Sound and music transformation environments: A twenty- year experiment at the "Groupe de Recherches Musicales"

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Abstract

Since the 1970s, the Inaís Groupe de Recherches Musicales (Music Research Group) has been developing the computer tools needed for the creation of electroacoustic works by the composers it invites. The history of the successive projects and the conclusions that can be drawn, offer a wealth of information concerning the experience acquired by the researchers in contact with the musicians.

1 Introduction

For fifty years, the Groupe de Recherches Musicales has been one of the leading international centres for music research and creation, particularly devoted to electroacoustic music. Its major historical role since the first discoveries by Pierre Schaeffer in 1948, the keen interest expressed by the composers, from the fifties to the present day (Varèse, Messiaen, Stockhausen, Berio, Henry, Parmegiani, Bayle, Risset, etc.), and the considerable catalogue of works of all styles (about 1300) created in its studios, played in the concert hall or published on more than 70 records.... would never have been possible without intense experimental research, both into the production of increasingly powerful tools, and into validation of the conceptual or perceptive hypotheses which underpinned their production.

Right from the first confrontations between artistic desire and machine technology, the first diversion of tools from the radiophonic studio, Pierre Schaeffer and his colleagues felt the need for the design and construction of tools suited to the musical problems of electroacoustic composers. At the same time as developing its creative musical influence, the GRM has conducted sustained research and development activities, to which it to a large extent owes its name. From the first Phonogènes to the latest computer simulation algorithms, the objective has been unchanged: to offer composers a collection of accessible, operational, general-purpose tools, but which can be customised for independent utilisation ensuring that the creator enjoys full aesthetic freedom of choice.

From these fifty years of musical history and technological development at the GRM, we can discern five technological periods: concrete, analogue, non-real-time data processing, real time, personal microcomputing. To each of these periods corresponds a GRM research program, leading to the production of prototype tools offering the composers a universe for exploration of new worlds of sound, whose impact on their stylistic concerns is undisputed. The field of technological development covered and the wide variety of tools finally produced would seem to imply a disorganised and random series of works with little correspondence between them. But with the hindsight now available to us, it is clear that there has been a continuous objective in the production of the tools, whatever the technological period considered.

2 The GRM's tools

As early as the fifties, the duality of a pragmatic experimental attitude associated with a search for rationalisation undoubtedly marks the initial electroacoustic works: on the one hand the first stone in the foundations of concrete music, etching of a 78 rpm disk loop (the first sound loop) is an alteration of a standard etching procedure; on the other the functional rearrangement of several disk loop turntables played together is an immediate technological construction response to the emerging problem [1]. Since then, electroacoustic composers have constantly oscillated between diverting available industrial technological functions and solutions tailor-made to their desires.

Furthermore, before undertaking a historical review of the GRM's developments and tools, it should be recalled that they have always been designed for use by the composers - with no technical assistance - after very brief instruction. These composers are individuals with a high degree of artistic independence and musical skill but, with a few exceptions, have no scientific skills and it is not their role to replace the scientist and waste their energies on fundamental research.

2.1 Concrete and analogue tools

From the first Studio d'Essai de la Radiodiffusion (experimental radio broadcasting studio) of the fifties, the following standard diverted and reappropriated procedures should be remembered: sound recording, in particular close-ups, increasingly fine splicing of magnetic tape with scissors, transposed speed playback, time loop playback, increasingly complex mixing and the tape recorder playback head to record head feedback. A few scientific appliances were gradually added: bank of 30 bandpass filters, variable filters, etc. At the same time the most specific technological developments, the prototypes of which have unfortunately nearly all been lost, were transposition devices controlled by keyboard or slider, amplitude modulators (Morphophone) and the Phonogène Universel, without doubt one of the first multiple playback head harmoniser, built by Jacques Poullin in 1967.

A second period saw the birth of a number of specialised appliances: ring modulators, impulse trigger, feedback or echo chambers, and the first synthezisers. In 1965, a modular syntheziser was conceived by Francis Coupigny and subsequently built in 1971 by the Electronique Médicale et Industrielle company. In addition to the techniques already mentioned, it was the main attraction of the composing studio and made a significant mark on the sound of the works of Parmegiani, Bayle, Reibel, Malec in the 70s, both through its capacities - since unequalled - for rich polyphonies with self-synchronised oscillators using complex cyclic processes, and its ability to transform radical sounds: amplitude modulation, ring modulation, numerous filters, etc., controlled by the first gestural control devices.

2.2 The early days of computers, Studio 123

Alongside major developments in analogue synthesis tools and gestural control prototypes, a data processing research team was slowly built up, running early tests on a shared data processing system and jointly drafting a work dealing with the problems of frequency modulation, distortion, Music V and real time projects. The team initially comprised Bernard Durr and Pierre-Alain Jaffrenou, then above all Bénédict Mailliard and Jean-François Allouis, plus for a short time Denis Valette and Jean-Paul Toullier.

