify them as typical or atypical, while the behavior is being carried on. An simple but effective approach tested, consisted in considering the person leaving the room as an event x, and approximate its probability with an exponential distribution of the form $p(x) = \frac{1}{\beta}e^{\frac{-t}{\beta}}$, where β is the average time the person has spent in the room in the past, within the same time bracket.

The probability that the person leaves the room before the time t_e is given by the accumulated probability function $P(x, t < t_e) = 1 - e^{\frac{-t_e}{\beta}}$, and as a result, the probability of the person *typically* leaving the room after time t_e is given by $P(x, t > t_e) = e^{\frac{-t_e}{\beta}}$. By using t_e as the current time elapsed since the activity began, and β as the average time the person spends in the room according to the previous registered entries, we notice that this probability is one for $t_e = 0$ (meaning the person always spends some time in the room,

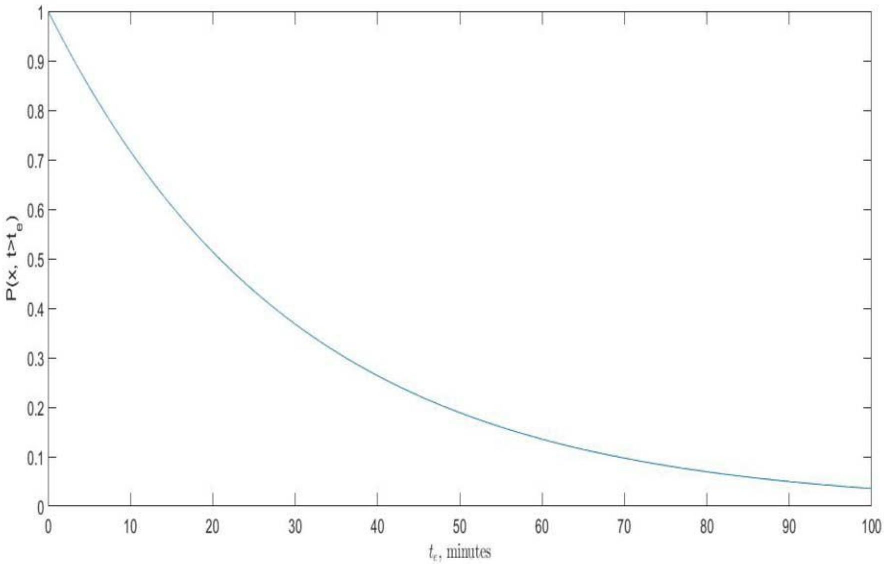

Figure 1. Probability a typical behavior is ended after t_e, with $\beta = 30$ minutes

when entering the room), but it quickly tends to zero when the elapsed time exceeds the corresponding average time. This means that the likelihood this specific behavior is typical diminishes as the elapsed time increases. This probability can be interpreted as a "survival function" [6]. The critical value of the probability to classify a behavior as atypical, can be tuned for each one of the agents according to the user needs. A plot of $P(x,t > t_e) = e^{\frac{-t_e}{30}}$ is shown in figure 1, where $\beta = 30$ minutes.

Notice that these specific agents only signals an abnormal behavior when the time staying in the room is significantly larger than the expected time, but it does not signal when the staying time is less than or close to the expected time. This approach helps to reduce false positives, but it may delay the time the person gets help in an emergency case.

3.1. Long term detection of changes on behaviors

Long term abnormal behaviors represent a change on the typical routine of the person [4,5]. The proposed framework allows the definition and inclusion of agents to monitor the expected times and time brackets for the behaviors registered on the behavior model data base. A radical change on any of these parameters over time, indicates changes of routine that can be classified as "abnormal" or "atypical" (even though they do not necessarily signal a health problem). Although we are presently working on the design of agents to monitor changes of routine of a person, we have not implemented them in this prototype for lack of long term behavior data.

4. System implementation

A prototype for a system using the described framework was constructed using C#, as part of a master thesis at the University of Southeast Norway (USN) [6], using a small three rooms apartment layout as described in figure 3. The system state database was populated using both simulated and real data taken from an activity journal kept by a student living alone for 4 weeks, indicating the time entering and leaving each room of the apartment. Notice that the system state database contains only ”discrete” information. Concurrent work is being carried at USN to build the module for sensor data preprocessing and the interface between the sensors database and the system state database indicated on the systems architecture depicted in figure2. A ”MonitorAgent” and a ”ModelsAgent” classes were defined in C#. When instantiating the MonitorAgent class, the created object is assigned a combination of the state variables representing the activity to monitor. An Event Handler method called ”OnNewActivity” informs the MonitorAgent when there is a new entry on the system state database. The MonitorAgent object then receives the combination of state variables from the database, and compares it with its own. If the combination matches, the MonitorAgent object starts a timer and request the corresponding activity model parameter to a previously instantiated ModelsAgent object. If it exists a corresponding entry, the ModelsAgent object retrieves the information from the models database. If the entry does not exist, it starts a method to query the system state database to retrieve the information matching the activity. With this information, a model for the activity is created and registered on the model database, and the information is passed to the MonitorAgent object. One a model is created, it is updated every time an activity matching the model activity combination occurs, but the previous model is kept, in order to monitor long term behavior changes in future developments. The MonitorAgent object uses the time elapsed since the activity was detected and the expected time on the corresponding activity model, and calculates the probability of the person staying in the room for more then the time elapsed, using a discrete exponential distribution, as explained previously. An notification of abnormal or atypical behavior occurs when the probability of staying in the room drops below a predetermined value, tuned for each activity. If the activity finishes before this probability value is reached, no notification is issued.

5. System performance

The prototype was tested using simulated and real data stored in the system state database for a period of 4 weeks, and with simulated new data entries to start the monitoring process. The architecture and implementation showed to be flexible enough to easily add new monitor agents, without modifying previously defined ones. The preliminary tests were very satisfactory, showing how the model database is populated dynamically as the activities matching the monitor agents were presented, and the monitoring agents alerted when the time realizing an activity (in this case, staying in a given room) exceeded significantly the expected value based on previous registers for the same activity. Research to define and implement more complex behavior monitors agents (checking for sequences of activities) are currently under development.

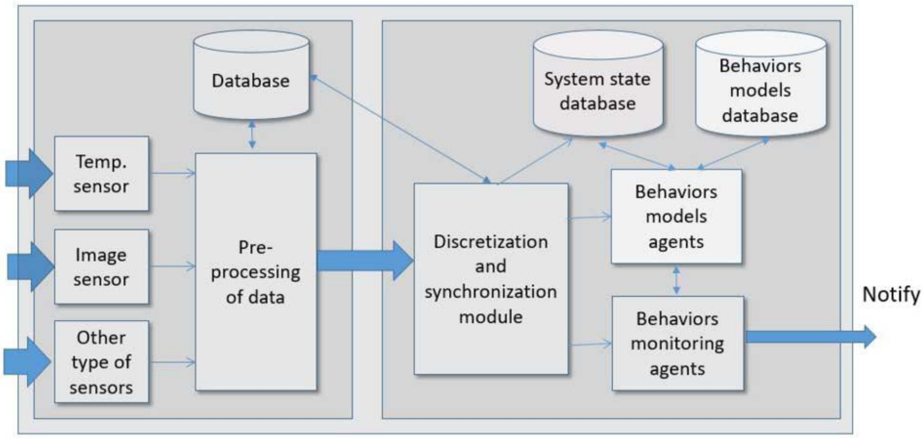

Figure 2. Monitor system architecture

Figure 3. Behavior monitor lab at USN

6. Conclusion

An agent approach method to monitor the behavior of people living alone was proposed and tested with a prototype developed in C#. The system builds up on a discrete event framework architecture previously developed and published by the authors. The system was tested defining agents to monitor the time the person spends in each of the rooms of an apartment. The criteria to detect atypical behavior assumed an exponential distribution for the event ”the person leaves the room”, using the previous history average time spent on the room as the modeling parameter. An atypical behavior is signaled when the time elapsed since the person entered the room is much greater than the average time provided by the model, as indicated by the survival probability function. The prototype was tested to monitor specific kind of behaviors (time staying in a room), but the architecture is flexible enough to allow the addition of different agents to monitor more complex behaviors. The prototype was tested using real and simulated data collected for a period of four weeks, and fed into the system state database. More tests using longer periods of data are required to evaluate the reliability of the system, and to fine tune the threshold probabilities to classify different behaviors as atypical.

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A Reinforcement-Learning-Based Approach for the Planning of Safety Strategies in AAL Applications

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Abstract. Cognitive Impairment diseases such as Alzheimer influence millions of people around the world. One usual trait of such diseases is that patients may perform irrational behaviors, which may result in danger to family members or to the patient him/herself. An Intelligent Ambient Assisted Living Systems should provide solutions able to react to those situations in order to guarantee the safety of the patient. Unfortunately, the unpredictable and irrational nature of patient's behaviors makes the development of such systems hard and complex. In this paper, we address this issue by presenting a reinforcement-learning-based solution to define a recovery process from dangerous situations by dynamically defining a safety strategy. The definition of an intelligent recovery process is the final goal of our work. We are testing the first prototype of our solution into a simulated environment.

Keywords. Ambient Assisted Living, Reinforcement Learning, Machine Learning, Planning

1. Introduction

Cognitive impairment diseases such as Alzheimer influence millions of people around the world. One usual trait of such diseases is that patients may perform irrational behaviors, which may result in danger to family members or to the patient him/herself.

Addressing these situations allow guaranteeing the safety of patients who suffer from cognitive impairments. To address that, methodologies, tools and other technologies have been provided over the last decades. In this direction, ambient assisted living systems (AAL) are one of the most important categories of solutions. One of the main features of an ALL is the monitoring and recognition processes of the patient's behaviors.

A monitoring activity only is not enough, an AAL should also provide mechanisms to automatically react when dangerous behavior is recognized. The goal of such mechanisms should be restoring the safety of the current situation by interacting with the patient's surrounding environment. This task is quite challenging due to issues:

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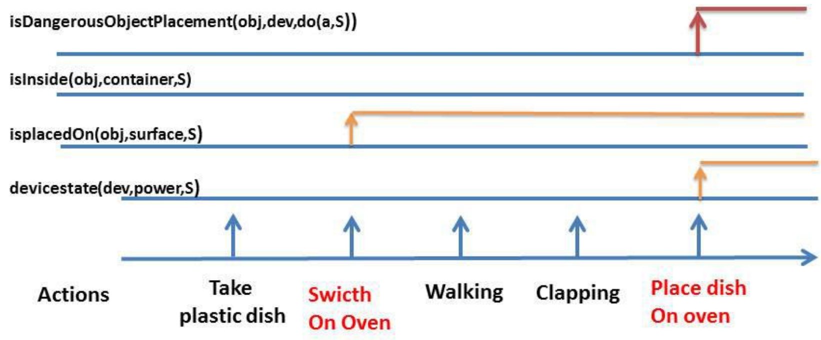

Figure 1. Object Misplacement Scenario

1) The knowledge of the set of all possible dangerous situations is unknown or costly to get in the know
2) Well-known dangerous situations have been handled by fixed strategies defined at design-time.
3) Although we are able to detect anomalous situations, as time passed, a patient could show new behaviors or modify some of those that we have modeled. In this scenario, it is important to provide a process able to learn these new behaviors and modify those already existing itself. Of course, If a novel dangerous situation is detected, it will be costly set new strategies at run-time.

Our final goal is going to overcome these three issues. The contribution of this paper aimed at presenting an approach to address the second issue by defining a reinforcement-learning-based process to concerns the dynamical definition of strategies at run-time aimed at restoring the safety of patients.

We have trained an intelligent agent in charge to define a recovery strategy if a dangerous situation is detected. The recovery strategy concerns a sequence of actions that interact with the devices placed into the environment such as heaters, triggers, etc. Once a dangerous situation has been detected, the agent has to define a strategy on how recovering the environment to a safe situation from a dangerous one. The agent has been trained based on the application of a Q-learning algorithm.

We are testing the first prototype of our solution into a simulated environment in which dangerous situations have been simulated. The environments have been described in our previous work [1], where we used the first-order logic to define a model of the monitored environment to recognize dangerous situations. All situations have described by means of logic predicates named *fluents*.

Figure 1 shows an example of a dangerous situation that we have modeled in [1] in which an inflammable object is placed in contact with a turned heater on. This situation can be recognized as a dangerous situation for the safety of a patient. When this situation is detected, the agent states that is necessary switching the heater off and then sending an alarm. These two actions define a recovery strategy.

The objective of our research is to develop an intelligent recovery system able to define a strategy from any possible dangerous situations at run-time. This will reduce the cost of finding out all possible dangerous situation as well as guarantee an efficient planning of strategies at run-time instead of at design-time.

The state-of-the-art related to AI planning ranging from robotics to education. One direction of research focuses on the adoption of robots to make easy teaching general AI concepts [2], as well as more specific AI topics, such as neural networks [3]. Another topic of interest focuses on teaching robotics concepts such as mobile robotics [4]; related works targeting the teaching of emerging robotic applications, such as field robotics for undergraduate Computer Science Education [5]

In the field of AAL, static strategies defined at design-time have been proposed in [6] and [7]. The authors use probabilistic techniques to model behaviors and activities like cooking; when an error is detected pre-recorded verbals, prompts or pre-defined actions are used to help the users. Our solution, on the other hand, dynamically plans a sequence of actions that return the environment from an anomalous situation to a safe one.

2. Reinforcement learning

Reinforcement learning (RL) is a paradigm of learning concerning how to map situations and actions in order to enlarge a reward signal. The learner does not know a-prior which actions to take to earn a reward, in another hand, it must find out which actions return the highest reward by examining them. In the most interesting and challenging cases, actions may affect not only the immediate reward but also the next situation and, through that, all subsequent rewards. These two characteristics, trial-and-error search, and delayed reward are the two most important distinguishing features of reinforcement learning [8].

Figure 4 shows a logical view of the iteration between the agent and the environment. At time t, for the current state s_t, the agent performs the action a_t that it is submitted to the environment. As response to the action, the environment provides a new state s_{t+1} and the reward r_{t+1}.

Q-learning is a reinforcement learning technique. It is able to make a comparison with the expected advantage of the available actions (for a given state) without feeling the necessity for a well-known model of the environment, for this reason, it is a *model-free* algorithm.

Q-learning can address problems with stochastic transitions and rewards, without requiring of being adapted. It has been made evident that for any finite Markov decision process (MDP), Q-learning, after all, achieves an optimal policy, in other words, starting from the current state, it gets the maximum achievable value of total reward over all successive steps [9]. This property is the motivation that makes us decide to adopt the of Q-learning for our work.

The problem space consists of an agent, a set of states S, and a set of actions . By performing an action $a \in A$ the agent can move from state to state.

Performing a specific action in a given state makes the agent to earn a reward. The objective of the agent is to increase as much as possible the value of its total future reward.

It achieves its goal by learning which action is optimal for each state. The action that is optimal for each state is the one that has the *highest long-term* reward.

The total reward is a weighted sum of the awaited values of the rewards of all future transitions starting from the current state.

The steps of the Q-learning algorithm are shown in 2. After initializing the state, until the agent does not reach a terminated state the agent will select an available action

Output: action value function Q
initialize Q arbitrarily, e.g., to 0 for all states, set action value for terminal states as 0
for *each episode* **do**
    initialize state s
    for *each step of episode, state s is not terminal* **do**
        $a \leftarrow$ action for s derived by Q, e.g., ϵ-greedy
        take action a, observe r, s'
        $Q(s,a) \leftarrow Q(s,a) + \alpha[r + \gamma \max_{a'} Q(s',a') - Q(s,a)]$
        $s \leftarrow s'$
    end
end

Figure 2. Q-learning Alghoritm

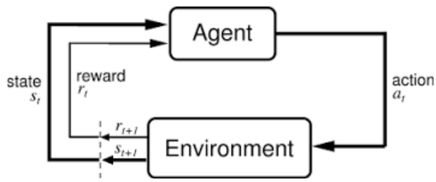

Figure 3. Iteration Agent-Environment

a from its actions-set. Generally, the action *a* has been chosen by a greedy policy.
The selected action is submitted to the environment in order to receive the rewards *r* and the next state s'. The core of the algorithm is the value iteration update formula below:

$$Q(s,a) \leftarrow Q(s,a) + \alpha \cdot (r + \gamma \cdot \max_{a'} Q(s',a') - Q(s,a))$$

The *Q(s,a)*, named Q-function, embodies the knowledge of the agent, it provides a reward for an actions *a* in the state *s*.
The learning rate α defines the percentage of newly information updates the Q-function. A factor of 0 states that the agent learn nothing, while a factor of 1 makes the agent take in account only the most recent knowledge.

The discount factor γ defines the *importance* of future rewards. A factor of 0 will make the agent to consider only the current rewards, while a value close to 1 will make it attend for a long-term high reward. A discount factor equal or exceeds 1, may get the action values to diverge.

3. Proposed Approach

Within the house, a patient can perform many kinds of activities in different rooms. In [1] our work focused on the monitoring of possible activities which can happen in the kitchen.
Within a kitchen, we also typically find devices such as an oven or microwave, which can be switched on or off by the patient. Objects and devices can interact following a patients actions; for example, a patient can place an object on a device or in an inappropriate position.
The first step is to design a representation of the environment that for each time *t*, we are able to know the state of each device and object.
For the purpose of this work, we have defined a state representation to model all those

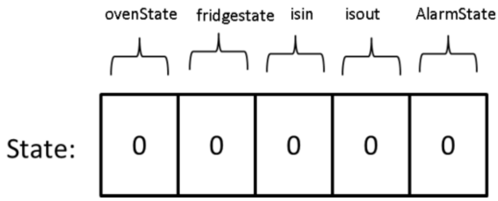

Figure 4. State Representation

situations concerning the dangerous situation described in Figure 1.
A dangerous situation is the result of a sequence of users' actions which gets the current situation to be dangerous due to the misuse of devices and items in the environment.
Figure 1 describes a typical example of the dangerous situation. Turing the oven on does not get the situation to e dangerous until an inflammable object such as a plastic dish has been put on it.
The state of the environment is described by a binary vector where each component states the status of a device or the interaction between objects and devices (Figure 4).
Basically, the state describes what happening within the real monitoring environment. A process to update the state depending on the environment changes is a future direction of our work.
A possible solution is applied the approach defined in [1] to updates the state by means of the values of the fluents.
As an example, the component at position zero means that the oven is turned off. In our work, the components of the state vector means the following:

0 ovenstate; stating the power state of a oven
1 fridgestate; stating the power state of a fridge
2 isin; stating if a inflammable object in on the oven
3 isout; stating if an object is inside a generic container
4 alarmsent; stating if the alarm has been sent

The set of actions aimed at manipulating the values of the vector state. The available actions are: {*switch on oven*, *switch off oven*, *switch on fridge*, *witch off fridge*, *sent alarm* }.
The starting state is randomly selected from the whole set of states in which is detected a dangerous situation as in Figure 1. The agent has to learn how to reach the terminated state.
For the purpose of this paper, the terminated state is the one in which the alarm has been sent and the oven has been turned off (Figure 5).
The reward function is described in Figure 6. The agent earns a reward equal to one when it reaches the terminated state, zero otherwise. At the end of the training process, the agent knows how to reach the safe state from any possible states.
The training of the agent follows the algorithm in Figure 2. The number of episodes is set at 100. An episode means a sequence of states, actions, and rewards, which ends with the terminal state.
Figure 7 show the evolution of the training process, it is possible to note that at the beginning of training the number of necessary actions to reach the terminated state is high, the agent explores a huge number of actions and state before reaching the terminated state.

