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Creativity and Machine Design

Robots and machines have become very prevalent within recent years. We use robots to assemble cars, explore dangerous areas, and even as servants to clean our houses. In the future, we might even see robots help in delicate complex tasks like performing surgery. Many people think that the process that goes behind designing a robot is unimaginative, involving a lot of dull equations and assembly lines. In reality, the design process can be very creative.

While the process behind designing a machine is creative, it should be noted though that eventually engineers were going to design robots to perform these tasks. Leonardo Da Vinci sketched early ideas for a helicopter in the thirteenth century, which only became a reality in twentieth century. Robotic maids that can clean the house was a futuristic idea that was seen in the 1960's cartoon "The Jetsons", but the idea of having a robot vacuum the floor has only became popular in the last year or so with iRobot's Roomba. Once engineers found the way to control their machines through the use of microcontrollers and programming, the cost effectiveness and precision of machines enabled them to be used in a wide variety of tasks. Although the ideas for the next tasks for machines may not be creative, the process that goes into developing that machine is a creative process.

One of the most popular vacuum cleaners at this time is iRobot's Roomba. The creative engineering behind the Roomba enables the robot to much less expensive when compared to other robotic vacuums of the same size. Most of the other robots use a complex set of sensors and integrated programming to navigate across a floor. The Roomba on the other hand uses a creative and inexpensive system of infrared sensors in order to keep the price and complexity to a minimum.

MIT's Introduction to Design and Manufacturing class, 2.007, teaches the entire design process. The class is also a contest in which the students' machines compete on a large obstacle ridden table. Each round is only forty-seconds long. Each machine must be under the ten pound weight requirement and under the size constraints. The students are only given a limited amount of materials to construct their machine. The course tries to combine the creativity aspect of machine design with the precise nature of engineering. When first starting to work on the problem, the students usually come up with a large number of underdeveloped ideas. In order to organize and develop our ideas, we are taught to follow the provided design process. In the very beginning, the students are told to only think about the various methods to score. By playing around with the table enough, a student can start playing around with the table in his or her mind. This thinking produces the useful insight and information necessary to build the machine. The course also uses a funnel design method, where the previous decision leads to a new branch of ideas and decisions. For example, thinking about one strategy can lead to 5 concepts that can execute the strategy, and one of the concepts can lead to 5 different modules. This type of thinking is seen in T.F. Hanson's Engineering Creativity. Hanson calls the set of decisions his Decision Tree, which is a way to "attempt to organize our attack on the design problem" (1987, p.64). At the center of the tree is the first decision made which all other decisions stem from. In the case of 2.007, the student's strategy would be in the center. Out from the center come various branches, going out further and further as the number of decisions increase. In 2.007, the next branches would be concept, modules, and components in the order of increasing decisions. The tree is broken up into 6 or more sections, depending on how many designs you are thinking about. This Decision Tree provides a great way to compare and see all the different designs after each decision.

The first step in building a machine is the design phase. In this phase, the engineer first must identify what the problem is. In the case of the robotic vacuum cleaner, the engineers had to find a way for a robot to clean the floor. As simple as it sounds, there are actually a lot of solutions to this problem. The robot can clean hardwood floors, carpeted floors, or both. The robot can do wet floor cleaning or dry floor cleaning. The robot can be autonomous or remote controlled. It almost seems that there are an infinite number of ways to clean a floor. However, the ultimate goal of the project was to get the most profit out of selling its robotic vacuum. In addition to wanting a lot of people buying their product, the company also wanted to minimize the costs to produce it. These constraints are the creative factors of the design process. Without the constraints, any simple design would work. For example, if there were no constraints in building bridges, than even a piece of cardboard would suffice for a bridge. The constraints are what force engineers to think up of new creative ideas which meet all the desired requirements. In the case with the robotic vacuum cleaner, the company decided that an autonomous, yet random, carpet cleaning robot would appeal enough to the customers to buy it while keeping production costs low enough to generate the maximum profit. The use of a simple system of infrared sensors, instead of usual array of complicated sensors, was the company's creative solution to a robot that can cover the majority of the floor while being relatively inexpensive. This balance of low costs and functionality is what made the Roomba a popular robotic vacuum.

In the case of the 2.007, the students had to find the way to score more points than their opponent. The possible scoring methods included dumping mass into the mass bin, rotating the paddle wheels, and pushing the time elapse button. The robots could also prevent the other robot from scoring, like setting up a fence to block their opponent's mass bin. The main constraint was the forty-five seconds allotted for the contest. In order to figure out what was the way to get the most points, the students had to look at the scoring equation used to determine the final score. By graphing the different variables, the students were able to determine that putting mass into the mass bin first and then spinning the paddle wheels was the best way to score. This is why most students ended up building a fool-proof way of obtaining a shot-put.