In 1978, the GRM received its first computer, intended for both research and composing. It was a "large" PDP11/60 mini-computer from DEC, using 16-bit calculation with floating point unit. A rewritten version of Music V was installed on it, but it was violently rejected by the composers. The harsh question then arose of whether or not to sacrifice the most well-known generation of GRM composers, obstinately opposed to the form and syntactical abstraction of a computer code. The solution to this dilemma was found when Jean-François Allouis wrote the first Studio 123 transformation software, designed to be independent and easy to handle, controlled by the predetermined conversational code enabling the basic parameters of an algorithm to be modified. The success of this simplified formula has continued unabated with the users. Under the leadership of Bénédict Mailliard, a brilliant mathematician, the project grew until 1985, when about thirty programs offered a vast range of transformations, from the simplest to the most sophisticated and which could be combined to provide the composers of the early 80s with an extraordinary selection of new sounds: editing-mixing, micro-splicing, resonant filters, very sharp filters, vocoders, spatialisers, etc. [2]. These tools, written in Fortran and still in service in their original form, are also happily explored by the students of the "Conservatoire supérieur de Musique" in Paris. Of the emblematic works of Studio 123, one should mention: Erosphère by F. Bayle, Sud by J.Cl. Risset, Don Quichotte Corporation by A. Savouret, Wind Chimes by D. Smalley. For a few years, the team comprised Bénédict Mailliard, Jean-François Allouis, Yann Geslin and Jean-Yves Bernier, who was subsequently replaced by Alain Dumay.

2.3 SYTER - a real time system

As compared with the efficiency and tangibility of traditional studio tools, non-real-time work is not natural to the GRM's composers and was only accepted with difficulty. In 1978, Jean-François Allouis laid the groundwork for a series of cabled processors known as SYTER (Système TEmps Réel). The Digilog company built about 10 examples of the most complete version from 1985 to 1987. It comprises a PDP11 type host computer containing a modular dedicated processor, graphic control accesses, to which are added input/output interfaces, hard disks and a midi interface. While offering computer power of 96 complex 24-bit integer arithmetical operators at 32,000 Hz, defined by low-level macro-instructions, Syter is above all equipped with a user-friendly programming software called SYG, which also provides interactive control and graphic visualisation of the data set parameters [3]. The Syter processor, based on a fairly general algorithm structure, was from the beginning suited to various applications: synthesis of all types, spectrum analysis computing, image processing. Following the path of previous research, the GRM emphasised adapting sound transformation algorithms: elementary filters, time processing, unit reverberators, etc., to which were added spectrum analyses, synthesis devices and then mixing and looping software. The CNRS laboratory in Marseille (Risset, Arfib) also adapted wavelet synthesis and phase-shifting devices for it. Several industrial and military projects were based on a Syter system and a recent version (Genesis) is proposed by Digilog. The career of the 123 non-real-time software continued on the Syter PDP11 host computer and the composers had a broad range of tools combining the high definition of non-real-time software with the interactivity of more restricted algorithms on the real time processor.

Syter was created by Jean-François Allouis, Jean-Yves Bernier (graphic writing) and Richard Bulski (wiring) with the subsequent help of Hugues Vinet for the editing software, Yann Geslin for the interface and André Prot, Thévenot and Oussin for the industrial developments by the Digilog company.

2.4 The GRM Tools

In 1991 Hugues Vinet initiated migration towards personal computing by developing tools for controlling the DSP 56001 cards from the Digidesign company. This was the DSP-Station, an environment which gave birth to a sound restoration tool, then GRM Tools, a group of fifteen music transformation algorithms, marketed as of 1992. The project was picked up in 1994 by Emmanuel Favreau and ported to a TDM Pro-Tools system and then a Steinberg VST environment [4]. GRM Tools are controlled via an interactive intuitive interface and are an elegant adaptation of the best algorithms explored on the GRM computers for a microcomputer platform accessible to all. Depending on the generation of Digidesign board concerned, algorithms for banks of linear phase filters, various other filters, harmonisers, unit reverberators, micro-splicing or even additive synthesis are proposed. As calculation of certain complex filters required high arithmetical precision, porting of the 123 algorithms to Syter and then to GRM Tools was at the expense of a drop in computer power and accuracy. In 1998, the most recent version, developed using native C++ code, promises accuracy easily equal to that obtained in non-real-time twenty years ago, but with an execution speed blurring the distinction between real time and non-real time.