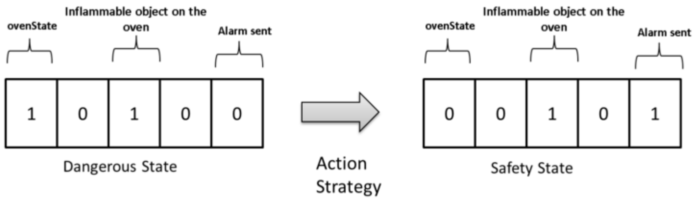

Figure 5. Transition from Danger State to Safety State

$$R(s,a): \begin{cases} r=1, & s=\text{terminated state} \\ R=0, & s!=\text{terminated state} \end{cases}$$

Figure 6. Reward Function

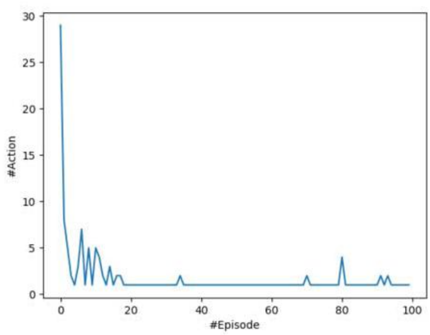

Figure 7. Evolution of the Training Performance

As long as the agent learns the number of actions to get the goal reduces, this means that the agent has been learning episode-by-episode.
The total amount of time for the training counts few minutes cause for three reasons:

- the environment is not too much complex, due to that the space of the states is small and the exploration of the states is quickly
- the staring states for each episode are those in which is detected a dangerous situation as in Figure 1
- these are only one safe situation to reach

In the novel experiments, we are investing on this points to make the learning more complex e deeper.

4. Results

The Q-function can be described as a table, named *Q-table* (Figure 8). Basically, the Q-table embodies the *knowledge* that the agent has learned after the training. The rows of the table figure all states that the agent has reached during the training, the column is

State	switch_on_oven	switch_off_oven	send_alarm	switch_on_fridge	switch_off_fridge
10100	0.000000	0.000000	0.000000	0.000000	0.000000
00100	0.000000	0.000000	0.000000	0.000000	0.000000
01100	0.000000	0.000000	0.000000	0.000000	0.000000
01101	0.000000	0.000000	0.000000	0.000000	0.000000
00101	0.000000	0.000000	0.000000	0.000000	0.000000
11100	0.000000	0.000000	0.000000	0.000000	0.000000

Figure 8. Q-Table at Beginning of Training

State	switch_on_oven	switch_off_oven	send_alarm	switch_on_fridge	switch_off_fridge
10100	0.000000	0.109661	0.000000	0.000000	0.000000
00100	0.000000	0.063529	0.833228	0.012283	0.000000
01100	0.000000	0.012283	0.000000	0.000000	0.203358
01101	0.000000	0.000000	0.000000	0.000000	0.100000
00101	0.008056	0.227600	0.999823	0.012096	0.119946
11100	0.000000	0.000000	0.000000	0.000000	0.000000

Figure 9. Q-Table at End of Training

all the available actions. Each component of the table (s_i, a_j), represents the reward that the agent will earn doing the action a_j in the state s_i.
The Q-table figures the reward for each action in a given state, at the beginning of the training, the Q-table is empty (Figure 8) in accordance with the hypothesis that the Q-leaning is a free-model algorithm. Using its knowledge the agent is able to reach the terminated state from any given one.
The number of the states depend on the training, the longer and more complex the training is, the bigger is the set of the states.
In the testing stage, we have asked the agent how to reach a safe situation starting from the state $s_a \equiv [1,1,1,0,0]$, where s_a describes a dangerous situation in which an inflammable object is in contact on an oven, the oven is turned on and the fridge is turned on.
The latter entity (the status of the fridge) does not influence the agent that provides as planning strategy S: [*send alarm, switch off oven*] which brings the agent to reach the terminated state so a safety situation.
Another test has been made by asking the agent to reach a safe situation from the state $s_a \equiv [1,0,1,0,1]$, in which the alarm has already been sent but the oven is still turned on. The agent got the strategy S: [*switch off oven*].
These tests demonstrate that the agent is able to provide different recovery strategies from dangerous situations.
In our scenario, the actions do not interact with a real device cause we use a simulated scenario.

5. Conclusion

In this work, we have presented the preliminary results of a reinforcement-learning based approach to address dangerous situations in AAL System. The main issue that we are addressing consigning the automatically definition of a strategy to restore a safety situation when a dangerous one has been detected. The state-of-the-art adopts fixed strategy defined at design-time instep we doing it at run-time. The first validation of our work has been done by training an agent to learn how to solve a specific dangerous situation.
In future work, we want to apply the proposed approach to a more complex the environments with multiple possible dangerous situations and investigate the application of deep reinforcement learning algorithm to address more complex scenario.

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Identification and Analysis of Emotions in a Game Based Therapy for Patients with Cognitive Impairment

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Abstract. In this paper, we present a proposal for emotion recognition in a game-based therapy for patients with cognitive impairment. Cognitive impairment is a problem of global scope, where therapies have been sought to mitigate their progress, a way to do it is by using computer-assisted therapy because it performs a cognitive stimulation through software with exercises (designed by specialists) to be solved by the patient. Within the computer system, we seek to analyze specific characteristics to help psychologists to define a series of exercises appropriate to the patient using computational intelligence. Additionally, we aim to include other parameters, in particular, the emotional state of the user, as it has been found that they play an important role when interacting with the software. In this research, we are using novel technologies designed by IBM, such as the TJBot and IBM Watson platform. With the help of these tools, the proposal for the detection of user emotions in human-agent interactions is being considered and preliminary experiments were performed where good results were obtained.

Keywords. Cognitive Impairment, Game Based Therapy, Affective Computing.

1. Introduction

Humans can have feelings that influence behavior, which is in a short period and they are named as emotions [1,2]. As a consequence, all the time, people reflect emotions in different activities that they perform. Knowing the influence of emotions on people's behavior [1], the analysis of emotions may be essential to understanding how an individual feels at a particular moment through the identification of emotion, for this research, it will focus on the identification of emotion in a computer-assisted therapy environment.

Computer-assisted therapy has been integrated into the treatment of different diseases in the area of mental health [3]. The application of this type of therapy has also

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been carried out in specific diseases such as depression [4] and cognitive impairment [5]. The therapies mentioned above have different implementations, and distinct objectives have been carried out, however, an element that has not been reported in these therapies is if an analysis of the patient's emotion about the therapy was reported.

For this research, we analyzed the model described in paper [5], where the patients who review the therapy are people suffering from cognitive impairment, therefore, they are taking a type of therapy, which is based on computer games. Since the methodology that is being used in the game-based therapy was analyzed, it is commented that there is the possibility of creating an implementation of the recognition of emotions. For this case, we create a proposal that is made with different tools, where information is obtained of the process of emotion recognition that a patient presents in an environment in which the execution of systems participates in the form of interactive software with the user. The aim is to use the extracted characteristics to create a model based on emotions and create a play environment that it will be successful because play environment is a critical factor in the process of playing [6] that the user feels comfortable with what is being done and the system tries to avoid user's frustration. Although the basis for this proposal is the affective computing, the development of research is working with human-agent interaction and sentiment analysis that are related, as seen in [7].

The paper is structured as follows: in section 2, background presents the topics and tools that are being used for emotion recognition and game-based therapy for patients with cognitive disorder. Section 3 presents our proposed methodology for the identification of emotion and how it is used in the game based therapy. Section 4 presents preliminar results obtained from different conversations and TJBot. Finally, section 5 shows conclusions and considers directions for future work.

2. Background

2.1. Cognitive Impairment

Cognitive impairment is the loss of the ability to process thought [8], this deterioration is a characteristic for a more general illness, which is known as dementia. The World Health Organization (WHO) explains that dementia is a syndrome that results in deterioration of memory, intellect, behavior, and ability to perform activities daily [8].

Dementia is developed, in a more substantial number, by older adults, but this does not mean that it is a consequence of aging, its cause comes from different diseases and injuries that affect the brain, examples are a stroke or Alzheimer's disease [8]. WHO data [8] indicates that about 47 million people are suffering from the disease and approximately, 10 million new cases are detected each year, where Alzheimer's disease is the most common, having between 60 and 70% of the cases. As mentioned previously, the vulnerable group for the disease is the older adults, therefore it is one of the leading causes of disability and depends on this group worldwide [8].

Dementia does not have a cure. Instead, some interventions can be offered to support and to improve the lives of people with dementia, their caregivers and families [8]. In the research, we are working with Computer-Assisted Therapy, in [9] is defined the use of computer programs and computational tools to assist in the alleviation of diseases or symptoms, this includes the possibility of improving the efficiency of primary treatment.

2.2. Emotion and Affective Computing

In the paper [10], explains that emotion plays a vital role in daily life, influencing decisions, reasoning, and attention. It is also associated with the quality of life, the well-being of people and the effects on immune system.

Physiological measures have been used by psychologists to distinguish some human emotions[6], but this research has worked with computational tools that are based on psycholinguistic, it can be found in a research field to analyze the psychological and neurobiological causes that allow humans to obtain, to use, to understand and to elaborate language [2].

The purpose of psycholinguistics is to understand words and their construction to reflect personalities and emotions [2]. Once the obtaining of the emotional information is understood, now the objective of having this information must be understood.

Affective computing is based on emotion as a factor in influencing the way of computers are used. Therefore, it is defined as the study and creation of systems and artifacts that can be recognized, interpreted, processed or stimulated by human emotions [11].

This research seeks to integrate the affective computing to the game based therapy of patients who have cognitive impairment, to know if emotion is a variable to consider when generating appropriate exercises for a specific user.

2.3. TJBot

TJBot is a project to program a robot that uses the services offered by IBM Watson's platform. In the post [12], explains that the robot can be built of different components such as a cardboard cutout to make the body, a Raspberry Pi to code the functionality and to perform the different processes that are required. Other components can be added to improve its features are an RGB LED light, a microphone, a servo motor or a camera. TJBot has different applications, such as responding to emotions and using the voice to control it or to chat with it, as explained in the post [12].

2.4. IBM Watson

IBM Watson started a deep natural language processing system. It achieves accuracy by attempting to assess as much context as possible. Its objective was based on achieving accuracy trying to evaluate as much context as possible when processing information that is not structured, but that is related to a subject of prior knowledge [13].

The system is evolving into a tool in the form of a collection of services that use analysis for language, speech, vision and data information to develop applications. Each Watson service works with an API for its interaction [2].

2.5. Tone Analyzer

An essential issue in the paper is the identification of emotions of a user, the IBM Watson platform has a service that performs, called Tone Analyzer. In the article [2], explains that the service serves to infer emotions of a given text and to use linguistic analysis to detect three types of tones giving a written text, these are emotions, social trends and writing style.

The service identifies specific emotions such as Anger, Fear, Joy, Sadness, and Disgust. In the case of social trends, personality traits are identified using the Big Five model, this model focuses on five dimensions that are Affability, Consciousness, Extraversion, Neuroticism and Openness, each of these dimensions is explained in the article [2]. On the subject of writing style, the service identifies three different forms that are Confident, Analytical and Tentative.

It is important to know that features such as n-grams, punctuation, emoticons, curse words, greeting words and polarity of feeling are incorporated into the machine learning algorithms to classify emotion categories [2].

2.6. Measuring the quality of Tone Analyzer

In the emotion recognition tool, is relevant to know what is its precision for the detection of emotions, in the documentation [14] is explained that its service is based on different papers. Some papers of them are related to affective text and different models that some researchers have developed to perform classifiers of emotions detection through text analysis. For example, the test in this papers [15,16] work with databases, such as ISEAR and SemEval, where they are different texts that have been classified into defined emotions.

In the post [17], IBM describes a series of improvements in its service that makes its performance improve against the models that are handled in the area. These improvements are expansion in the training data, new feature selection process, different classifiers, improved lexicon support and expanded support for emoticons, emojis, and slang.

3. Methodology

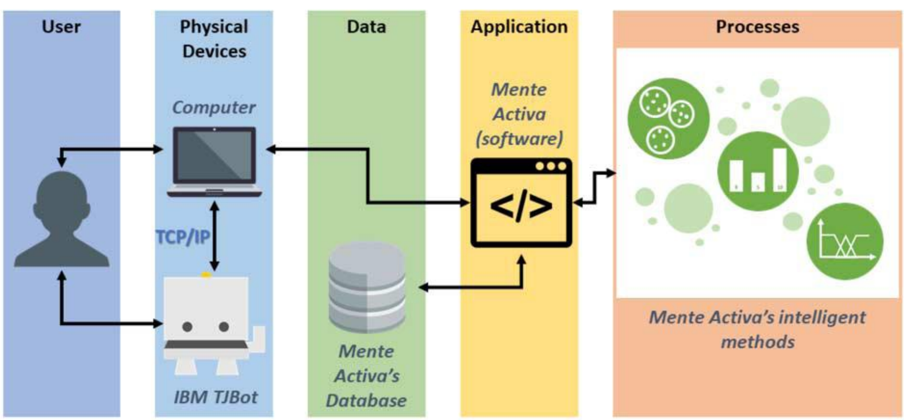

Figure 1. Block diagram showing interaction in a game based therapy implementing the TJBot robot.

As explained above, a methodology has been developed to generate an interaction between a patient and the environment of game-based therapy, in figure 1 a representation is made of user interaction with the game system and the robot that will identify the emotions, we will give a detailed explanation below.

Currently, a patient performs different exercises in therapy, through a computer, it which uses a program called ”Mente Activa”, this program works at the prevention, detection, evaluation, and monitoring of patients with dementia and cognitive impairment [5]. The program purpose is that the user benefits from a cognitive stimulation through interaction with games, showing an evaluation of their performance to the psychologists and they can suggest a new series of exercises appropriate to the patient. The process is a way to help suggest the selection of exercises, and it has been through some techniques of computational intelligence, as explained in [9].

On the other hand, in emotion recognition, it has been proposed to perform an interaction between a patient and a robot, in this case, it is TJBot, with the objective that the user can interact with the robot through a conversation. In the figure 2 can be seen that interaction is made between the robot and the IBM Watson platform, where at first, the user establishes a communication with the robot. The robot is communicating with the servers from IBM to work with the IBM Watson platform, also within this platform, different services are being used simultaneously, then each of them will be explained.

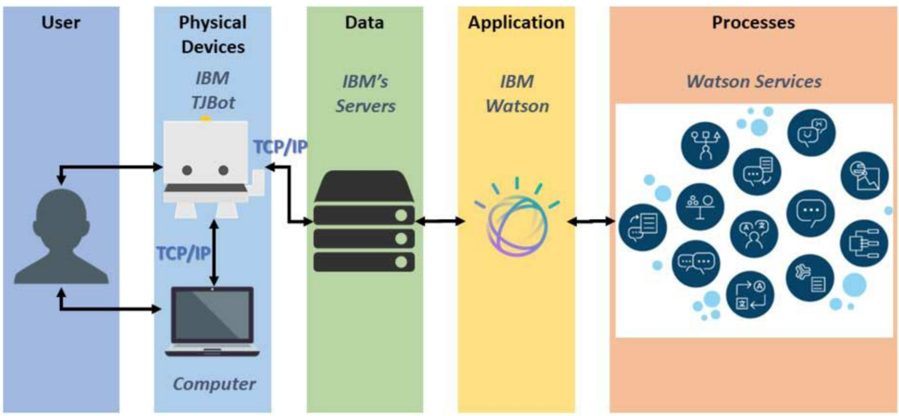

Figure 2. Block diagram showing interaction between user and IBM Watson platform.

In this proposal, the ”Speech to Text” service is used to receive the voice of a user and transcribe to text. The second service is the ”Language Translator”, this is to receive the text in one language and to translate it in another, it is important to clarify that we have to use this service because we are working on the implementation of a language that users in our area can use.

A third service is ”Conversation”, this is to create the dialogue that the robot will talk to the user, to obtain text for analysis with the ”Tone Analyzer” service, it has been explained previously. Finally, the ”Text to Speech” service is used, which creates the sound from the text, where the robot will give a response to the patient when they are in the conversation.

The flow of the data is described as a communication from the robot to the IBM server, which in turn communicates with the IBM Watson service and this performs processing that results in a response depending on the service used. That is why it can be said that IBM Watson services create a human-agent interaction between the patient and TJBot.

In the next section, the experiments that were performed to test the implementation of the interaction between a patient and the robot and the analysis that has been obtained will be described.

4. Experiments and results

The experiments aim to see how efficient the integration is with the different services that several users used for the identification and analysis of the emotion shown.

In the research to test is necessary to apply the proposal because the purpose of the test is to evaluate a human-agent interaction integrating sentiment analysis and to analyze the results obtained. A conversation was made with TJBot where the user is asked to talk about it. Once the user has talked with the robot, it will ask a question about how the user feels, and it will wait for the user to answer, then the robot gives a response depending on the emotion that has the better score, or it can say that this has not found an emotion.

In the first experiment, different people performed the tests who are not patients detected with dementia or cognitive impairment. The group for the test was men and women with age around 21 to 29 years, where they were asked to speak with the robot using the word "robot" to get the attention of the robot and so the robot would respond to the conversation. The information about the emotion recognition through the text was collected using speech recognition and using translation Spanish to English, and the results are shown in the table 1.

The table 1 organizes the tests in the following way. First, the transcription obtained by the service "Speech to Text" is written. Then, in the next column the translation made by the service "Language Translator" is shown. Finally, the following five columns show the scores obtained from each emotion, from the statement analyzed by the service "Tone Analyzer ".

In the scores, the cells were painted in different colors to indicate essential aspects. The green color means that the best score of one emotion has a significant difference to the other emotions, but it does not achieve more than 0.50, which would indicate relevance about the presence of the emotion in the statement. The yellow color represents that the scores of emotion with other emotions are close values. While the color blue is a score with more than 0.50 and this score indicates that the value of the emotion is separable from the others and has a presence in the statement.

From the results, in this first experiment, it is suggested that most of the phrases are given belonging to emotion with more presence than the other emotions available in the service. Therefore we observed that there are texts that share the highest score, more than one emotion but we can also visualize that the values tell us that they do not have enough presence in the text. Therefore we could be sure that the text is not showing adequate information to classify it.

If a more in-depth analysis is carried out, it can be seen that the services of the IBM Watson platform have some errors and limitations for the transcription of the text, as well as the translation from Spanish into English. These results are important because although there are limitations that have been explained in other paper [7], it is expected to be a start to the collection of emotions through the sentiment analysis using the voice of the user. Therefore some test could be performed in the future to contrast if the emotion obtained through the voice can get similar emotions if it will be done in writing or directly using phrases in the English language.

Original sentence	Translated sentence	Anger	Disgust	Fear	Joy	Sadness
"Tengo muchas cosas por hacer el día de hoy y no quiero terminar las"	"I have many things to do today and I don't want to end"	0.1140	0.0629	0.2168	0.2099	**0.4155**
"Me encuentro presionados porque aún no tengo nada de mi proyecto"	"I am pressured because I am not yet nothing my project "	0.0245	0.0191	**0.5472**	0.0162	0.3289
"Me ciento vienen general aún que tengo mucho trabajo por hacer"	"I percent are generally still have much work to be done"	0.0527	0.0122	0.0953	0.1136	**0.4633**
"Aturdida porque me dieron muchos regalos en mi cumpleaños"	"Dazed because I gave many gifts in my birthday"	0.0203	0.0067	0.0129	**0.8159**	0.1248
"Estoy cansada y quiero un café porque tengo mucho trabajo"	"I am tired and I want a coffee because I have a lot of work"	0.2440	0.0479	0.2054	0.1154	**0.5735**
"Me siento bien salía a correr por la mañana con un amigo"	"I feel good to be out in the morning with a friend"	0.0155	0.0045	0.0230	**0.8919**	0.0532
"En estos momentos me siento muy extasiado"	"Now I am very ecstatic"	0	0	0	**0.8804**	0
"Mi amigo me dijo mentiras el día de hoy"	"My friend told me lies today"	**0.4211**	0.1291	0.0829	0.1359	**0.4091**
"Acabo de escuchar un ruido muy extraño"	"I heard a very strange noise"	0.3057	0.0398	**0.6217**	0.0198	0.0912
"Hola no quiero hablar contigo robot"	"Hello I do not speak with robot"	**0.1036**	0.0397	**0.1121**	**0.1449**	**0.1107**
"Me siento muy activo el día de hoy"	"I am very active today"	0.0450	0.00343	**0.1211**	**0.1063**	**0.1298**
"Tengo sueño estoy muy muy cansada"	"I dream I am very very tired"	0.2048	0.0079	0.1778	0.0633	**0.7347**
"Extraño mucho a mis abuelos"	"Very strange to my grandparents"	0.0520	0.0131	0.2460	**0.5377**	0.1147
"Mi novio me hizo sentir mal"	"My boyfriend made me feel bad"	0.1042	0.1349	0.2014	0.0501	**0.7536**
"Me siento muy feliz robot"	"I am very happy robot"	0.0038	0.0033	0.0060	**0.8780**	0.0088

Table 1. Showing sentences from the users and the emotions detected.