When first thinking about solving an engineering problem, the numerous factors and variables may seem overwhelming. The mind starts to fill with all sorts of numbers and new ideas start to arise. While most would think an engineer's job is instantly find an answer to the problem, Hanson does not believe this is the case. Hanson states that the creative engineer goes through an "incubation period" when the engineer should "deliberately avoid thinking about the problem" while "not engaging the subconscious in another creative problem" (1987, p.20). In this period, all the information and numbers the engineer first saw when he or she first approached the problem becomes subconsciously manipulated in engineer's mind. While the engineer goes about his or her daily life, the subconscious continues to manipulate the numbers until it gets an answer. At this moment, the engineer is overcome by a "sudden flash of insight" and solves the problem. The engineer's subconscious is able to manipulate the variables thanks to the engineer's imagination. Irving Singer talks about imagination and possibilities in his book <u>Feeling & Imagination: the Vibrant Flux of Our Existence</u>. Singer explains that "imagination belongs to our awareness of all other types of possibilities" (2001, p.32). The imagination allows the engineer to tinker around with all the possibilities in an attempt to solve the problem. Engineers can imagine what will and will not work by using their imagination in addition to several idealizations based in fundamental physics. Singer states that the "intellect constructs ideas of what shall count as perfections" in order to compromise with the imperfect cosmos (2001, p.69). Complex systems have a lot of complex physics that explains the system's behavior, but only a small number of the factors contribute a significant result. For example, if an engineer wanted to study a vibrating object, the engineer can linearize the system in order to make the calculations simpler. This approximation though is only valid under small perturbations. Otherwise, the ideal imagined system no longer models the realistic system. The engineer's imagination may want to construct a very tall and elaborate building, but the idealizations remind him that all the forces should not cause the building to buckle in.

Luck also seems to be a factor in the design process. For example, Alexander Fleming mistakenly discovered penicillin after returning from vacation. Fleming apparently forgot to wash his Petri dishes and returned to see something growing on the dish. He noticed that the mold growing on the dish had no bacteria around it. He found that the mold secreted a chemical to fight the bacteria. This became known as penicillin. Fleming was creative for realizing that mold could be used to fight bacteria. The normal idea is that mold is almost as dirty and germ ridden as bacteria. Who would have thought one rotting blob could prevent another rotting blob? John Sheehan in his article "On Applied Science" states that "through the flexibility of the method [we] synthesized a number of variants of the molecule" (1960, p.97). The other researcher's creativity was seen as they manipulated the penicillin to get different variants with different advantages. Penicillin is now used frequently to save lives as a strong anti-biotic.

While luck can lead to a creative idea, total concentration on a problem can also have the same effect. Alex F. Osborn writes in his book Applied Imagination that “all-out intent begets an all-around awareness which also helps us creatively” (1957, p.195). When dealing with a lucky situation, the person must be aware of the problem and all the information behind it in order to take advantage of the lucky opportunity. If Fleming had not been aware that the mold was repelling the bacteria, he may not have discovered penicillin. Putting in a lot of attention on the problem can raise alertness. If a person only thinks about the problem, even the minutest detail becomes very apparent to the researcher. When a small change happens in an experiment, like how the mold repelled the bacteria, the person will be notice it and start to develop a creative solution to the problem. Osborn continues to write “as awareness goes beyond receptivity, it becomes active curiosity” (1957, p.195). This curiosity keeps the researcher asking questions in order to solve the original problem. Eventually, the researcher will ask the question that will lead to an important piece of information in solving the problem. Lastly, Osborn states that “we tend to overestimate the power of inspiration and wait for lightning to strike us” (1957, p.196).

Sometimes, if a researcher just continues to work on the problem, eventually an answer will come. By continuing to work, the researcher's awareness increases because the problem is now a significant part of the researcher's life. The increase in awareness may help the researcher catch an important fact necessary for solving the problem.

Most people think that creative people are naturally isolated from the rest of society. The idea of the starving artist always brings up the idea of an outcast who lives by themselves in a dark apartment trying to create something new. While engineers are not normally seen in this way, a lot of engineers like to think on their design problems alone. Hanson writes "the history of creativity seems to support this theory, since it lists achievements by individuals rather than teams" (1987, p.22). When a group of creative engineers are together, everyone's ideas tend to interfere with each other. Usually, the most outspoken engineer ends up convincing the other engineers that their idea is the best. Hanson adds "a creative thought may occur to someone in a committee meeting, but it probably means that person was not paying attention to the meeting" (1987, p.23). Once the engineer gets an interesting idea, that person's mind starts to play around with the idea and possible uses. That person may be missing the meeting, but at that moment nothing other than the idea matters.