After analyzing the results of the previous experiment, a new experiment was conducted where information was investigated from a group of users of similar age to the vulnerable group suffering from cognitive impairment. As a result of research, we found a paper [18] where the authors comment that they performed an analysis of the dimension emotional to a group of older adults with characteristics similar to what we are looking for, with the difference that these people had favorable mental conditions. We considered this information would be necessary to take the phrases that these people said in the paper and see how psychologists categorized those emotions against what the analysis of the IBM Watson service can throw off.

In this case, we tried to implement the conditions of the previous experiment, where the sentences were taken from paper [18] and used in a conversation with the robot for the IBM Watson platform to create the transcription and then the translation. The results of this experiment can be visualized in table 2.

Original sentence	Translated sentence	Classified as	Anger	Disgust	Fear	Joy	Sadness
"Intranquila a veces me canso año pensando pero no digo nada para no preocuparte de eso"	"Sometimes I get tired restive year thinking but not saying anything to not worry about it"	compassion	0.1095	0.0374	0.1298	0.0968	**0.7747**
"Moralmente pues ayer veces a ratos en que me ataca la tristeza porque recuerdo todos los momentos en que trabajaba y yo me sentía agusto"	"Morally because sometimes I spend yesterday attacked the sadness because I remember all the times when he worked and I felt August"	sadness and depression	0.0715	0.0306	0.2350	0.0295	**0.8286**
"Me da miedo que llegue la noche y a veces me da miedo miedo a lo que será de mí a veces me da miedo y yo"	"I am afraid that it night and sometimes gives me fear fear of what will be me sometimes gives me fear and I"	anxiety and fear	0.0063	0.0067	**0.9538**	0.0155	0.0411
"Me siento con ganas de morirme para no seguir dando de raya tando molestia"	"I am willing to die for not continue to trouble both bay"	guilt	0.1245	0.0141	0.2358	0.0488	**0.7847**
"Que tener uno poder querer hacer las cosas y que ya no poder alcanzar o no algo que necesita nada me dan pena"	"Having one power to do things that no longer able to achieve or not something you need anything give me penalty"	shame	0.1136	0.0593	0.1680	**0.2704**	**0.3037**

Table 2. Showing sentences from phrases of old people and the emotions detected.

An analysis of the results in table 2 shows us that most of the sentences expressing an emotion represented as a score of presence in a text, the results in bold type show which was the emotion of greater punctuation that obtained for the phrase. In the last example, "Tone Analyzer" was not able to identify the emotion because emotion values are not significant in the text. It is important to mention that for this second experiment, the same limitations as in the first evaluation regarding the transcription and translation of the information were observed. It can also be analyzed that the authors of the paper [18] handle a better number of different emotions to classify the information and it can be suggested that the sentiment analysis service classified the phrase to an emotion close to what the psychologists are classifying.

5. Conclusions and future work

In this paper, we presented a proposal for the identification and analysis of emotional information in users participating in a game-based therapy environment. In order to facilitate the interaction between the human and the computer system, we used an open source robot designed by IBM, call TJBot. TJBot helps to obtain the user emotions while playing the game, via voice dialogs.

The proposal is managing the use of a human-agent interaction, as well as the use of software that is based on computational intelligence models for text analysis.

Preliminary experiments were performed in order to compare the results of IBM Watson and a database previously analyzed by psychologists, with good results as most of the sentences were identified successfully.

As future work, we are planning to develop a fuzzy logic model in order to integrate the emotional information in the game-based therapy. This is a work in progress project, and we hope to report our results in future conferences.

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Towards an Innovative Architecture to Monitor and Handle Emotions in Work Scenarios

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Abstract. Stress and sadness are some of the factors that affect the quality of life of people. Inadequate attention to health and safety regulations at work causes about 2 million work-related deaths annually. In this paper, we propose a novel architecture able to monitor the emotional state of the user and allow personalized feedback through a smart music player application. There are research initiatives aiming to predict, detect and intervene when dangerous conditions are found, although there is little research focused on obtaining and processing emotional information obtained from social networks. The architecture proposed can detect and handle the emotional state of the user and offer personalized music therapy to improve their mood. The emotional state is detected analyzing the tweets from the user, and the IBM Tone Analyzer is used as a tool for processing the information. Preliminary experiments were performed with encouraging results.

Keywords. Affective Computing; Twitter; Burnout; Stress; Alzheimer's Disease; Primary Caregivers; Emotions; Feelings; IBM Watson.

1. INTRODUCTION

Stress, fear, and sadness are some factors that occur in school, work or home, affect the quality of life of people, and the inadequate care causes about 2 million deaths, 271 million accidents and 160 illnesses caused annually by poor care [16].

Several studies have focused on to treating stress factor conditions at work. Rodriguez [18] obtained recordings of patients with Alzheimer Disease (AD) and used the software PRAT to locate pauses in the speech. Marconato [14] applied music therapy individually, showing a decrease in stress levels. Pedrazzani [12] explained how AD patients indicate a lower quality of life. Ashis [8] processed non-verbal gestures searching for a pattern behavior before a state of frustration. Using musical sessions, Lone and Blasi [3] in an isolation area with musical sessions with a 30-40 min. Showing chosen correctly, the music can stimulate the hypothalamus so that it releases endorphin and works as a beneficial sedative duration and Cyril [5] selected and classified the emotion of the songs. Picard [5] shows that textually or verbally,

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emotions are more precise than when they have to be recognized facially by another person.

Marconato in 2001[14] Proved that music therapy shows a decrease in the level of stress, although to improve the results musical preferences could be added. Picard en 2009 [9] seeking to predict when a person will be frustrated, suggest that there is valuable nonverbal information to predict when to intervene, for what textual information can also be used to know the current state of the person. The study of Lone and Blasi [3], although limited to the time and place where the musical sessions took place, shows points that can be used to improve the musical therapy by saying that each person reacts differently to the music, depending on the tastes, so they should use and respect the tastes of the listeners. Cyril and Herrera [5] show that information relevant to the classification of music based on emotions is the lyrics of the song. Having a dataset of classified music can be used to offer music that best suits the emotional state of the person, improving the results of the therapy.

We propose a novel architecture for an intelligent application of music reproduction using the Affective Computing approach [18] [20] as an enabler for the design of machines that can recognize, express and communicate emotions. Our architecture uses the micro blogging platform Tweeter and the Fuzzy Logic paradigm in order to deal with imprecise information that combines rules and define actions producing one or several output values [35]. We present preliminary results of text classification performance between IBM Tone Analyzer and SemEval data base.

The paper is organized as follows. In Section II, we provide basic definitions for the proposed project and discuss current works on stress, quality of life, music therapy and affective computing. In section III, the components of the proposed architecture are explained and in the preliminary results section, textual analysis and correlation are made between the text classification results made by semEval and Watson. Finally, in section IV we show the results obtained from the comparisons of the classifications made with Watson and SemEval.

2. BACKGROUND

In this section, we explain the terms overload of work, stress, quality of life, burnout and primary caregiver. We also define the levels of integration, understanding, generation, and platform of the taxonomy proposed by Schwark [20]. We also explain the difference between emotions and feelings using the taxonomy of the levels of homeostatic regulation proposed by [33].

2.1 Affective computing

Affective computing is the topic concerning the design of emotionally intelligent machines that can recognize, express and communicate emotions and respond to humans using emotions. The goal of affective computing is to use positive, affective communication found in human interaction and apply it to human-computer interaction [20].

The principles of affective computing lie within the field of human factors in the topic of human-computer interaction and the finding that humans interact socially with computers and machines, similar to how humans communicate with other humans. Based on this notion, it is likely that this interaction can be improved using the principles that govern human-human interaction [20] Although it is likely that we are far from a computer to feel emotions like humans, Picard says: "affective computers need only express emotions, not feel them"[17] The affective computation according to is organized as follows:

Affective understanding: A computer can understand the affective state of the user.
Affective generation: the ability of a computer to create an emotional response that ultimately seems genuine and has a positive impact on the user.
Application: involves research on which areas the affective computation can be used and which facets of the task should be improved [20].

2.2 IBM Tone Analyzer

Tone Analyzer is a service part of IBM Watson, which uses linguistic analysis to detect emotional and language tones in written text [25].

2.3 Work Overload, stress and quality of life

Overload is the psychological result of emotional, physical and social combinations that arise when caring for a sick person, especially if it is Alzheimer's [1].

The work overload related to the care of older adults is defined as "a concept of multiple dimensions where stress, negative feelings or difficulties that originate the care of an elderly person appear, and includes aspects of physical health, emotional, social and financial " [15]

Stress is the adaptive reaction of the organism to the demands of its environment. The workload is defined as the amount of physical and mental work that a person can perform. Psychological workload refers to the total load of information that a worker must perceive and interpret when performing his activities [33].

The physical workload refers to the increase or excess of activities that require physical effort [16] and occurs when the worker perceives that work demands exceed their abilities and resources to fulfill their work obligations in a successful manner and a set period.

The burnout syndrome is defined as a state of physical, emotional, and mental exhaustion as a result of the worker being exposed for long periods of time to multiple demands at work is the lack of capacity of the worker to face the labor or personal requirements, a syndrome of emotional exhaustion and cynicism that frequently occurs among individuals who perform their work in contact with people. The central aspects of burnout are: Emotional tiredness is the increased feelings of emotional exhaustion in the face of the demands of work, so workers do not feel any attraction. When these resources are exhausted, the worker perceives that he is not able to face labor demands [16].

Dementia is one of the most demanding problems of the 21st century. It is expected that by 2030 there will be 63 million people with dementia in the world [6]. Alzheimer's is a type of senile dementia, with progressive and irreversible cognitive decline and multiple cognitive deficits, one of which is the memory, sufficiently intense to have an impact on daily life. [6].

Given the complexity of the symptoms and the progressive nature of this type of disease, the affected person comes to require another that attends and accompanies, and that assumes the main tasks of care. This last person is the primary caregiver, and she must have carried out her work for at least three months to identify her in this role.

The primary caregiver can be informal, that is, a person who is not a health professional, and most of the time does not receive remuneration for performing this activity belongs to the family network of the patient, although it can also be a neighbor or friend of the dependent person [1].

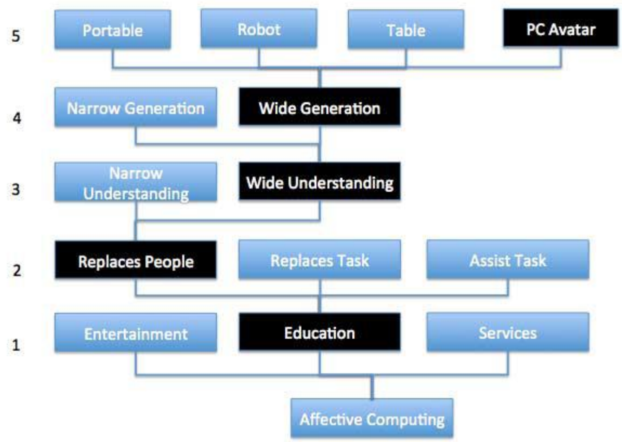

Figure 1. Taxonomy of affective computing in use. Adapted from Schwark [20].

2.4 *Affective computing taxonomy*

The taxonomy of the affective computer was proposed initially by Schwark [20]. This taxonomy contains five levels: Platform, Affective Generation, Affective Understanding, Level of Integration and Purpose. They are levels where decisions must take place for any affective computer system that will be implemented in society.

At the Goal level, the purpose of the system must be defined. Determining the essential purpose is a critical first step in the design of the system because all other decisions about the system must take into account the goal of the system.

At the integration level, one must decide how to integrate the system into society.

In the stage of affective understanding, the level of affection that the system will understand is decided.

The level of affective generation specifies how much affect the system needs to communicate with users.

In the last level, it is decided on which platform the system will be developed. If you are going to be a virtual tutor on a PC or a robotic structure.

In figure 1 a sample of affective computing in use is shown. The selected affective computing application is an educational tutor that is designed to replace people, possess a full understanding and ability to generate affect, and is best represented as a PC avatar platform due to the affective needs of this system [20].

Figure 2. Taxonomy of affective computing. Adapted from Schwark [20].

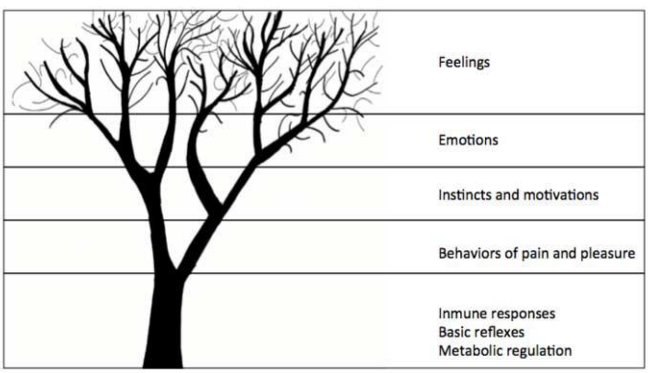

Figure 3. Levels of automated homeostatic regulation, from the simple to the complex. Adapted from [34].

To remove ambiguity in the terms feelings and emotions: the levels of homeostatic regulation, differentiating one from the other as follows: Emotions are actions or movements, many of them public, visible to others because they are produced in the face, voice, in specific behaviors. Some components of the emotion process are not visible to the naked eye, although they can be made visible through hormone test and wave patterns electrophysiological. The feelings are always hidden; invisible to all who are not their legitimate owner, because they are the most private property of the organism in whose brain it takes place. Having these explanations, we will manage the emotions of the people who visibly express through tweeter and the therapy that we offer will modify the emotions and feelings. [34]

3. ARCHITECTURE

In this section, we explain the MP3 player, user, Tweeter, Analysis and classification modules and the fuzzy logic module, the main component of our architecture (see Figure 4).

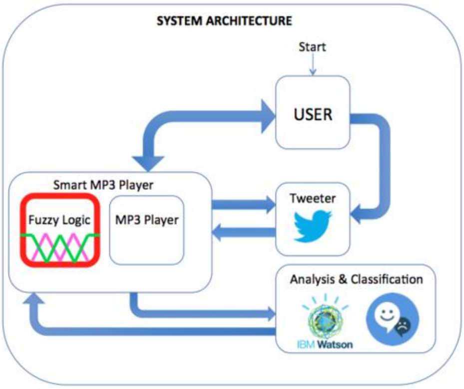

Figure 4. Smart MP3 player architecture.

User: The user is the caregiver subject of heavy workload during the day.

Twitter: form of communication in which users can describe their current status in small publications by instant messages, mobile phones, etc. Tweets are sent to the Tone Analyzer service for mood classification.

Analysis and classification: In this module, we obtain user's tweets, analyze the text using Tone Analyzer and obtain the feeling detected in the text. We are considering the use of Tone Analyzer (part of the IBM Watson) as a reliable and mature tool to process and classify in real time the information generated by the user.

Smart MP3 Player: It has 2 modules, the MP3 player and the fuzzy logic module, which is the central part of our proposed architecture. The design of fuzzy logic module is not considered in future work and is not included in this paper.

The fuzzy logic module is responsible for asking and receiving the tweets made by the user and then send them to Tone Analyzer, be classified based on emotions and get the response, which will be received as a parameter to design the personalized playlist based on emotion perceived in the Tweets. With the fuzzy logic module disabled, the music player works like a regular music player application.

4. PRELIMINARY RESULTS

In this section, we show the tests to evaluate the reliability of the classification made with Tone Analyzer.

To evaluate the reliability of Tone Analyzer, 5 headings were randomly taken from the trial.tar.gz file[2], and the classifications made with Tone Analyzer were obtained.

The textual analysis is shown in table 1. In the first column, the text to be classified is shown, the second column shows the classification made by semEval and the third column shows the rating made by Tone Analyzer. Table 2 shows a more in-depth comparison making the correlation of 996 classifications between both classifiers.

Tone Analyzer API version 2016-05-19 only returns a response if any of the emotions measured are higher than .5 so there are cases in which there seems to be no response, and it is because the percentage is lower than .5.

	SemEval					Tone Analyzer				
Text	Anger	Disgust	Fear	Joy	Sadness	Anger	Disgust	Fear	Joy	Sadness
1. Nigeria hostage feared dead is freed.	.18	0	.52	**.66**	.20	0	0	**0.96**	0	0
2. Sony Hates Europeans, Will Prevent The Importing of PS3	**.34**	.8	**0**	0	0	**.64**	0	0	0	0
3. Happy birthday, iPod	0	0	0	**.71**	0	0	0	0	**.91**	0
4. Bad reasons to be good	**.9**	.3	0	.15	.25	0	0	0	0	**.70**
5. Parachutist dies at bridge-jump festival classes	.6	.6	.33	.6	**.88**	0	0	0	0	**.78**

Figure 5. Comparison between semEval and Watson classification.

Watson does not have the surprise emotion, so, for an equivalent analysis, the value corresponding to surprise has been suppressed in column 2. As a summary of the textual analysis of the statements we have the following:

a) In SemEval, Joy is the second highest ranking, followed by fear. In Tone Analyzer Fear is the predominant Emotion.
There is .4 difference between each classifier. The Watson classification is higher.
b) Anger are highest rankings in both.
c) The most predominant is joy with .71 and .91 by SemEval and Watson respectively.
d) The Anger is the most dominant feeling in the two classifications with .9 with SemEval and .70 of sadness with Watson.
e) The two classifications are very similar with sadness assigning .88 and .78 SemEval and Watson respectively.

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[2] http://nlp.cs.swarthmore.edu/semeval/tasks/task14/data.shtml

The results of the correlation between SemEval and Tone Analyzer are shown in table 2.

Table 1. Correlation between SemEval and Tone Analyzer classifications.

Anger	Disgust	Fear	Joy	Sadness
.3957	.2009	.2012	-.2994	.2437
.3423	.5194	.0566	-.2195	.1333
.1863	.0039	.5497	-.2169	.1801
-.3670	-.2459	-.3633	.4743	-.3720
.0780	-.0025	.1186	.2891	.4780

Each element in table 3 contains the p-values corresponding to table 2 matrix to test the hypothesis of non-correlation against the alternative hypothesis of a non-zero correlation accepting that there is a relationship between emotions classified in semEval with emotions classified with Tone analyzer.

Table 2. P-values.

Anger	Disgust	Fear	Joy	Sadness
.0000	0.0000	.0000	.0000	.0000
.0000	0.0000	.0744	.0000	.0000
.0000	0.9012	.0000	.0000	.0000
.0000	0.0000	.0000	.0000	.0000
.0138	0.9368	.0002	.0000	.0000

Table 3. Classification of results in relationship index.

Emotion	Rank	Interpretation
Anger	.3957	Weak
Disgust	.5194	Between moderate and strong
Fear	.5497	Between moderate and strong
Joy	.4743	Weak
Sadness	.4780	Weak

5. CONCLUSIONS AND FUTURE WORK

In this paper we presented a novel architecture for processing and analyzing real-time feeds in social networks (Tweeter). This architecture aims to provide personalized music based therapy to reduce stress.

The correlation shows a weak interpretation of Anger, Happiness, Sadness and a moderate to strong interpretation for Disgust and Fear. this may be due to the time between the creation of semEval in 2007 and the query in the tone analyzer in 2018. Textual analysis shows a similarity between the responses of both classifiers giving both classifiers the highest ranking for the same emotion.

This is a work in progress, but our results are encouraging. The next step is to design a fuzzy logic model for processing digital information collected from the user, and provide recommendations to the smart music application module.

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INLIFE - Independent Living Support Functions for the Elderly: Technology and Pilot Overview

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Abstract. In this paper, we present the European H2020 project INLIFE (INdependent LIving support Functions for the Elderly). The project brought together 20 partners from nine countries with the goal of integrating into a common ICT platform a range of technologies intended to assist community-dwelling older people with cognitive impairment. The majority of technologies existed prior to INLIFE and a key goal was to bring them together in one place along with a number of new applications to provide a comprehensive set of services. The range of INLIFE services fell into four broad areas: Independent Living Support, Travel Support, Socialization and Communication Support and Caregiver Support. These included security applications, services to facilitate interactions with formal and informal caregivers, multilingual conversation support, web-based physical exercises, teleconsultations, and support for transport navigation. In total, over 2900 people participated in the project; they included elderly adults with cognitive impairment, informal caregivers, healthcare

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professionals, and other stakeholders. The aim of the study was to assess whether there was improvement/stabilization of cognitive/emotional/physical functioning, as well as overall well-being and quality of life of those using the INLIFE services, and to assess user acceptance of the platform and individual services. The results confirm there is a huge interest and appetite for technological services to support older adults living with cognitive impairment in the community. Different services attracted different amounts of use and evaluation with some proving extremely popular while others less so. The findings provide useful information on the ways in which older adults and their families, health and social care services and other stakeholders wish to access technological services, what sort of services they are seeking, what sort of support they need to access services, and how these services might be funded.

Keywords. active aging; elderly support systems; cognitive impairments

1. Introduction

The numbers of older people with some form of cognitive impairment are rising and will continue to do so as life expectancy increases [1]. Across Europe there is also a growing number of mainly ICT-based solutions targeting this population that have until now been developing in parallel. Harnessing these solutions and making them available at scale could help to alleviate this growing problem, by supporting older adults with cognitive impairment to remain living independently for longer.

The majority of older people with cognitive impairment want to live independently for as long as possible. New technologies can support independent living and overcome many problems that occur in daily life [2]. This means supporting people to function within and outside the home, including travel. All of these domains require further evaluation along with greater understanding of the acceptance of technical systems by older adults, and their needs and desires as customers within the European and international market. The major challenge is in providing a holistic service that can address all aspects of a person's life and the challenges posed by cognitive impairment.

Loss of cognitive functions, abilities and capacities may be further exacerbated by other age-related conditions, such as limitations of mobility, visual and hearing impairments (e.g. macular degeneration), diabetes and stroke [3]. Additionally, many older people living alone feel lonely, which is strongly related to physical or mental health [4]. Reduced social contacts and social participation may be due in part to impaired communication, which is also common in many neurological conditions. Dementia and other progressive conditions (e.g., Parkinson's disease, Huntington's disease, motor neuron disease) may interfere with communication in a number of ways including the ability to produce and comprehend speech, or to initiate, maintain and end conversations [5]. People with neurological diseases may also experience restricted vision, hearing, mobility, and motor skills, which further complicate communication and reduce opportunities for social participation. There are also frail older people who have both cognitive and communication difficulties but no formal diagnosis and therefore receive limited support.

Additionally, many people in Europe live in countries other than where they were born and where they speak different languages to their mother tongue. When these people develop cognitive and communicative difficulties, the demands on interaction partners and carers can be compounded. The growing multilingual and multicultural population of older people highlights the need for easily accessible communication tools, methods and strategies [6]. Adaptable responsive solutions are needed to tackle these cognitive, physical and social communication challenges to keep older adults participating in the social world.

Development outcomes of past projects (such as the German project insideDEM[2], the Canadian project Age Well[3], or the British project Sphere[4]) have shown the potential to deploy real ICT with pragmatic user groups (i.e. diversity in users with cognitive impairments either as the primary symptoms or as co-morbidities). ICT applications and services should be valuable for the needs of older people with cognitive problems while remaining affordable. Adopting technology is known to be very important for self-efficacy of people with cognitive impairment [7], but there currently exists a spectrum of reactions to IT from openness to adoption through to rejection or abandonment.

The INLIFE project[5], an EU H2020 project that ran from 2015 to 2018, aimed to prolong and support older adults with cognitive impairment to maintain independence through interoperable, open, personalized and seamless ICT services that support home activities, communication, health maintenance, travel, mobility and socialization, and with novel, scalable and viable business models, guided by feedback from large-scale and multi-country pilots. In this paper, we first present an overview of the project, including the system architecture, and then present the initial results of the pilots carried out within the framework of project. At the end, we discuss the findings and their implications.

2. Method

A. Participants

First, a baseline assessment was conducted with 953 users. Next, six pilot sites were established in Greece, the Netherlands, Slovenia, Spain, Sweden, and the UK. Four groups of participants were identified for INLIFE: older adults living with cognitive impairment, informal caregivers, health and social care staff, and representatives of stakeholder organizations. Each site recruited representatives of each of the four participant groups, totaling 1958.

B. Measures

All pilot sites used the EQ5D [8] and the Quality of Life in Alzheimer's Disease [9] questionnaires. Several sites also used a measure of cognitive function concordant with the measures used in local memory services, either Mini Mental State Examination [10] or Addenbrooke's Cognitive Examination III [11]. Informal caregivers also completed the Zarit Caregiver Burden Interview [12] to provide an assessment of their subjective experience of distress related to caregiving for a family member with cognitive impairment. Participants also completed a demographic and socioeconomic status questionnaire. This included questions relating to current living arrangements,

[2] http://insidedem.de/

[3] http://agewell-nce.ca/

[4] http://www.irc-sphere.ac.uk/

[5] http://www.inlife-project.eu/

education, employment status, access to healthcare, and total annual family income. At the end of the pilot phase participants completed questionnaires relating to their experience of using INLIFE during the study and their intention to use it in the future.

C. INLIFE platform

The INLIFE architecture comprises an open cloud-based platform integrating 17 services across four themes: Independent Living Support (7 services), Travel Support (3 services), Socialization and Communication Support (3 services) and Caregiver Support (4 services; see Fig. 1). The INLIFE technical infrastructure was designed to support older people with cognitive impairments in a variety of indoor and outdoor activities. This was to be achieved through monitoring user activities and preferences in an unobtrusive way. INLIFE was also designed to provide help and support to caregivers. The intention was to provide easy, transparent, personalized and contextualized access to INLIFE services and applications through a single application center.

Different tools used in the project are spread among many different devices and technologies. For example, fall detection and user activity level are recorded and recognized on a smart watch on the user's wrist. When the user is driving a car, he or she uses the dedicated application that works on an Android tablet, while socialization and cognitive assessment is facilitated by carers using a web browser on a computer. A common platform was designed in order to gather data sent across different devices, to allow user authorized access to all of the services and to allow carers different levels of access to user's data depending on their role. Furthermore, the platform analyses user's behavior and usage of the system, and through a matchmaking procedure recommends new tools for the user that might prove useful (Fig. 2). For example, active users of the travel support module might also be interested in the activity monitoring service

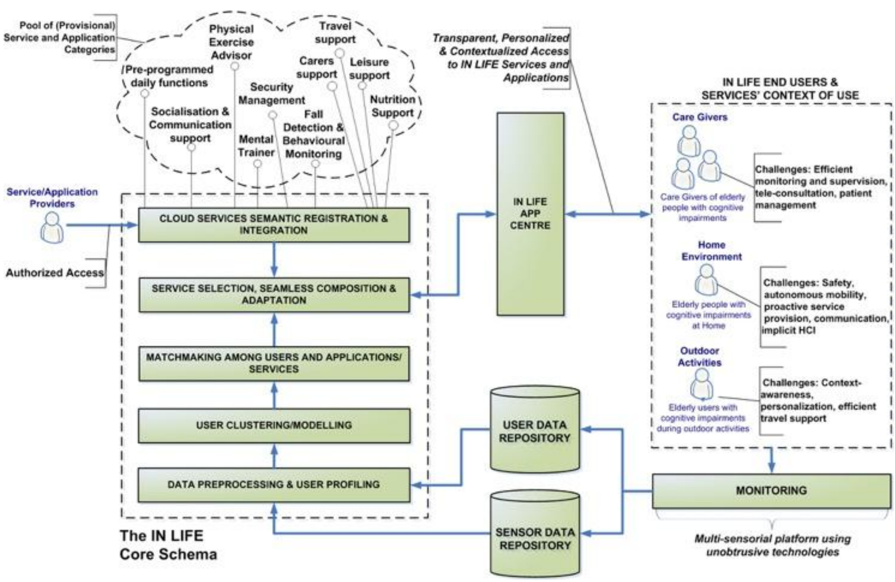

Figure 1: INLIFE conceptual architecture.

provided on a smartwatch in the fall detection module.

Most of the tools have an intermediate server for facilitating the tool at the country of use as opposed to one central server for all of the tools and services. This architecture allows better response times, lower costs for data transmission, and is more robust to a single point of failure. Furthermore, due to different legislation in each country, it is not always allowed to share or store certain data about the users outside their country of residence or where the data were collected. Servers use the REST protocol over HTTPS for communication. Depending on the type of the data, the data are anonymized, encrypted and/or only stored locally. RFC 4880 standard is used for encryption services.

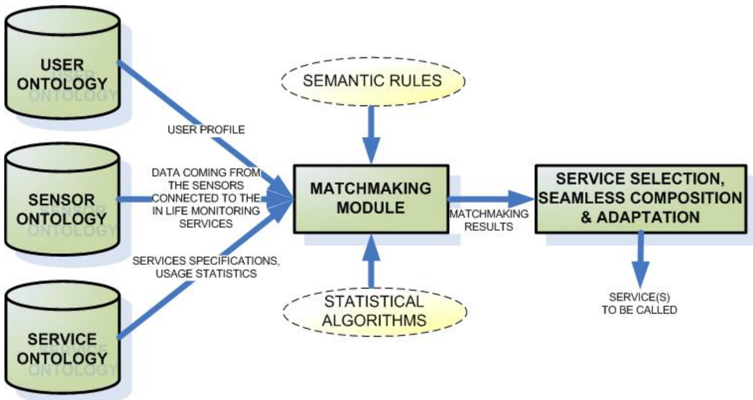

Figure 2: INLIFE service matchmaking.

D. Procedure

Participants were recruited at the six pilot sites between January 2016 and September 2017. Recruitment was conducted across a range of services including outpatient clinics, assisted or supported living facilities, and long-term care and nursing homes. Assessment was undertaken at baseline before the introduction of any INLIFE services. This comprised the formal measures and demographic questionnaires to characterize the participant groups prior to offering the INLIFE services.

The pilot phase immediately followed the baseline. Each pilot site offered a different combination of services to their participants to maximize the feedback for the wide range of services (Table 1 & Table 2) – some services, such as leisure support, were offered at several sites, while others, such as the fall detection wristwatch, were offered only at a single site. The same formal measures were repeated and after using the INLIFE services participants completed the questionnaires relating to the experience and future intentions to use.

Table 1. Services offered to people with cognitive impairment at each pilot site

Pilot site					
Greece	Driving assessment	Trip planning	Physical activity monitoring	Guardian angel	Mental training tools
NL	Web-based exercises	Health monitoring	Teleconsultation	Leisure support	
Slovenia	Fall detection wristwatch	Home security functions			
Spain	Daily functions assistant	Public transport support	Web-based exercises	Leisure support	Virtual training
Sweden	Socialization and communication support	Multilingual support	Leisure support		
UK	Leisure support	Daily functions assistant			

Table 2. Services offered to informal caregivers, healthcare professionals and stakeholders

Pilot site	Informal	Healthcare	Stakeholders
Greece	Guardian Angel Physical activity monitoring	Guardian Angel Physical activity monitoring Mental training tools	Whole INLIFE platform
NL	Patient management and monitoring	Web-based exercises Patient management and monitoring Leisure support	Web-based exercises Patient management and monitoring Teleconsultation
Slovenia	Caregiver monitoring Fall detection wristwatch	Caregiver monitoring Caregiver scheduling Fall detection wristwatch	Fall detection wristwatch Security functions Whole INLIFE platform
Spain	Daily function assistant Web-based exercising Public transport assistant Leisure support	Daily function assistant Web-based exercising Leisure support	Daily function assistant Whole INLIFE platform
Sweden	Socialization and communication support Multilingual support	Socialization and communication support Multilingual support	Socialization and communication support Multilingual support
UK	Leisure support Daily function assistant Whole INLIFE platform	Leisure support Daily function assistant Whole INLIFE platform	Leisure support Daily function assistant Whole INLIFE platform

3. Results

A. Participants with cognitive impairment

Across the six pilot sites 803 older adults living with cognitive impairment took part in the baseline assessment. They were aged 39-104 and 60% were female. One third lived with a spouse or other family member(s), with 27.5% having only primary education, 17.5% secondary education and 13% higher education. Fifty-one percent had access to government-funded health care with only 1.25% having private insurance or self-paying for healthcare.

In the pilot phase of INLIFE, data was collected from 1163 older adults with cognitive impairment. They ranged in age from 39-104 years, 60% were female and

37% lived with spouse or family. Thirty-one percent had primary, 16.6% secondary, and 16.8% higher education. A little over 1% stated they had no formal education. Fifty-one percent had access to government-funded healthcare and 7% either self-pay or private insurance. In both the baseline assessment and the pilot study, a substantial number of people provided no answer or chose not to answer, including almost one half when asking about the healthcare insurance.

B. Informal caregivers

In the baseline phase of the project, there were 140 informal caregivers. Eighty-seven percent were family members of people living with cognitive impairment and 6% were friends. Half were under 60 years of age, with a further 40% aged between 60 and 75 years of age. Sixty-five percent were female.

In the pilot phase, data were recorded from 362 informal caregivers. Eighty-two percent were family members and 2.7% were friends. Two-thirds were female, with 53% aged under 60 years of age and a further 36% aged between 60-75 years of age. Again, in both cases, some people provided no answers.

C. Healthcare professionals

Ten healthcare professionals were recruited in the baseline phase of the project. They were all nurses, aged under 60 years of age and 70% were female. In the pilot phase, data were collected from 407 healthcare professionals.

D. Stakeholders

In the pilot phase data were collected from representatives from 26 stakeholders including health and social care providers, housing, charitable sector, community services and long-term care. Fifty-eight percent were female, 46% were under 60 years of age, and 35% between 60-75 years of age.

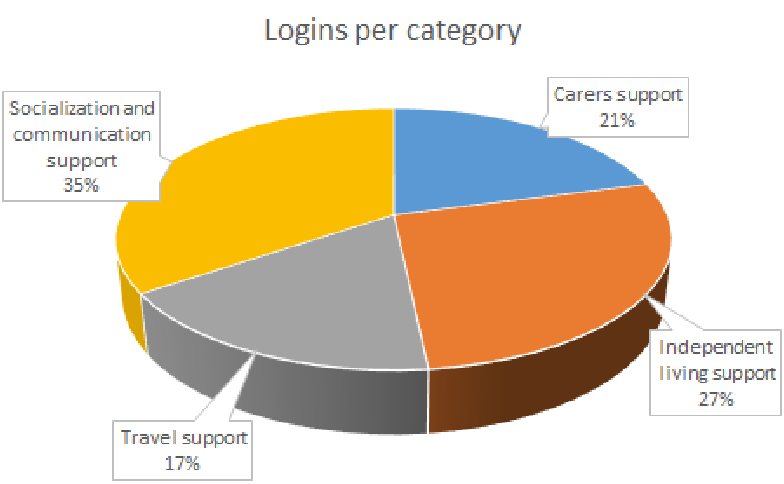

Figure 3: INLIFE application center – logins per category

E. Accessing the INLIFE platform

All 17 INLIFE services were accessed through the INLIFE application center and the percentage distribution of logins from a service belonging to a particular category are shown Fig. 3. As can be seen, the distribution across the four categories varies with Socialization and Communication Support accounting for about a third of all logins.

In respect of the end of pilot questionnaires regarding the use of the INLIFE platform, over 67% of older adults living with cognitive impairment said the system was easy to start using. Fifty six percent said they felt the INLIFE platform would increase their confidence in day-to-day activities and 53% agreed it might increase their independence. When asked about future use of INLIFE, the majority of each of the four participants groups said they would be prepared to pay for the service: older adults 57%, informal caregivers 61%, healthcare professionals 73%, and other stakeholders 50%. On the other hand, if the service were free, then 70% older adults with cognitive impairment, 100% of informal caregivers, 99% of healthcare professionals and 100% of other stakeholders would use it again.

4. Discussion

The project has recruited participants from a wide range of settings to test the integrated INLIFE platform. The analysis to date suggests firstly that older adults with cognitive impairment are interested in using technology in all aspects of their daily lives. The results show that the majority of elderly users found it rather easy to start using the INLIFE system, even though most of them did not have much technology knowledge at the start of the study. The majority of the users who indicated that they found it “difficult” or “very difficult” to use were very elderly with no technology knowledge, and/or no education, vision issues, or hand tremor. Some users did not know how to use it, had various degree of memory/cognitive decline or had experienced some kind of malfunction.

Regarding the services available, those in the support for independent living category and socialization and communication support were accessed the most. This may in part reflect the distribution of services that were tested across the pilot sites. The feedback on all four categories was generally positive with older adults feeling that the services could support their independence. All types of users appreciated the potential of the INLIFE services for supporting them in their daily lives whether this was living with cognitive impairment or caregiving. The possibilities for continuous monitoring and communication between the older adults and caregiver through INLIFE were noted. Additionally, a majority of participants in each of the four participant groups said that they would use INLIFE in the future, especially if it was freely available to them.

In respect of lessons learnt the example of the Slovenian pilot illustrates some of the practical issues of implementing the INLIFE services. The Slovenian pilot focused on testing the smartwatch-based technology for fall detection, a service offered in the Support for Independent Living category. User reaction to the technology varied. Generally, the users found wearing the smartwatch convenient as they were already used to wearing wristwatches. Users who were living independently at home - the younger and more active part of the group involved in the pilots, who can be viewed as the target demographics for the technology - embraced the watch and actively used it [13]. Some users became more active and started going out for walks or doing chores around the house, because of the renewed sense of security. On the other hand, the users in nursing homes were less interested in using the watch as they already felt secure. Furthermore, users with advanced stages of dementia were unable to remember even basic instructions for the watch and were therefore not able to use it for the intended purpose.

The main complaints about the watch were related to the size and ergonomics, as the device used was rather large. The watch was not waterproof which meant it had to be removed before taking a shower. A major issue turned out to be the battery life, as the watch required charging on a daily basis. When analyzing the number of false alarms, the users did not seem to mind having about one false alarm per day (one they could also cancel manually and did not necessarily result in a call to the call center). They stated that false alarms reminded them that the system is still functioning properly and that there was someone (the call center operator) actively taking care of them.

Based on the findings in the pilot, the Slovenian team decided to work on developing dedicated hardware instead of the commercial hardware with dedicated software used in the pilots, to allow better ergonomics and waterproofness, and significantly longer battery life by keeping only the sensors and interfaces that are relevant for the fall detection system to work. The lessons learnt from other pilot sites will be described in detail in future publications.

INLIFE was an ambitious project with the intention to provide a range of services for older adults living with cognitive impairment in the community. This was approached by bringing together a range of services, some of which were mature and others that were emergent, to offer support for all aspects of life of older adults living with cognitive impairment. The six pilot sites provided access to different demographic and socioeconomic groups of participants and different models of health and social care provision. The project also provided the opportunity to examine real-world implementation of not just one, but multiple services accessed through a single portal. Additionally, the INLIFE services were offered on a range of devices including wearables, tablets, and smartphones. As the data analysis continues the lessons learnt are only beginning to emerge but we anticipate the findings of INLIFE having an impact for developers, researchers, service providers and, of course, older adults living with cognitive impairment.