While the engineer would like to think creatively by themselves, most companies set up groups to tackle new products. Hanson states that the communication between creative engineers is “comparable to linking two or more computers using Samuel Morse’s first telegraph” (1987, p.22). An engineer can understand their own idea really well, but the idea becomes convoluted when that person tries to convey it another person. This causes a really good idea to turn into an unappreciated bad idea since no one can understand the concept.

Some classes at MIT have started to teach a new process that will help communications between students working on design projects. In 2.007, the students are required to use the Peer Review Edit Process, or PREP for short. The students develop ideas on the problem individually, so not too stifle each other’s creative process. The student then must jot down the pertinent equations and a clear description of physics involved. The student should be able to describe the physics as this shows a clear understanding of the problem and clearly describes the problem to the other group members. Then the group comes together and comments each other’s ideas. After looking over all the comments, the individuals back and improve on the ideas. This process enables the individual to be as creative as he or she wants while expressing his or her idea to the entire group.

The first step in the design process is to gather all the necessary number, which allows the engineer's mind to play around with all possibilities. However, sometimes the engineer doesn't have all the numbers necessary. The engineer has several options to get around this. The engineer can either estimate the numbers for a quick reality check or run an experiment to get the numbers. Choosing what experiment is also a creative process. Sheehan states that there are two types of science. The sciences are the "purely pencil-and-paper [science] of coordinating data or perhaps trying to extrapolate the data a bit; the other trying to design experiments which will uncover new principles and furnish new data for the theoretical person" (1960, p.95). The engineer that performs all calculations by hand is not creative. That person is not creating a new equation or new method to solve the problem. Once this engineer runs into a problem that has not been encountered before, he or she will no longer be able to solve the problem because there is no equation to solve it. The experimental engineer will only need to apply the design process to his problem to find a new solution. In this case, the problem is how to extract the missing data. The engineer will then proceed to digest all the information and come up with a new way to get the necessary numbers. This experiment might even lead to a new equation, which the pencil-and-paper scientist can use.

If a computer were to create something, would it be labeled as creative? In August of 2000, researchers Hod Lipson and Jordan Pollack developed a system that was able to translate the computer's design into a prototype. The idea behind the system is called artificial life, where researchers try to build complex systems using fundamental theories of life, like natural selection. This simulation gives the computer a string of commands which act as an artificial genome. Each string tells the computer to build another device. The strings are also allowed to combine to make new systems. The devices where printed out using a new method of rapid prototyping. In the end, their computer built some systems that were able to perform basic locomotion. Does the fact that the computer made a machine make the computer creative? The ability to create something does not necessarily mean the act is creative. The computer is only following the program its owners have programmed into it. In this case, the programmers have programmed a natural selection simulation. In a way, the computer is under too many design constraints. The program only allows for one process to continue, while a creative person's mind actually undergoes different phases of design. The natural selection program chooses the next machine to continue using a range of criteria to find the best machine. However "there can be no feedback from the physical world into the evolutionary process".

What would happen if the environment changed, which would cause the criteria to change? The computer's machine may not be functional under these new conditions. While the computer may or may not end up with a functional machine, the creative engineer will always come up with some machine since he or she can always use a different thought process to find the answer.

The design process actually involves quite a bit of creativity. The problems and ideas for new machines are not necessarily creative. Technology is constantly evolving. When a piece of technology is cheaper and more efficient than the old method, technology will replace it. Part of the creativity come from the constraints placed on the problem. By finding and exploiting the constraints, engineers can come up with new and useful machines. In order to organize ideas and to get a better understanding of the problem, it is sometimes important to take a couple steps back and work on another task. This incubation period gives your mind some time to sort through all the information and hopefully give you a flash of inspiration. However, a flash of inspiration does not always occur. At times like this, it is best to sit and concentrate on the problem. Your increased concentration will make you more aware to the problem at hand, letting you notice small but important facts. This increased awareness can also help when luck happens to knock on the engineer’s door. Most creative people prefer to think alone because the ideas of others can stifle and interfere with their own ideas, losing a potentially important idea. The first thing to do when attacking a design problem is to get all the necessary information. If this is not possible, the creative engineer will perform an experiment to find the necessary information.

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