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7th International Workshop on the Reliability of Intelligent Environments (WoRIE'18)

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Introduction to the Proceedings of WoRIE'18

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The present section of these Proceedings is devoted to gather the papers accepted to be presented at the *7th International Workshop on the Reliability of Intelligent Environments* (WoRIE'18), to be held within the *14th International Conference on Intelligent Environments* (IE'18) in Rome (Italy) on 25-28 June 2018. The five previous editions of this workshop were held in Seoul (Korea), London (United Kingdom), Prague (Czech Republic), Shanghai (China) and Guanajuato (Mexico), within IE'17, IE'16, IE'15, IE'14 and IE'12 respectively, while the first one was held in Salamanca (Spain), within the *2nd International Symposium on Ambient Intelligence* (ISAmI'11). Therefore, this event is being progressively consolidated as a meeting point where researchers, academics and professionals working on some of the aspects related to the development of Intelligent Environments (IE) can discuss about how to make them more reliable, securer and/or safer.

IE or Ambient Intelligence (AmI) systems, as they are also known, are characterized by being made up of [1]: (1) An *operational layer*, which deploys a network of sensors, processors and actuators in a certain environment (e.g., a hospital, a workplace, a residential building, a transportation system, a cultural-heritage site, etc.) and has, as its backbone, a middleware that is in charge of appropriately distributing the relevant events and data among the mentioned elements, which are respectively responsible for sensing, computing and controlling the events, information, devices and appliances in such environment. And (2) an *intelligent layer*, which applies some methods and techniques coming from Artificial Intelligence (such as machine learning, case-based planning, speech recognition, knowledge representation, computer vision, and multi-criteria decision making, among others) to make the system smarter in order to offer adequate solutions to problems associated with important challenges related to the population ageing that developed societies has to face nowadays, such as people assistance, intelligent and adapted transport, social inclusion, healthcare, lifelong learning, independence, and quality of life, to name just a few.

The tech industry is interested in transferring the knowledge accumulated after years of research and development in this field to the society. Hence, products and systems are being marketed that can be classified within the category of IE. Examples of these are the self-driving cars. However, a self-driving car crash that killed a woman happened in Arizona recently [2]. This fact clearly indicates that reliability, safety and security are crucial and essential aspects in this type of systems, and therefore they require additional efforts to produce systems in which people can rely.

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As IE are context-aware systems, it is necessary sensing and recognizing the specific situations in which a given IE is to adapt the system behaviour and offer the best and smartest services to its users with the minimum effort from them [3]. To do that, these systems need a really complex combination of very varied hardware components and cutting-edge software modules that are executed on a distributed basis. Moreover, people to whom a certain IE serves can interact very differently with it. Hence, the development of IE is a very difficult task, and a considerable challenge.

Consequently, we think it is imperative to apply the best methods, techniques and practices in the diverse stages of the development of IE. Good examples of these are: requirement specification, modelling, validation, testing, simulation, verification, and others coming from Software Engineering [4], which can help us to analyse and ascertain the correctness of these error-prone systems, with the aim of increasing their reliability, safety and security, as well as incrementing the user confidence in them.

Despite a series of methodologies to improve the development and the reliability of this type of systems have been proposed in the last years (e.g., the ones presented in [5], [6], [7], [8] and [9]), the truth is that each is generally only applied by the group that proposed it. Accordingly, we consider that a greater effort and collaboration is necessary to provide a more holistic and unified methodology that can be collectively adopted by our community.

To conclude, we would like to thank Fulvio Corno for accepting our invitation to give us the keynote speech of this edition, which he has titled as *User Expectations in Intelligent Environments*. The selected contributions, which include: the improvement of location accuracy by comparing sensed images with the ones stored in a server, conversational assistants for people with dysarthria, and the integration of Multi-Agent Systems with Resource-Oriented Architecture for the management of Internet of Thing objects, represent a well-balanced distribution of theoretical and practical contents. With all this, we hope to have a successful and fruitful workshop, where all the audience actively participate and discuss on the topics addressed. We also expect that readers enjoy the selected papers included in these proceedings. Last but not least, we wish to express our sincere thanks to: the authors of the submitted papers, for their very interesting and high quality contributions; WoRIE'18 Program Committee members, for their excellent work and invaluable support during the review process; and IE'18 Workshops Chairs, for their help and support. All of them have made possible to successfully organize the present edition of this workshop.

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User Expectations in Intelligent Environments

Issues and Opportunities in the Interaction of Intelligent Users and Intelligent Environments

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Abstract. The definition of Intelligent Environments has always been focused around their *users*, aiming at helping them in a smart and transparent way, and avoiding bothering them or acting against their will. The complexity of IEs, whose technologies range from sensors to machine learning, from distributed architectures to tangible interfaces, from communication protocols to data analysis, challenges researchers from various fields to contribute innovative and effective solutions. In this quest for technical solutions to the myriad requirements of an intelligent environments, user expectations are often left behind, and while researchers tend to focus on niche technical aspects, they risk of losing the big picture of an IE "helping users in their daily life".

Keywords. usability, user expectations, user modeling, interaction

Introduction

Every definition of Intelligent Environment (IE) [1], Ambient Intelligence (AmI) [2], Smart Environment (SmE) [3], since the early inception of these disciplines and the key seminal works, puts a strong emphasis on the *users* living, working or otherwise exploiting the smart space. All researchers agree that the benefit for the users, the help that the system may provide them in their daily lives and activities, the usability of their interfaces, and the ability to serve, understand, and anticipate their needs and desires, should be the primary goal of every IE being designed, and its true *raison d'être*.

If this is the primary goal of our research area, we should question how well we, as a research community, are pursuing it, and investing in its direction. Even a cursory look at the literature on the relevant journals and conference proceedings reveals that a really limited number of works directly involve end users, or their needs, in research objectives or methods. The complexity of Intelligent Environments, in fact, requires significant advances in several research areas, including sensors, wireless communications, localization, power optimization, communication protocols, device-to-device interoperability, intelligent distributed platforms, big data storage and analysis, prediction and recommendation capabilities, just to name a few. There is no surprise, therefore, that the width of this interdisciplinary field attracts research from many different specialized disciplines, aiming at providing a useful contribution to the many issues raised by IE and AmI systems. During the talk we will analyze from the qualitative and quantitative points of view the contributions of past papers to the different disciplines.

However, the lack of focus on user needs, user behaviors, and actual interaction of real end users (who are provably anthropologically different from researchers and engineers) is at the basis of many failures, both at the research level (where interesting results fail to be applied) and at the market level (where technically advanced products fail miserably [4]). Some illustrative examples will be analyzed, and some learned lessons will be discussed.

The reflection stemming from this analysis can be summarized by analyzing the difference between a *enchanted* house (or castle, if you prefer) and a *haunted* one: both mansions are autonomous in performing some actions (playing music, controlling doors and windows, providing food and entertainment, etc.) and thus could be powered by similar intelligent systems. The main difference lies in the user perception: the actions of an enchanted house are *expected*, *desired* and *welcomed* by the user, that lives in a proactively friendly environment. On the other hand, the haunted space will execute actions contrary to the will of the user, who will feel trapped by an hostile entity.

To ensure that the IEs that our research community is developing will be of the enchanted kind, and not of the haunted one, we will finally discuss some design criteria [5] or design methods [6] that could and should be incorporated in our research agendas.

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Improvement of Localization Accuracy with Consecutive Images Using Pre-Map

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Abstract. In this paper, we propose a consistency adjustment algorithm for a new localization method based on a client-server model of mobile devices such as indoor mobile robots and smart phones to realize intelligent environments. The distance of movement is calculated using feature points of consecutive images, and subsequently the range of the estimated position is reduced based on the distance. We already have developed an indoor location estimation infrastructure called Universal Map (UMap) using the pre-map. UMap generates a two-dimensional image as a database in advance. The system performs an indoor location estimation by matching the database image and the sensor image. While the maximum error in the previous scheme using only UMap was 76.11 m, the maximum error in this proposed method was reduced to 1.42 m.

Keywords. localization, line-segment-feature, 2D-3D matching, Image feature point

1. Introduction

In recent years, many mobile computers including smartphones have been developed and widely spread. At the same time, many services utilizing the self-position using these terminals are being provided. Although Global Positioning System (GPS) is widely used, radio waves do not reach indoors and accurate position estimation cannot be performed. There are several methods using Wi-Fi Fingerprint [1] and Simultaneous Localization and Mapping (SLAM) [2-3] in indoor position estimation, but installation and creation costs are high because they use infrastructure and expensive sensors. In order to solve the problems, we have developed a low-computation, low-cost location estimation infrastructure that uses an image called Universal Map (UMap) [4]. However, when we use UMap in a structural environment with high similarity, a totally different position estimation may be made. In this paper, we propose a position estimation method with time consistency by comparing front and rear sensor images. We also describe the system design, implementation and evaluation results.

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2. Background

2.1. Related Work

There is a problem that the estimation result differs in position estimation, and research to solve it has been done.

Yuqi proposed an indoor location estimation method using a WiFi fingerprint and magnetic [5]. However, the installation of infrastructure in this technique, there is a problem in that it takes a cost to such maintenance.

Grisetti and colleagues proposed a method called Graph-Based SLAM [6] that uses sensor information such as robot odometry to narrow down the position of robot stochastically and estimate the position [7]. By combining a plurality of methods from these studies, it is found that there is a possibility of improving the position estimation precision.

In this research, we refer to the theory of Graph-Based SLAM and make it possible to estimate position with time consistency.

2.2. Universal Map

UMap is a position estimation infrastructure using a preliminary map with line segments as landmarks, and takes a map image database search method based on similarity calculation. SLAM has at the same time map building and position estimation. However, UMap it can be said that the low-operation since the use of the pre-map. Also, this is a server client method, all processes are performed by the server, and the client performs camera shooting only, so it costs less.

A schematic diagram of UMap is shown in Fig. 1. UMap consists of configuration server, clients, the three agents. The client in UMap, is the presence to have a camera. For example, a human or a mobile robot. Performing position estimation using the sensor image data received from a client on the server, and subsequently the client receives the estimated position. The agent detects a change in the environment (when you move or set up posters and furniture), inform the server. The server performs a semi-permanent system operation by adding writes the changes to the database.

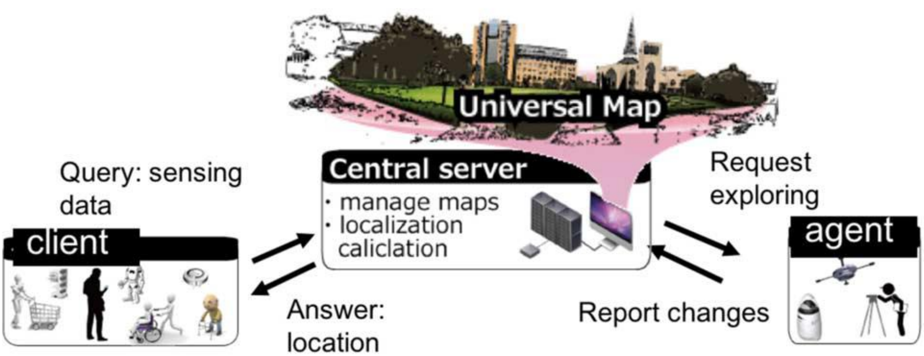

Figure 1. Universal Map [4].

3. Design of Consistency Adjustment (CA)

In UMap, it is not possible to estimate the position with some time constraint, and in a structural environment with high similarity, different position estimation may be done. Therefore, by comparing feature points of the input sensor image used in UMap, the existence position is stopped stochastically. After that, the position estimation range is restricted before and after the estimated position with the smallest error, and the position estimation is performed again to perform position estimation with temporal consistency. This time, the temporal consistency is that the client is moving continuously with respect to time elapsed.

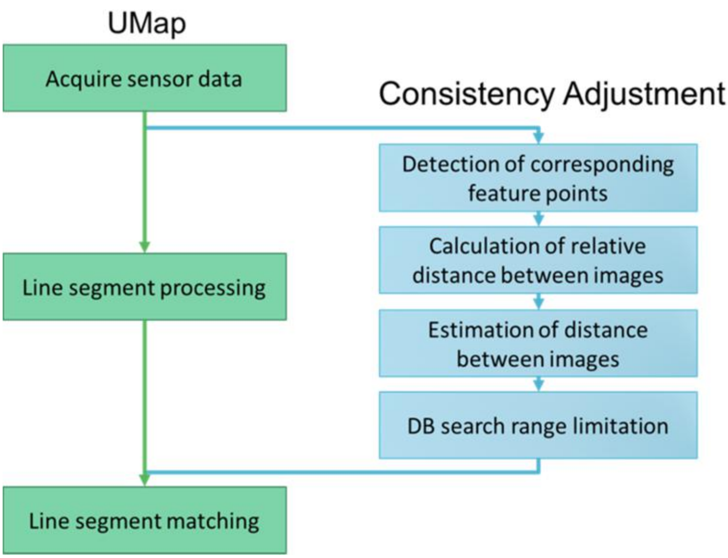

Figure 2. Consistency Adjustment System.

3.1. Estimation of Travel Distance

For estimating the moving distance, we use the sensor image and the distance to the wall measured by the laser rangefinder. The estimation method is shown in Fig.2. The thick line in Fig. 3 is the wall, the point on the wall is the common feature point, and θ is the direction of rotation from the wall. There are feature points common to each other in consecutive sensor images. The distance d_N to the camera and the wall is measured using a laser range finder. Furthermore, we calculate the relative movement amount of the robot according to how far the feature point moves from the camera center. Also, by knowing the distance to the wall, it is possible to estimate the actual moving distance m_N, m_{N+1} of the robot. These calculations are based on Eqs. (1), (2) and (3).

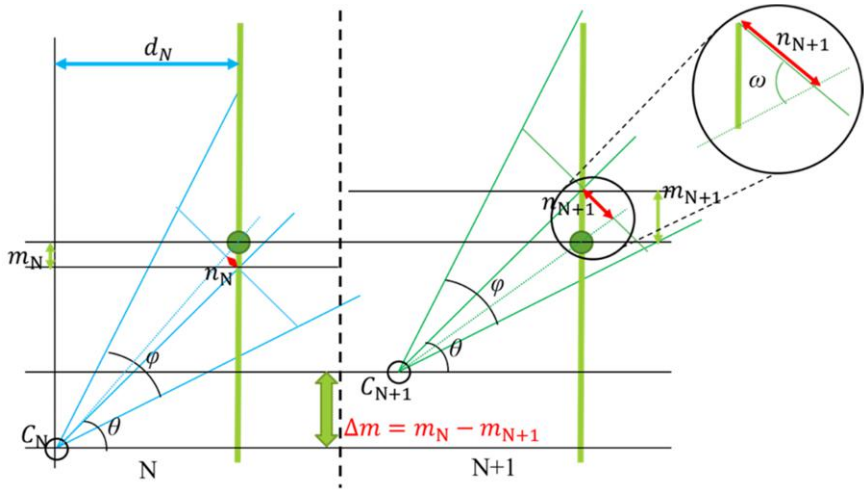

Figure 3. Short caption.

$$\omega = 90 - arctan\left(\frac{|n_N| * tan(\varphi)}{width}\right) \tag{1}$$

$$m_N = d * tan(\theta + 90 - \omega) - d_N * tan(\theta) \tag{2}$$

$$\Delta m = m_N - m_{N+1} \tag{3}$$

3.2. Position Estimation Range Narrowing Down

For the narrowing down of the position estimation range, a value considering the estimation error is used as the estimated movement distance obtained by comparing the front and rear sensor images. In addition, self-evaluation Eq. (4) in UMap is used to select the reference position of position estimation to be performed again.
P() is a self-evaluation value, A() is the number of nonzero pixels, DB_i is the i-th database image, SEN is the input line segment image, and LC is the logical product of DB_i and SEN. For the narrowing down of the position estimation range, a value considering the estimation error is used as the estimated movement distance obtained by comparing the front and rear sensor images. In addition, self-evaluation Eq. (4) in UMap is used to select the reference position of position estimation to be performed again.

$$P(LC, DB_i) = \frac{A(LC)}{A(DB_i) + A(SEN) - A(LC)} \tag{4}$$

This time, intended status are those of when the client has moved parallel to the smooth wall. If the client meanders, since seeking m per one image, the system moves normally. However, if the wall is put things in front of the wall or curved, the system does not work properly.

4. Experiment

4.1. Experiment Environment

An experiment was conducted in the corridor on the 5th floor of the O building Sagamihara Campus Aoyama Gakuin University. A 2D image was generated from the CAD data on the 5th floor of the O building as a database (Red frame in Fig.3). As for the generation range, the origin is the end of the eastern corridor. $0.0 < x < 90.0$ m, $-1.5 < y < 4$ m, $z = 1.14$ m, the x axis direction is incremented in increments of 0.10 m, the y axis direction by 0.20 m increments, and the z axis direction is fixed. In each viewpoint coordinate, an image was generated by rotating the gaze point in the horizontal direction by 90 degrees in the range of $45 < \theta < 315$ deg, and a total of 36032 databases were used. In input data set creation, smartphones were fixed on a caster with a tripod, and 50 pictures were taken while moving (Blue frame in Fig.3). In addition, the true value of the photographing position was measured using a laser range finder when photographing. The smartphone uses Xperia X Performance, the image file format is JPG, the image size is 1200 × 720 px, and the angle of view is 72 × 48 deg.

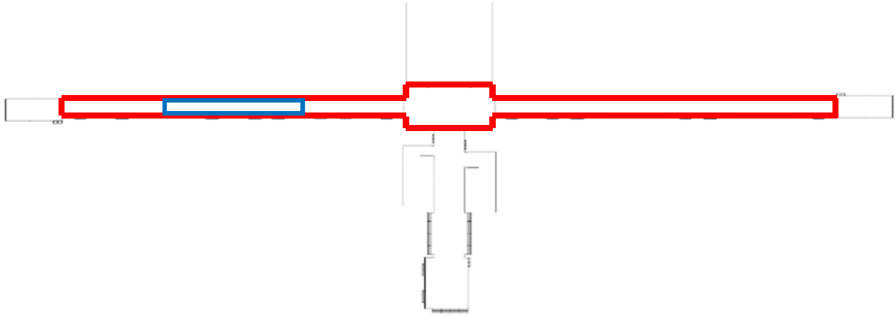

Figure 4. Map of experiment environment.

Figure 5. Experimental device.

4.2. Experimental Result

This time, experiments were carried out respectively in the conventional method (UMap) and the proposed method (UMap + CA). The results of the experiments are shown in Fig. 6. Fig. 6 is a plot of the respective estimation result to the map. True value is blue points, UMap is green points, UMap + CA is red points. In the conventional method, an error of 76.11 m at maximum was obtained. This is probably because the experimental environment is a structural environment with a high degree of similarity raised in the problem of UMap. On the other hand, the proposed method was able to reduce the error to 1.42 m at the maximum. As a result, it was shown by the proposed method that the position estimation accuracy was improved compared with the conventional method. In addition, Fig. 7 shows that even if we look at the cumulative probability distribution of errors in the conventional method and the proposed method, the accuracy was improved.

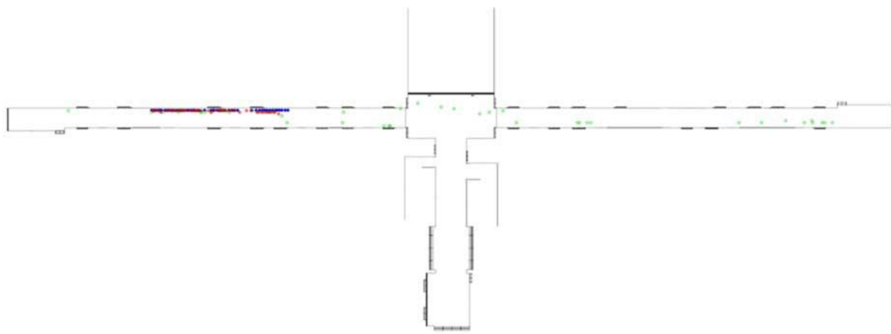

Figure 6. Map of experiment results.

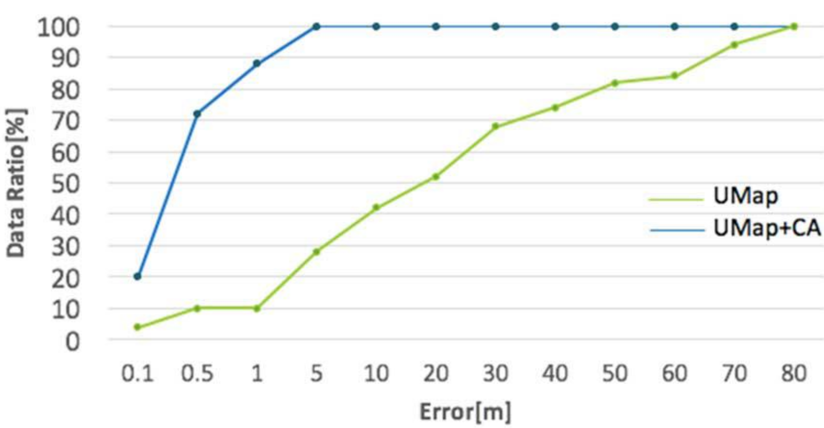

Figure 7. CDF of experiment result.

5. Conclusion

In this paper, we proposed a system that estimates the position estimation range by estimating the moving distance of the robot by comparing the front and rear sensor images, and estimates the position. It was shown that the position estimation accuracy was improved compared with the previous method. However, an error of 1.5 m still needs to be reduced. As a cause of this error, it is conceivable that the common point of correspondence at the time of narrowing down the position is not considered completely, and the distance to the actual wall could not be estimated correctly by the notice on the corridor. Moreover, since the next estimation was made while having the error, the error could be accumulated. A solution to this problem is to divide the position as a reference when position estimation is performed again into a plurality of positions.

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HLSI: Intelligent Sensors with HTTP Connection to Servers

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Abstract. Sensor devices are inevitable for realizing intelligent environments by obtaining the physical-world status. Their functions are normally self-contained and merely provide input values to the processing unit. However, sensors are becoming easy to be connected to the Internet and thus our group proposed the notion of SWNW, abstracted sensors utilizing the knowledge at remote servers. In this paper, we describe an enhanced implementation of SWNW using HTTP and an instance of SWNW as HTTP-based Location Sensor using Images (HLSI). HLSI consists of a server maintaining an image database and clients, normally smartphones, capturing images and exchanging information with the server. This paper describes the design and implementation of HLSI.

Keywords. HTTP, image, sensing, localization

1. Introduction

The idea about intelligent environments can be realized in one of two ways. The first solution provides user devices with intelligence and the other embeds intelligence into the environments. In the both approaches, sensors play a key role to extract information from the real world. Nowadays, as the Internet has evolved, many functions and devices that were isolated from others can be connected with each other. Sensors are one of them and we proposed SWNW [1] to utilize the information and knowledge in the Internet. The basic architecture of SWNW is shown in Fig. 1. In SWNW, sensors are virtually integrating the knowledge at some server connected with the Internet. The value obtained at the physical interface is pre-processed to be handled in digital and the converted information is sent to a server. On receiving the information, the server further converts it to a high context, which is returned to the physical device. Finally, the device provides the user with the high-context result. We are also creating a system called Universal Map (UMap) [2] to identify the location of an image taken with a smartphone by using the image as an input to an image-matching database. If we establish a well-defined protocol between a smartphone and a server maintaining the database on top of HTTP methods, we will broaden the utilization of UMap as an instance of SWNW at any place as long as the place is covered in the database without concerns about the existence of firewalls.

Based on the above motivation, we propose a system, HTTP-based Location

Sensor using Images (HLSI) and define the necessary messages exchanged between a client device and a server. This paper describes the design and implementation of HLSI and shows some results of preliminary experiments.

The rest of the paper is organized as follows. Section 2 describes related work. Sections 3 and 4 explain UMap and HLSI, respectively. Section 5 shows the result of preliminary evaluations.

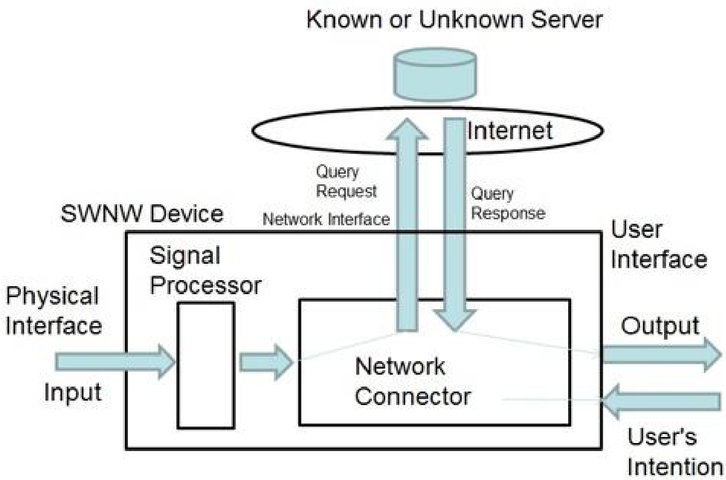

Figure 1. Architecture of SWNW.

2. Related works

This study is an extension to our previous work [2]. The basic principle in our system [2] is based on Simultaneous Localization and Mapping (SLAM) using straight lines [3], but we used a scheme of matching line segments extracted from an image taken with a camera with a 3D-edge map on the server. The study shares the same scheme with the previous work, but clients can send the image information to the server using HTTP. Thus, the server can exist at any place as long as it is being connected to the Internet.

A broader discussion related to our work is whether the functions should be placed in the cloud [4] or at the edge [5]. As the Internet connection has become stable, many functions are placed in the cloud and many commercial services have been provided using the cloud. The disadvantage of using the cloud is a large latency in the network. To reduce the network latency, an approach of processing at gateways was proposed as cloudlet [6] and the approach is generalized as fog computing [7]. Both cloud and edge have pros and cons with respect to fault tolerance, reliability, and responsiveness. Our approach takes the both ideas. When a function becomes commonplace and can be implemented in small application software, it can be installed at the edge. In addition, when many sensors in a local area are connected to the same service, fog computing becomes suitable.

Another related area is intelligent sensors [8]. The concept of intelligent sensors has many functionalities such as data processing including prediction. Our work realizes one aspect of intelligent sensors.

3. UMap

UMap itself is a localization system and various devices besides smartphones can be clients of UMap. The key idea behind UMap is an indoor localization using an image taken by a client. The captured image can tell where the client exists. However, using the whole pixels of image will lead to long computing time, thus feature points are being used in many systems. Instead of feature points, we use line segments as a localization landmark based on the idea that many line segments can be detected in the environment containing artificial objects. Using line segments is more robust, reliable, and stable than using feature points; a long-term operation is possible since it is robust against the change in luminescence. Furthermore, detection of line segments is conducted for each of the RGB components to enhance the accuracy of detection.

The UMap consists of two stages: creation of database and handling queries to the database. In the creation stage, a 3D wire frame map is generated on the server. An agent in the matching engine receives an instruction with an image from the server and searches for the item related to the image and when there is a change in the image, it modifies the database. When the server receives an input image from a client, the server performs edge matching between map on the server and the image. Since the photograph is 2D, 2D/3D matching algorithm is required to match it and wire frame map on the server. In many image processing systems, feature points are extracted, but we take another approach in UMap. In UMap, line segments are used as localization landmarks based on the assumption that many line segments are found in the environment where we usually live; walls, shelves, and artificial objects exist in the indoor environment and many buildings are observed in the city.

Fig. 2 shows how UMap functions as a system. A query with an image is transferred to the central server of UMap and the response of the query is returned to the client. The information in the central server is simultaneously altered by agents.

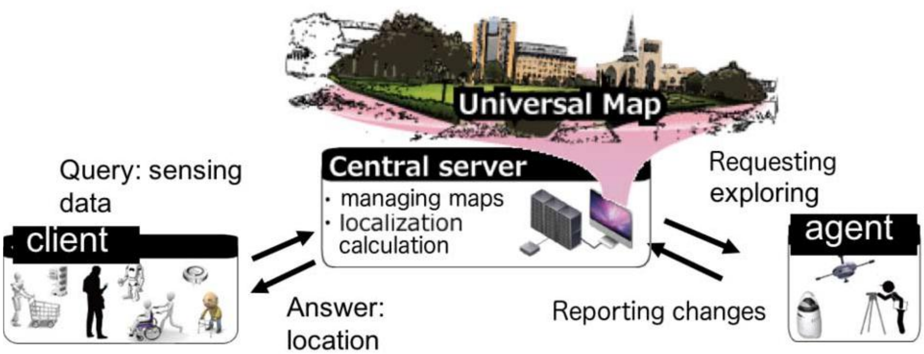

Figure 2. System of UMap.

4. System design

4.1. List of designed methods

We have divided the functions of the server into two: Line Segment Detection (LSD) and UMap server. LSD server is responsible for creating line segments from an input image while UMap server searches for the location corresponding to the line segments. The methods between a client, LSD and UMap servers are listed in Tables 1 and 2.

Table 1 contains the primitives for the interface between a client and the LSD server. The client sends image files to the LSD server and the server can begin the process of estimating the location of the client based on the received image.

Table 1. List of methods for client-LSD-server interface.

Name	Function
set_url	Setting the IP address of LSD server
get_url	Returning the URL of LSD server
set_img_file_path	Setting the path of image data
get_img_file_path	Returning the path of image data
file_to_bytes	Converting the image data to bytes
make_query	Creating query data
send_request	Sending a request with POST method to LSD server

Table 2. list of methods for LSD-server-UMap-server interface.

Name	Function
do_post	Entry of operations when LSD server receives post request
analyze_input	Analysis of query
choose_line_detection_met hod	Choosing a line detection method
register_image_to_DB	Registering the image to DB
execute_DB	Executing operation to DB, e.g. insert, update and select.
convert_string_to_image	Converting base64-encoded-string data to image
send_image_with_HTTP	Sending HTTP request using POST method

Table 2 is a list of the primitives defined at the interface between the LSD server and the UMap server. The database of location is maintained in the UMap server and these primitives are necessary to maintain the database and query processing.

4.2. Flow in HLSI

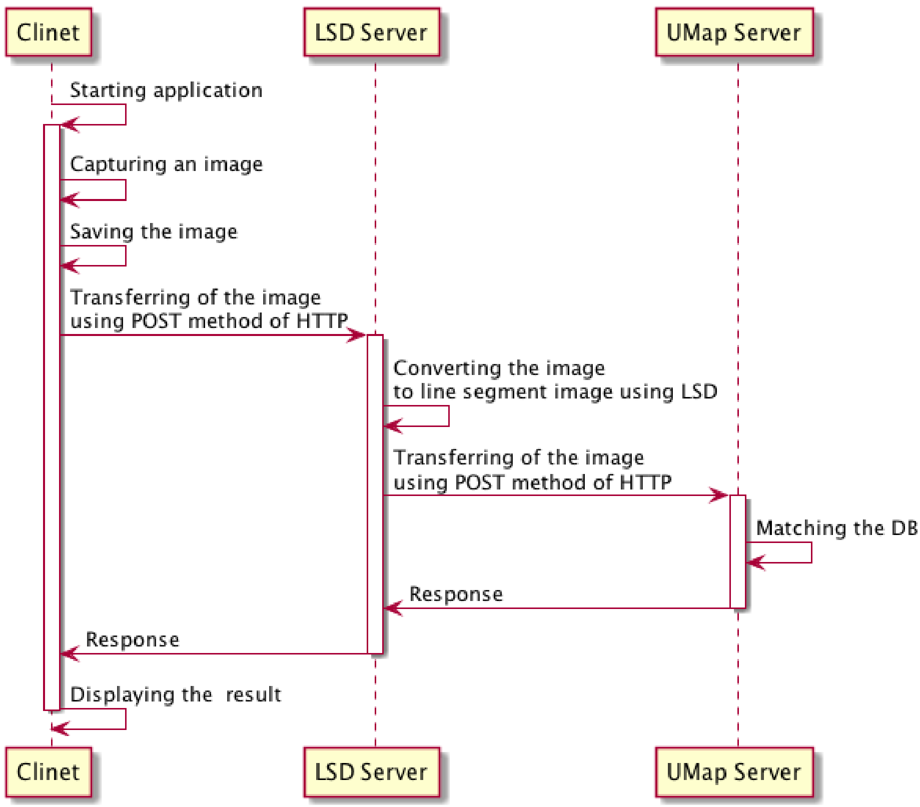

Fig. 3. Flow of messages in HLSI.

Now we explain how the client, the LSD server, and UMap server exchange messages between them. Once the client captures and saves an image, it transfers the image to the LSD server using POST method. After receiving the image, the LSD server extracts line segments, the base information in UMap. The LSD server sends the line segments to the UMap server where the location corresponding to the line segments is estimated.

The UMap server sends the result of estimated location to the client through the LSD server. The client receives the result and presents the user with the estimated location.

We assume that the client device is always connected with the Internet and the servers are visible from the client. This assumption is reasonable since smartphone users tend to use WiFi in the buildings.

5. Preliminary evaluation

We conducted a simple experiment of sending five kinds of images with 1.5 MB to LSD and UMap servers from an Android phone and measured the round-trip time (RTT) to obtain the results. Each image was sent ten times and we calculated the average and the standard deviation of the measured RTT. The results are shown in Fig.4. Currently, the execution time for the line-segment matching process is large and the reply is returned in approximately two minutes. This is a bottleneck at the server side and we need to investigate an improvement in the matching scheme. However, the prototype system was shown to work properly in the Internet in terms of a combination of functions.

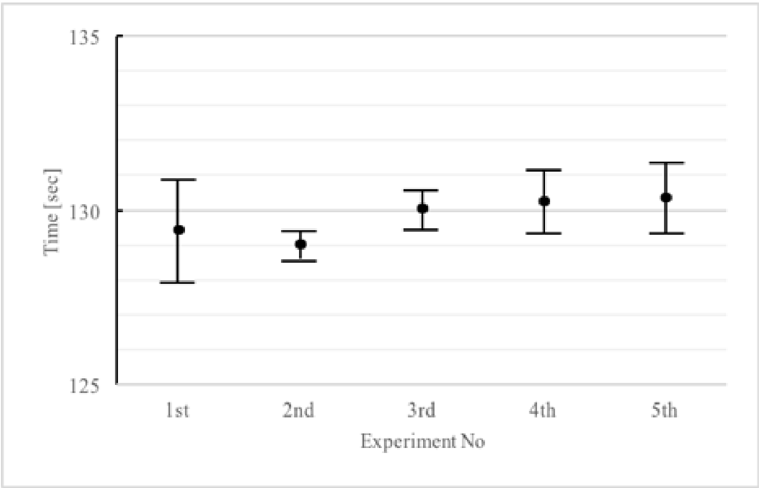

Figure 4. Measured RTT in HLSI.

6. Conclusion

We have proposed HLSI and implemented a prototype system consisting of Android phones and a UMap server. Although we have verified the basic function of HLSI, there is a performance bottleneck at the server. Our future plan includes faster image processing at the server and utilization of images in a wider area.

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"Hey Siri, Do You Understand Me?": Virtual Assistants and Dysarthria

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Abstract. Voice-activated devices are becoming common place: people can use their voice to control smartphones, smart vacuum robots, and interact with their smart homes through virtual assistant devices like Amazon Echo or Google Home. The spread of such voice-controlled devices is possible thanks to the increasing capabilities of natural language processing, and generally have a positive impact on the device accessibility, e.g., for people with disabilities. However, a consequence of these devices embracing voice control is that people with dysarthria or other speech impairments may be unable to control their intelligent environments, at least with proficiency. This paper investigates to which extent people with dysarthria can use and be understood by the three most common virtual assistants, namely Siri, Google Assistant, and Amazon Alexa. Starting from the sentences in the TORGO database of dysarthric articulation, the differences between such assistants are investigated and discussed. Preliminary results show that the three virtual assistants have comparable performance, with an accuracy of the recognition in the range of 50-60%.

Keywords. dysarthria, conversational assistant, smart home, persons with disabilities, virtual assistants

1. Introduction

The last five years have seen the spread of voice-controlled smart environments, powered by virtual assistants like Siri or Amazon Alexa. Nowadays, people can speak to their smartphones, smart watches, smart homes, connected vacuum robots, and even smart cars, with the aims of setting alarms, controlling other devices in their smart environments, playing music, or requiring various types of information (e.g., the weather forecast). This spread of voice-controlled devices was possible thanks to the advances made in speech recognition, and was seen as a viable alternative to touch screens. Displays, in fact, are typically more expensive and bulky as components, and they are impossible to operate hands-free. By using speech as the primary input, virtual assistants can bypass or minimize the more "conventional" input methods (i.e., keyboard, mouse, and touch), thus making voice-controlled devices useful and accessible to people with disabilities. However, while persons with motor disabilities may benefit from these virtual assistants, those with cognitive, sensory, or speech disorders may be unable to fully use them. For example, Bigham et al. [1] demonstrated that the Google's speech recognition system

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does not work well for people who are deaf and hard of hearing, and they expected that recognizing deaf speech will remain challenging for both automatic and human-powered approaches.

In this paper, we present an initial work on enabling people with speech impairments to access voice-controlled devices, adopted more and more in smart homes around the world. In particular, we focus on people with *dysarthria*, a motor speech disorder characterized by poor articulation of phonemes that makes it difficult to pronounce words. We investigated the interaction of people with dysarthria with three of the most used virtual assistants, included in several standalone and mobile devices: Apple's Siri, Google Assistant, and Amazon Alexa. With such users, at what point do virtual assistants become limited and demonstrate a low reliability? Could people with different degrees of dysarthria easily access and be understood by those voice-controlled devices? Even if the percentage of recognized speech is low, could virtual assistants leverage the context as extracted from the requests to provide a suitable answer?

To answer these questions and investigate the differences between the three virtual assistants, we extracted 17 appropriate sentences from the TORGO database of dysarthric articulation [2]. The database contains dysarthric speech samples from eight speakers with cerebral palsy (CP) or amyotrophic lateral sclerosis (ALS) and was developed in a collaboration between the departments of Computer Science and Speech-Language Pathology at the University of Toronto and the Holland-Bloorview Kids Rehab hospital in Toronto, Canada. We, then, submitted each speech sample to every virtual assistant, separately, and analyzed the given answers. We were interested in the dysarthric *sentence comprehension* and in the *consistency of the answers* as indicators of the reliability of such assistants. With the former, we evaluate the accuracy of the speech-to-text recognition, while the latter is an indicator of the appropriateness of the responses provided by the assistants. Results show that the three virtual assistants have comparable performance for both sentence comprehension and consistency of the answers, with a correct transcription percentage of around 50-60%.

2. Related Work

Speech technology in general, and automatic speech recognition (ASR) in particular, is not new for people with disabilities. It was being used to increase accessibility in mainstream operating systems since decades, as an alternative method to control the computer or to compose document through dictation systems (e.g., Dragon [3]). For example, while speech recognition is available in Microsoft Windows since Vista, the latest version of the operating system include the Cortana digital assistant to help users set reminders, open apps, find information, and send emails and texts [4]. Similarly, speech recognition as an input to electronic assistive technology was investigated both in general and for dysarthria. Hawley [5] presents an overview, based on a literature review and clinical observations, upon the suitability and performance of speech recognition for computer access by people with disabilities, including people with dysarthria. He reports that, given adequate time, training, and support, commercial ASR systems for PCs are often appropriate for people with no, mild, or moderate speech impairments. People with dysarthria achieve lower recognition rates, but speech recognition can be still a useful input method for some individuals. Conversely, Hawley discovers that speech as a mean of controlling the home or other electronic devices is less reliable and more problematic, especially for dysarthric speech. To overcome this kind of issues, researchers investigated new methods and proposed dedicated ASR systems for dysarthria, e.g., by using ergodic hidden Markov models [6] or articulatory dynamic Bayes networks [7].

Specific HCI research in the domain of technology for people with speech impairments is, instead, still quite limited [8]. Sears et al. [9] offer an overview of HCI research for people with "significant speech and physical impairments", by focusing on communication aids. More recently, Derboven et al. [8] describe the design of ALADIN, a self-learning speech recognition system for people with physical disabilities, many of whom also have speech impairments. ALADIN is designed to allow users to use their own specific words and sentences, adapting itself to the speech characteristics of the user, and primarily targets smart homes.

Finally, a few works explore usability, reliability, and accessibility issues of virtual assistants. López et al. [10] present a usability evaluation of the most used speech-based virtual assistants (i.e., Alexa, Siri, Cortana, and Google Assistant) and highlight that there is still a lot to do to improve the usability and reliability of these systems. Bigham et al. [1], instead, focus on the issues that may arise from the usage of commercial virtual assistants by people who are deaf and hard of hearing. They propose two technical approaches for enabling deaf people to provide input to those assistants, i.e., human computation workflows for understanding speech and mobile interfaces that can be instructed to speak on the user's behalf. Similarly to the work of Bigham et al., we focus on the issues that may arise from the usage of virtual assistants, but we were specifically interested in dysarthric speech and in evaluating the current behaviors of these assistants.

3. Dysarthric Speech for Virtual Assistants

Dysarthric speech is the speech produced by people with dysarthria. Dysarthria is caused by disruptions in the neuro-motor interface, typically as a consequence of cerebral palsy or the Parkinson's disease. These disruptions distort motor commands to the vocal articulators, thus resulting in atypical and relatively unintelligible speech in most cases. Dysarthric speech may be characterized by a slurred, nasal-sounding or breathy speech, an excessively loud or quiet speech, problems speaking in a regular rhythm, with frequent hesitations, and monotone speech. As a consequence of these problems, a person with dysarthria may be difficult to understand and, in some cases, she may only be able to produce very short phrases, single words, or no intelligible speech at all. As a result, enabling modern ASR to effectively understand dysarthric speech is a major need, both for virtual assistants and for computers, since other physical impairments often associated with dysarthria can make other forms of input, such as keyboards or touch screens, especially difficult.

To begin exploring the issues of understanding dysarthric speech by contemporary virtual assistants, we extracted a corpus of sentences from the *TORGO database* [2]. The database is one of the few freely available[2] collections of dysarthric speech in English, and it consists of aligned acoustics and measured 3D articulatory features from speakers with either CP or ALS, all of them with various degree of dysarthria. The dataset contains

[2]for academic and non-profit purposes

both audio files and transcriptions of four types of sentences to control different abilities of dysarthric speakers: *non-words*, *short words*, *restricted sentences*, and *unrestricted sentences*. Non-words were used to control baseline abilities of dysarthric speakers, especially to gauge their articulatory control in the presence of plosives and prosody, like high-pitch and low-pitch vowels. Short words are useful for studying speech acoustics and for hypothetical command for accessible software. They include the repetitions of the English digits, and words like 'yes', 'no', 'up', 'down', 'back', 'select', etc. Restricted sentences are full and syntactically correct sentences, including "The Grandfather Passage[3]" and phoneme-rich sentences like "The quick brown fox jumps over the lazy dog." Finally, unrestricted sentences were natural descriptive text of 30 different images, to more accurately represent disfluencies and syntactic variation of natural speech.

To evaluate dysarthric speech with the three virtual assistants, we looked in the TORGO database for sentences similar to the commands used to control Alexa, Siri, and Google Assistant (e.g., [11]) in the home. We extracted 5 different sentences pronounced by 7 different speakers. Those sentences were extracted from all the types of sentences included in the dataset, excluding non-words. We, then, used these commands to evaluate the sentence comprehension and the answers consistency of the virtual assistants. The five unique sentences are:

1. Some hotels are available nearby
2. Please, open the window
3. Today's date
4. Start
5. Play

4. Evaluation

The evaluation of Siri, Alexa, and Google Assistant for dysarthric speech focuses on *sentences comprehension* and *consistency of the answers*.

For *sentence comprehension*, we evaluate the accuracy of the speech-to-text recognition process adopted by the virtual assistants. Both Siri and Google Assistant, in fact, provide the user with the transcription of the received command (if operated on devices with a display). The evaluation of the comprehension is, therefore, given by the similarity between the expected transcription (as provided in the TORGO database) and the transcribed output of the assistants, both in terms of the number of correctly recognized sentences and as the Word Error Rate (WER). Alexa, instead, does not provide a transcription of the request but it only gives a binary indication about the recognition of the input (i.e., it warns the user if it was not able to recognize the input speech). Therefore, we only qualitatively compared Alexa with the other assistants, for this criterion.

Consistency of the answers is an indicator of the appropriateness of the assistants' responses, given as the number and percentage of times that the three assistants provided appropriate responses to the user's queries. Even if the accuracy of the speech-to-text recognition process is low, in fact, virtual assistants may leverage the context or some specific recognized keywords to provide a suitable response.

[3]a public domain text frequently used to gather a speech sample that contains nearly all of the phonemes of American English.

4.1. Study Description

We extracted the 5 sentences reported in the previous section from the TORGO database, as pronounced by 7 persons with dysarthria (5 males and 2 females). Since the sentences were not available for all the users, we obtained the audio files of 17 sentences, overall. In details, the first sentence was pronounced by two people (F3 and M5), the second sentence by F4 only, the third by M5 only, the fourth sentence by all the users except M4, while the last sentence was pronounced by all the users. After the selection of the sentences, we ensured that all the speech samples were perfectly recognizable by a human listener, to avoid submitting to the assistants any sentence that even a person would not be able to understand. Tables 1, 2, 3 report all the 17 sentences with the details of the study.

The evaluation took place in a quiet room of our university. The speech samples were played on a laptop connected to an external speaker. Each sentence was played for each virtual assistant, separately, and the results of the operation (i.e., recognized request and related response) were noted down by the experimenter. The virtual assistants were run on dedicated devices: an iPhone 7 (iOS 11.2) was used for Siri, a Nexus 5X (Android 8.1) for Google Assistant, while Amazon Alexa was used through a browser-based interface (i.e., the Amazon Echo Simulator [12]). The Amazon Echo Simulator console, in particular, was useful to help overcome the absence of the requests transcription.

Before starting with the evaluation, we extracted from the TORGO database the same 5 sentences but pronounced by people without any speech impairment. We carefully and successfully checked that each virtual assistant recognized and transcribed those speech samples without any errors nor problems.

5. Results and Discussion

Overall, the three virtual assistants performed similarly with the 17 dysarthric speech samples for both *sentences comprehension* and *consistency of the answers*, as reported in Tables 1 (results with Siri), 2 (Google Assistants) and 3 (Amazon Alexa), and summarized in Table 4. For what concerns sentence comprehension, Siri was the only assistant that *tried* to recognize all 17 sentences, by transcribing something. The other two assistants indicated, instead, that they were not able to recognize anything for some speech samples. Google Assistant performed the worst, with 4 not recognized speech samples, while Amazon Alexa did not recognize 3 sentences, only. However, this difference between the virtual assistants disappeared when analyzing the **correct** transcriptions and the relative Word Error Rate (WER)[4]. Siri, in fact, was able to correctly recognize 8 speech samples, i.e., all but one of the sentences pronounced by F3, F4, M3, and M4, with an average WER of 69.41% and an overall recognition percentage of 47%. Google Assistant performed better with a recognition percentage of 58.82%: it was able to recognize 10 speech samples, with an average WER of 15.38%. Differently from Amazon Alexa and Siri, Google Assistant recognized a sentence from M2 and one from M5, indeed.

[4]WER is a commonly used performance measure for speech recognition systems that includes substitution errors (i.e., miss-recognition of one word for another), deletion errors (i.e., words missed by the recognition system), and insertions (i.e., words introduced into the text output by the recognition system). It can be greater than 100% when the transcription has more insertions than deletions.

User	**Original Sentence**	**Siri Transcription**	**Correct?**	**WER**	**Siri Response**	**Appropriate?**
M01	play	hey	No	100%	Hello	No
	start	go	No	100%	You were saying	No
M02	play	hello	No	100%	Hi there	No
	start	can i	No	200%	Interesting question	No
M03	play	play	Yes	0%	Ok... (play some music)	Yes
	start	start	Yes	0%	I'm not sure I understand	Yes
M04	play	play	Yes	0%	Ok... (play some music)	Yes
M05	some hotels are available nearby	resume route girl or a rare burger nearby	No	140%	Ok. Here's what I found nearby	Yes
	play	siri hi	No	200%	Hi, what can I do for you?	No
	start	no		No	100% Ok, I didn't think so	No
	today's date	do you do do	No	200%	This is about you, not me	No
F03	some hotels are available nearby	show hotel are available nearby	No	40%	I found quite a few hotels fairly close to you	Yes
	play	play	Yes	0%	Playing all songs, shuffled	Yes
	start	start	Yes	0%	Ok...	Yes
F04	please open the window quickly	please open the window quickly	Yes	0%	Hmm, I don't see anything connected, but I can help once you've set something up	Yes
	play	play	Yes	0%	Playing all songs, shuffled	Yes
	start	start	Yes	0%	I'm not sure I understand	Yes

Table 1. The full list of sentences per user with the responses provided by Siri. The correctness of the transcription, the Word Error Rate, and the appropriateness of the response are reported.

Finally, for what concerns the consistency of the answers, all three virtual assistants were consistent in their answers, e.g., Siri with the "play" sentences always executed some music, Google Assistant always proposed some games to play, while Amazon Alexa always replied with "what do you want to hear?". The appropriateness of the responses was similar for the three assistants, as they leveraged the context or some specific keywords to provide a suitable answer. In particular, Google Assistant tried to provide a pertinent answer when it recognized some words, e.g., it showed a link to the AroundMe app or some TripAdvisor pages when it recognized "hotels" or "nearby". A similar behavior was exhibited by Siri with the "nearby" word. However, Google Assistant performed slightly better than Siri (11 vs. 10 appropriate responses), while Alexa

User	Original Sentence	Assistant Transcription	Correct?	WER	Assistant Response	Appropriate?
M01	play	-	No	-	-	No
	start	dart	No	100%	Search "dart" on Google	No
M02	play	play	Yes	0%	You can play one of this games from Playstore	Yes
	start	-	No	-	-	No
M03	play	play	Yes	0%	You can play one of this games from Playstore	Yes
	start	start	Yes	0%	This came back from a search of "start" in the dictionary	Yes
M04	play	play	Yes	0%	You can play one of this games from Playstore	Yes
M05	some hotels are available nearby	hotels available	No	60%	Search on Google (hotels)	Yes
	play	-	No	-	-	No
	start	-	No	-	-	No
	today's date	today's date	Yes	0%	12/12/2017	Yes
F03	some hotels are available nearby	someone tells are available nearby	No	40%	Here to help (suggest the "Around Me" app)	Yes
	play	play	Yes	0%	You can play one of this games from Playstore	Yes
	start	start	Yes	0%	This came back from a search of "start" in the dictionary	Yes
F04	please open the window quickly	please open the window quickly	Yes	0%	Search on Google (window quickly)	No
	play	play	Yes	0%	You can play one of this games from Playstore	Yes
	start	start	Yes	0%	This came back from a search of "start" in the dictionary	Yes

Table 2. The full list of sentences per user with the responses provided by Google Assistant. The correctness of the transcription, the Word Error Rate, and the appropriateness of the response are reported.

performed the worst, by providing 7 suitable response, only. It should be notice that the Siri approach of trying of answering in any case provided a benefit in this case: it moved, in fact, from 8 correctly transcribed sentences to 10, while Google Assistant moved from 10 to 11.

User	Original Sentence	Recognized by Alexa?	Alexa Response	Appropriate?
M01	play	No	-	No
	start	Yes	-	No
M02	play	Yes	Hi there	No
	start	No	-	No
M03	play	Yes	What do you want to hear?	Yes
	start	Yes	What do you want to hear?	Yes
M04	play	Yes	What do you want to hear?	Yes
M05	some hotels are available nearby	Yes	I'm still learning about bird questions. Try asking "tell me a bird fact" to learn more about them.	No
	play	Yes	-	No
	start	Yes	-	No
	today's date	No	-	No
F03	some hotels are available nearby	Yes	To search for local businesses you need to enter your address in your settings	
	play	Yes	What do you want to hear?	Yes
	start	Yes	What do you want to hear?	Yes
F04	please open the window quickly	Yes	Window quickly doesn't support there	No
	play	Yes	What do you want to hear?	Yes
	start	Yes	What do you want to hear?	Yes

Table 3. The full list of sentences per user with the responses provided by Amazon Alexa. The appropriateness of the response is indicated in the last column.

	Sentence Comprehension			Consistency of the Answers	
	Recognized Sentences	*Correct Transcriptions (# and %)*	*WER (mean)*	*Appropriate Responses (#)*	*Appropriate Responses (%)*
Siri	**17**	8 (47%)	69.41%	10	58.82%
Google Assistant	13	**10 (58.82%)**	**15.38%**	**11**	**64.7%**
Amazon Alexa	14	-	-	7	41.17%

Table 4. Summary of the results according to the sentence comprehension and consistency of the answers criteria.

5.1. Discussion

Starting from the results about dysarthric speech comprehension and consistency of the answers, a similarity and a couple of differences emerge. The similarity is related to the almost equal level of recognition, with a percentage of correct transcriptions around the range of 50-60% (more precisely, 47-58.82%): a similar range was already found for contemporary ASR systems used by users with other speech impairments [1]. While slight differences in which sentences were recognized by the assistants exist, they seem not to be significant, at least with the limited data available in the TORGO database. The main difference between the virtual assistants is, instead, related to the provided answers. While Siri always tries to answer any request, even if it does not recognize any word, Amazon Alexa and Google Assistant use an opposite approach as they provide a response if they recognize some words, only. Such fallback mechanisms, however, are different for Amazon Alexa and Google Assistant: while the former may say "I'm still learning about bird questions", the latter starts a Google search with the recognized words. Another difference we noticed during the evaluation is that Amazon Alexa tries not to reply to single-word commands as it seems to prefer longer sentences.

5.2. Study Limitations

We would like to acknowledge that this evaluation presents two limitations, which emphasize the preliminary nature of this work. The first one is the relatively low number of speech samples present in the TORGO database that are suitable for virtual assistants. The second one resides in the choice of playing sentences from a speaker instead of by a human speaker. This was, obviously, inevitable since we chose to adopt the TORGO dataset for this work. While we do not have any evidence that this choice negatively impacted the results of the evaluation, involving human participants may improve the ecological validity of the results.

6. Conclusion and Future Work

Voice-controlled smart environments, powered by virtual assistants like Siri or Amazon Alexa, are becoming mainstream. The reliability of the intelligent environment they control, strongly depend on their capability of understanding the requests they receive, and of correctly acting on the environment.

In this paper, we have presented an initial investigation of the accessibility challenges presented by such virtual assistants for dysarthric speech. By using 5 different sentences pronounced by 7 diverse speakers with dysarthria, we evaluated the performances of the three most common virtual assistants, i.e., Siri, Google Assistant, and Amazon Alexa, according to two criteria: dysarthric sentence comprehension and consistency of the answers. Preliminary results show that the three assistants have comparable performance and similar behaviors for both criteria, with a recognition percentage of around 50-60%. Similar recognition values were already found for contemporary ASR systems when used by people with other speech impairments, e.g., deaf people.

Future work will include a more extensive evaluation, both in variety and in number of sentences pronounced by people with dysarthria. Moreover, we would like to better assess such virtual assistants by characterizing their usefulness for different degree of dysarthric speech (e.g., moderate vs. severe) as well as by employing speech-controlled devices like Google Home and Amazon Echo instead of smartphones and web-based interfaces to better assess their reliability in an intelligent environment. Finally, we will use the outcome of this evaluation as a starting point to improve the accessibility and the recognition capabilities of such assistants.

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Integration of MultiAgent Systems with Resource-Oriented Architecture for Management of IoT-Objects

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Abstract. Recently, scientists have shown a special interest in the integration of agent-oriented technologies with the Internet of Things (IoT) in order to manage smarter IoT-objects and their resources. This paper proposes an agent architecture of Multiagent Systems based on Resource-Oriented Architecture (MAS-ROA), where the behavior of each agent is driven by a specific control workflow. This workflow enables agents to be able to perform sensing and control actions over IoT-objects by means of collaborative processes. In this way, IoT-objects managed by MAS-ROA agents can behave proactively, collaboratively, adaptively and smartly. In order to validate the proposal, an IoT ecosystem composed of many "things" (IoT-objects) is modeled and managed by agents based on MAS-ROA. The Multiagent System based on MAS-ROA was then contrasted with an implementation based on Service-Oriented Architecture (MAS-SOA) addressed by Devices Profile for Web Services (DPWS) to get insight about the differences in capabilities and performance.

Keywords. Internet of Agents, Agentification, Internet of Things, Service-Oriented Architecture, Resource-Oriented Architecture, Agent-based Services

1. Introduction

Recently, some theoretical and practical approaches have been proposed to create smart objects for Internet of Things (IoT). Two of the most relevant ones are related to the agentification of the IoT [1] and the *Internet of Agents* (IoA) [2] approaches. Both approaches propose the integration of agents with IoT technologies as a novel paradigm to control automatically, autonomously and smartly the real world through dynamic network of heterogeneous devices interconnected via Internet [3]. Hence, traditional passive IoT-objects can become active and consequently, the new generation of IoT-objects will require minimal or no user intervention to adapt their behavior to the changes that occur in their environments [4].

The IoA approach can be seen as a smart agent interaction, defined in an upper level that governs the IoT resources [5]. In parallel to this novel approach, two perspectives

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have been defined to realize the agentification of the IoT. The first one consists of embedding a software agent within the architecture of each IoT-object such as IoT-a [6], agent of thing [7], and smart object [8] models. On the other hand, the second approach suggests the design of Multi-Agent Systems (MASs) that control actively IoT-objects [9].

Regardless of the perspective used to agentify the IoT, the target is focused on controlling the IoT-objects smartly. For this purpose, a dynamic component capable of modifying the agent behavior autonomously according to the changes that occur in the operating environment is included [2]. To facilitate this adaptation process, several mechanisms have been merged within MASs to facilitate the design of their functionalities using ecosystems of services based on Service Oriented Architecture (SOA) or Resource Oriented Architecture (ROA) [10]. As a result, several approaches of MAS based on Service-Oriented Architecture (MAS-SOA) has been proposed [11,13]. However, because SOA web services are trending towards RESTful web services, another equivalent approach based on Resource-Oriented Architecture [14] can be defined (MAS-ROA) [15].

In this work we have focused on MAS approaches based on ROA for the agentification of the IoT. The main contributions of this paper are summarized as follows: (i) definition of an agent model based on the MAS-ROA approach that enables communication and control operations at the agent-agent and agent-object level via resources implemented with RESTful services, (ii) formulation of a workflow model oriented to control IoT-objects collaboratively through the dynamic composition of resources, and finally (iii) development of an agent model driven by dynamic control workflows easily adaptable by end-users at runtime as Yu et al. envision agent technologies and IoT ecosystems[2].

This paper is organized as follows: Section 2 presents a brief description of the MAS-ROA approach. In Sect. 3, a proposal of a reference architecture for the MAS-ROA approach is defined. In Section 4, a working example is detailed in which the MAS-ROA approach is applied to develop a system for controlling an Ambient Intelligence (AmI) scenario. Finally, Section 5 outlines our conclusions.

2. From MAS-SOA to MAS-ROA approach

The popularity and acceptance of service-oriented technologies for the development of distributed systems (e.g. web, mobile and ubiquitous applications) has led to the extension of web services and Service-Oriented Architecture (SOA) to areas such as agent-based technologies. Consequently, the MAS-SOA [11] approach has been proposed in order to take advantage of the benefits offered by web services —autonomy, interoperability, encapsulation, availability and discovery— and software agents —adaptability, proactiveness, reactivity, rationality, sociability and autonomy [16]— within a single unit of process such as a service-based agent.

2.1. MAS-SOA approach

The MAS-SOA approach has been realized in specialized frameworks [17,18] and practical applications [13,19]. Its main goals are focused on developing interoperable applications through the modeling of agent actions based on web services that can be used independently of the platform in which they were deployed. To achieve the agent goals, the developer can adopt two mechanisms, the modeling of the agent behavior in base of agent actions as static invocations of web services as well as the modeling of the agents in terms of search strategies in order to discover dynamically the suitable services.

In the first mechanism, agents must invoke one or more web services to execute specialized processes (e.g. algorithms, reasoning processes, data accessing, data validation, data fusion). In this case, the execution of the agent actions is merely sequential and, consequently, if the control flow is blocked by a failure, then the agent could not recover from that failure by itself.

In the second mechanism, a generic behavior have to model in terms of external services required by the agent. The agent can recover these services directly querying on distributed repositories such as the Yellow Pages implemented by the Java Agent DEvelopment Framework (JADE). In this way, the agent can be recovered by itself if any service fails.

The two possible strategies described above have had undoubtedly a positive impact on the development of modular MASs. In fact, the main benefits arising from merging of MASs and SOA revolve around self-adaptive, lightweight, fault-tolerant agents. Nevertheless, distributed systems based on SOA are recently scaling towards ROA [20] because RESTful web services has greater flexibility and lower implementation overhead than SOAP web services [21,10].

2.2. *MAS-ROA approach*

Resource Oriented Architecture (ROA) is an architectural style for distributed computing that proposes the design and development of software modeled by means of resources [14]. A resource is a distributed component that has a standard common interface through which it is directly accessed [20]. In general, the resources associated with REST architectures are implemented by RESTful web services [21]. This kind of web services expose data-types and functionalities through Uniform Resource Identifiers (URIs) supported by four web methods such as POST, GET, PUT and DELETE. From these methods it is possible to create, retrieve, update and delete resources, respectively [21].

MAS-ROA can be defined as a novel approach in which a multi-agent system is modeled as a set of single agents that achieve their goals from invoking a set of resources (implemented as RESTful services) distributed on the web. The use of such components enables agents to enhance the same properties reached by MAS-SOA agents. However, new benefits can be achieved such as a higher scalability, an improved uniform accessing, and a better performance in contrast to MAS-SOA agents [21]. These features are described as follows:

- *Lighter-weight smart agents.* The intelligence of the agents can be distributed for both architectures, MAS-SOA and MAS-ROA. In both cases, agents can be designed by decoupling the complex actions of the agent's internal structure and, consequently, the agent will be more lightweight. However, in the case of agents that adopt the MAS-ROA philosophy, they provide a better response time in the actions executed by invoking RESTful services [21].
- *Improved uniform accessing*. MAS-ROA's agents are compatible with the invocation of resources through URIs —typical of the modern Web. Thus, agents can

communicate and control diverse type of entities (e.g. agents, IoT-objects) and applications (web, mobile, ubiquitous). In addition, the use of a uniform interface facilitates user-machine and machine-machine interaction as IoA and IoT ecosystems demand.

- *Adaptive agents*. MAS-SOA agents incorporate a service discovery mechanism from which agents can determine at runtime the web services required to achieve their goals. This mechanism can be easily extended to the MAS-ROA approach in order to provide a more flexible mechanism. Therefore, agents can discover external counterpart agents dynamically and execute collaborative tasks with them invoking their corresponding RESTful services, in a scalable way.

3. Multi-Agent System based on Resources-Oriented Architectures (MAS-ROA)

A MAS-ROA architecture can be applied for developing general distributed MAS for web, mobile or ubiquitous applications. However, the reference architecture proposed in this study is specific for accessing and controlling IoT objects. These architecture is illustrated in Figure 1.

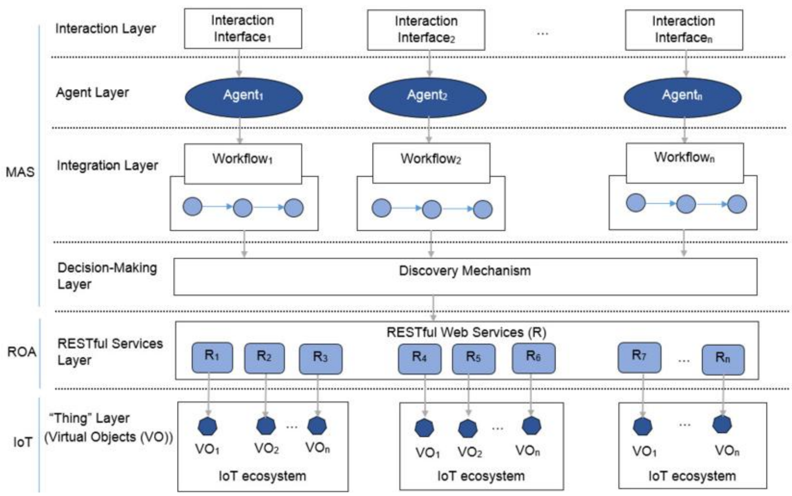


Figure 1. A reference architecture for MAS-ROA.

In general, the proposed MAS-ROA reference architecture (Figure 1) has been described using the N-layer architecture. Specifically, the architecture is composed of six layers such as: thing, service, decision making, integration, agent, and interaction layers.

At the lowest level of abstraction is the layer called *"Thing" Layer*. This layer is independent of the MAS-ROA architecture. It mainly consists of physical objects or "things" available in IoT ecosystems (e.g. sensors and actuators). This layer can include resources provided by middlewares such as openHAB —a specific platform that can access to resources associated with physical objects.

At the next level is the *Resources Layer* or ROA Layer. This layer manages and registers the RESTful services that enable the access to the available resources in IoT ecosystems. The deployed services are only functional components that execute actions over the IoT objects. In this level, these services cannot operate proactively.

Then, the *Making-Decision Layer* is in charge of accessing the RESTful service repositories in order to discover the most suitable services to meet a specific objective. This process is performed based on the context and data required by agents (e.g. the temperature and the humidity to control HVAC system).

The data requirements used by the *Making-Decision Layer* are determined on the basis of a control logic (workflow) from which the objects connected to one or more IoT ecosystems are accessed and controlled. Therefore, a workflow defines the sequence of invocations of specific resources that must be executed to fulfill the goals associated with the *Agent Layer*.

Finally, at the highest level of abstraction is the *Interaction Layer*. This layer enables agents external users and applications (e.g. web, mobile) to make requests for monitoring the conditions of IoT ecosystems and objects connected to them.

3.1. Agent model

Based on the MAS-ROA reference architecture (Figure 1), each agent must execute a set of tasks to manage its life cycle as well the interaction to other external entities over four basic components including: communication interface, discovery mechanism, control workflow and the agent execution environment. These components are illustrated in Figure 2.

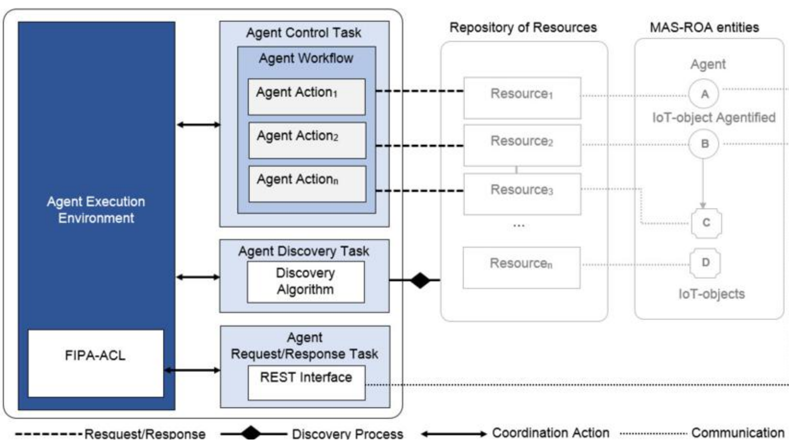


Figure 2. General schema of an agent based MAS-ROA approach.

3.1.1. Agent Request-Response Task

The communication process in a MAS-ROA is essential. An agent can communicate with external agents, IoT-objects and even with users. To address this issue, a specific task called *Agent Request-Response Task* is integrated into each agent to handle the interaction to other entity (e.g., IoT object or agent). In agent-agent interaction, the agent sender invokes a request to a specific REST interface identified by an URI in order to send a message to other counterpart agents using the Agent Communication Language (ACL) proposed by the Foundation for Intelligent Physical Agents (FIPA). Once the request is mapped to a FIPA-ACL message, counterpart agent can receive that message. After the message is processed, a response is returned by agent receiver to agent sender through REST interface. Figure 3 illustrates the corresponding schema.

The use of URIs to carry out MAS-level communication in MAS-ROA facilitates uniform communications over web, mobile and IoT applications. Additionally, the communication processes in MAS-ROA are mapped with the parameters of a FIPA-ACL message (e.g. sender, receiver, content, language, encoding) in order to maintain support with the agent communication standard.

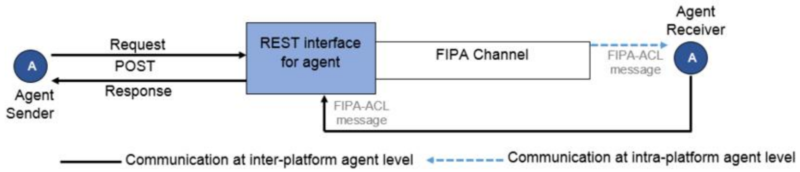


Figure 3. FIPA agent communication via REST.

3.1.2. Agent Control Task

This task is in charge of executing the control actions addressed by workflow over the objects connected to the IoT ecosystems. A workflow is the control unit that contains a description of the sequence of actions that the agent must perform to achieve its goals over the IoT ecosystem where the agent runs. The execution of the specific actions into the workflow is driven by the invocation of one or more requests to RESTful web services to get access indirectly to external resources (e.g. physical IoT-objects).

As Figure 1 shows, a workflow W_i can involve one or more invocations to specific RESTful web services $W_i < R_1, R_2, R_n >$. These services are found through a discovery mechanism executed over distributed repositories on the Web. Therefore, agent can select dynamically the suitable web services at runtime in order to fulfill its resource demands, and even change these web services by other ones when it is required (e.g. faults in servers, resources or IoT-objects).

3.1.3. Agent Discovery Task

This task is responsible to find the candidate web-services required by an agent when the workflow is executed. This task is executed frequently at different times of the agent's life cycle, such as: when the agent starts for the first time, while the agent has not completed its workflow, and when its workflow presents inconsistencies; that is, when some of the previously discovered resources report a failure in its operation.

The service discovery process consists of mapping the repositories of resources in a similar way as the JADE Yellow Pages mechanism does. This mapping process is based on a specific criteria which is based on the location context and data provided by the IoT-objects; for example, the temperature and humidity magnitudes of the room of a smart home.

3.1.4. Agent Execution Environment

The agent model employed by the MAS-ROA approach follows the guidelines of the reactive agent model. This model of agents provides autonomy based on the stimulus-response model with the capacity to react to changes in the environment in which it operates [16].

The *Agent Execution Environment* introduced as part of the agent model proposed for MAS-ROA synchronizes the life cycle of the agent. Taking into account the wide use and efficiency of the JADE framework, we recommend its use to implement this component. However, it is possible to use other frameworks (e.g. Jadex, Jason) [22], but the selected framework complies with the FIPA-ACL standard in order to ensure functional interoperability between agents that run over both intra-platforms and inter-platforms of agents distributed on the Internet.

4. Experimental evaluation

Some experiments are conducted in order to evaluate our proposed MAS-ROA architecture approach to control an IoT ecosystem through RESTful services. The experimental tests have been focused on evaluating the performance of the workflow of two agents invoking RESTful services and their capability in terms of communication (at intra-platform and inter-platform level), adaptation (performed by users and the agent itself), interoperability (using resources deployed on heterogeneous ROAs), and the capability of cooperation for the accomplishment of goals.

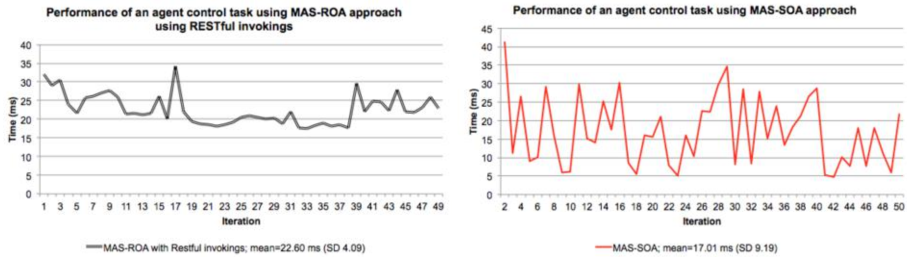
4.1. Scenario of IoT

This scenario consisted of four IoT-objects installed in the room of a smart home from which thermal and lighting comfort to their inhabitants must be offered. These objects —illumination sensor (IS), light bulb (LB), temperature sensor (TS) and heating system (HS)— were implemented with the openHAB platform because it provides a gateway for accessing to the physical IoT-objects through a REST interface.

Data associated to the resources IoT-objects were handled according to two workflows focused mainly on providing thermal ($W_{thermal}$) and lighting ($W_{lighting}$) comfort to inhabitants. The logic of control of $W_{thermal}$, specifies the necessity for reading the room's temperature (TS) and setting the heating system (HS) coherently. Likewise, the logic of control of $W_{lighting}$, defines the necessity for reading the room's lighting level (IS) and setting the light-bulbs (LB) installed in the same location.

4.2. MAS-ROA: workflows performance

We test both $W_{thermal}$ and lighting $W_{lighting}$ workflows —over a laptop with 2.5 GHz i7 Intel Core , 16 GB RAM and Windows 8.1 operating system— in order to compare the times required to be fully processed with an equivalent application based on MAS-SOA. The obtained response times are shown in Figures 4-a for MAS-ROA (invoking resources with HTTP dynamic Client) and 4-b for MAS-SOA (invoking services with the DPWS framework) after the execution of 50 iterations.



(a) Workflow based on MAS-ROA (b) Workflow based on MAS-SOA

Figure 4. Times required for processing (a) workflows based on MAS-SOA (using HTTP Dynamic Client) and (b) workflows based on MAS-SOA (using Devices Profile Web Services).

The response times required for MAS-SOA and MAS-ROA show that the workflows based on an architecture MAS-SOA required an average of 17.01 *ms* while in the case of the equivalent workflows based on MAS-ROA was required 22.60 *ms*. Although some previous works have shown an important difference between the performances of SOAP services compared to RESTful [21] services in favor of the last ones, our experiment tests seems to contradict this result (only 5.59 *ms* equivalent to 24%). The found differences depend essentially in a large extent on the technologies used. In MAS-ROA the OpenHAB platform introduces a complex framework to get access by a REST interface to heterogeneous physical IoT-objects. In contrast, MAS-SOA is implemented on lightweight services oriented to resource-restricted devices such as DPWS.

4.3. MAS-ROA: Communication performance

The communication performance was evaluated adopting a MAS-ROA agent through both the (i) JADE Gateway and a (ii) REST interface. The results obtained are illustrated in Figure 5. In general they show an increase of 76% of the time required by (a) respect to (b) to send a FIPA-ACL message and the corresponding response. However, despite the slight increase in the time required to communicate with an agent via its REST interface, the adoption of this mechanism facilitates greatly the communications at the level of inter-platform agents since the appropriate parameters are setting and encapsulated to avoid errors in communications. Even so, to minimize the time penalization of the MAS-ROA systems, it is possible to adopt a JADE gateway for the intra-agent communication process, which provides a FIPA communication mechanism at a lower level than the REST communication interface.

4.4. Additional evaluation

Further qualitative aspects were evaluated during the quantitative experiment, such as the scope for agent adaptability, and the support for interoperability in MAS-ROA. In summary, the agents invoked successfully RESTful services deployed in heterogeneous ROAs as long as those services had previously been publicly published in the Resource Directory. Additionally, the agents had the ability to manifest self-adaptation and external adaptation. On the hand, self-adaptation was accomplished by agents, which at the moment of receiving inconsistent responses from the current IoT-objects defined in their

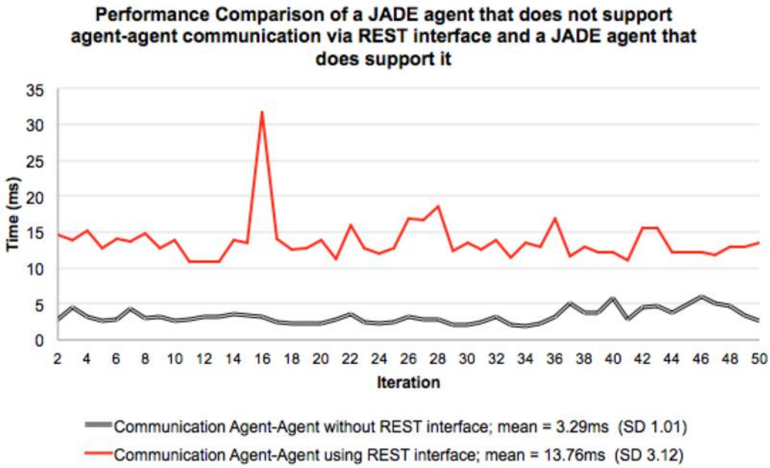


Figure 5. Times required to send&receive a FIPA-ACL message with the JADE Gateway and REST interface.

workflow, they are able to discover new equivalent REST services in the resource ecosystem. Hence, they can be recovered from resource failures. On the other hand, the external adaptation was also successfully supported by the agents after end-users changed the current workflow managed by the agent in observation. From this experience, it is recommended to create one or several workflows for each IoT-object so that agents can manage them consistently.

5. Conclusions

Resource consumption on distributed systems is currently a trend. The results obtained in this study show that agents based on SOA (DPWS services) and ROA (RESTful services) does not imply an excessive extra cost in terms of performance. Merging MASs with ROA allow for better performances because HTTP invocations use lightweight messages than generic SOAP web services [21]. However, this study has demonstrated that invocations on lightweight SOA infrastructures such as DPWS have quite similar results to RESTful services.

The use of URIs for establishing the agent communication facilitates the automation of tasks on IoT agentified scenarios because users, agents, IoT-objects and external applications (e.g. web, mobile) can interact uniformely in order to control heterogeneous IoT ecosystems. In any case, agents based on our proposal are capable to manage communications, control of IoT-objects and user-interaction using a same style. This enables interoperability between heterogeneous IoT ecosystems, agent platforms and external applications as real IoA applications for smart cities, healthcare, and smart industry demand.

MAS-ROA is a useful approach to perform the process of agentification of the IoT. In fact, our approach enables agents to coordinate control actions over IoT-objects deployed on heterogeneous ecosystems in a proactive and smart way by using a workflow that is prepared and put into operation at runtime by the agent itself. This mechanism helps us to carry out the adaptation of agents by both end-users (updating the workflow instance) and the agent itself (updating invocations to new resources). In addition, the adoption of MAS-ROA agents provide more lightweight MASs that can run within the IoT-objects themselves.

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Intelligent Environments 2018
I. Chatzigiannakis et al. (Eds.)

Subject Index

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Intelligent Environments 2018
I. Chatzigiannakis et al. (Eds.)

Author Index

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Intelligent Environments 2018

The term ‘intelligent environment’ (IE) refers to a physical space in which IT and other pervasive computing technology is interwoven and used to achieve specific goals for the user, the environment or both. IEs have the ultimate objective of enriching user experience by enabling better management and increasing user awareness of that environment. The accelerating pace of technological development calls for the realization of innovative IEs; something that scientists, researchers, and the general public would all like to see.

This book presents the workshop and tutorial proceedings of the 14th International Conference on Intelligent Environments (IE18), held in Rome, Italy, 25-28 June 2018. The conference focused on the development of advanced intelligent environments, and the 9 workshop and 9 tutorial proceedings included here emphasize the multidisciplinary and transversal aspects of IEs, as well as covering a number of cutting-edge topics, including: smart cities; environmental protection; smart sensing systems; personalized health and intelligent workplaces; ergonomics; healthcare; and education and learning.

Reflecting the latest research developments in IEs and related areas, this book will be of interest to all those interested in stretching the borders of the current state of the art and contributing to an ever increasing establishment of IEs in the real world.

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