2.5 Other projects: MidiFormers, Mars Station, Acousmograph

It is understandable that the main concern of the GRM researchers over the years has been constantly to improve the richness and variety of sound transformation tools, designed as the fundamental generators of the sound classes needed by the composers. Nonetheless, since 1990, given the explosion and diversity of technological options available to the musician, a certain transfer of know-how has taken place, in particular towards off-the-shelf items such as synthezisers and samplers. Thus a complex system for generating midi event streams with Max software was developed by Serge de Laubier in 1992 under the name of MacsOutiLs then MidiFormers, recreating some of the properties of granular synthesis, random variations, morphological accumulations. A second project is to apply a device of the same type to controlling the flow of events synthesised by an Iris-Mars station.

Finally, another field of research explores the field of scoring electroacoustic music, or at least and more modestly, the transcription of music already created. This project covers a vast range of applications which are not strictly musical, such as sonagrammes, phonological records. Initiated by Olivier Koechlin in 1988, it is now being continued by Didier Bultiaux [5].

It should be noted that all the developments described were the fruit of the work of a very small team, of no more than two to five people, aided from time to time by high-level students.

3 Examples of transformation algorithms

Of the many algorithms imagined by the GRM researchers, only a few were able to overcome the barriers of mathematical and programming feasibility, compliance with the power and wait time requirements, and actual sound benefits assumed and then proven with the users. Some categories of operations, warmly received by the users, gave rise to much reworking, retranslation and adaptation to the new computer platforms available. We will look at a few of the remarkable aspects of these tools, with regard to the determining or other aspects of their variants. We will intentionally omit all the basic and inevitable algorithms: filtering, signal correction and other utilities which make up a significant part of a studio.

3.1 Micro-splicing algorithms

Micro-splicing is an operation typical of concrete music, usually manual and time-consuming. When mastered well, this assembly of hundreds of fragments of several tens of milliseconds allows an amalgamation of heterogeneous sound materials, at the limit of the time discrimination threshold. Bernard

Parmegiani magnificently illustrated this technique in many works: Violostries, Dedans-Dehors. In 1979, he suggested to the team that this could be done using computers.

An initial version of the software called BRAGE (for brassage = shuffling) was produced in 1980, and then completely rewritten in around 1984. A version with random fragment size followed, then a version interpolating two sound files, which was rarely used. The particularity of these non-real-time versions is the ability to merge fragments of any size, sampled from a random field, also of any dimension: from a few samples to several minutes. Thus, apart from generating fusion phenomena, for which the algorithm was conceived, and which is now better known in terms of granular synthesis, the software was able to produce crossfading of textured sound and other sustained chords, infinitely small variations in signal stability, interpolation of fragments with silence or sounds of other types.

On the real time system, the algorithm had to be modified with a reduction in the time dimensions accessible, be it for the size of fragments produced, limited to the processor's RAM (barely more than a few seconds), or the random selection field, limited by the hard disk response time. Real time was however able to propose playback polyphony capacities and the addition of parameters adjusting the size of fragments and silences.

On the first GRM Tools, these dimension constraints were made worse (less than one second of memory), but have now been solved on the more recent versions. The addition of trajectory to the transpositions offers a higher quality of transformation, and devices displaying fragment dimensions and envelopes provides valuable help with understanding and controlling critical parameters. Finally, in the VST environment, the higher-power algorithm achieves a high degree of liberty in sizing and time positioning of the fragments.

3.2 Resonant filter algorithms

Another favourite of the GRMís composers is resonating a sound with a comb filter or a bandpass filter with a high overvoltage coefficient, using the principle of spectral movement imprint transfer. This operation, which is unknown to analogue studios, was proposed by J.F Allouis in 1979 and extensively developed and varied since then.

The first software (FLT), proposed a bank of 1 to 49 resonant filters, with a high Q value (1 to 10000), with a half-bandwidth of 1/10000 the filter frequency, giving inertia times of several hundred seconds. A cumbersome, controllable version followed, and then a vocoder version. The height distribution of the filters was for a long time a systematic equidistant distribution, which gave a strong tonal colour to the processing, before free or random distributions were proposed. I. Malec, F. Bayle and later on J.Cl. Risset made use of the capabilities of the algorithm with great success.

On Syter, calculation of the filter coefficient, which had to be performed by the host computer, and the arithmetical accuracy of the hard-wired processor limited the algorithm to production of 8 resonators with a short resonance period (1 second) but of controllable height. This is why comb filter algorithms were preferred and widely used, offering as they do a more pregnant harmonic colour.

The first GRM Tools continued development of larger numbers of comb filters, before VST again proposed a bank of large numbers of pure resonant filters of very high quality (RESON). Instrumentation of the parameters led to a use far different from the first versions and this is worth explaining: non-real-time, which is restricting and extremely time-consuming in terms of parameter description and response times, demanded constant filter bank settings. The composers became used to relying on variations in the source signals, which were then felt to be a processing control device and to playing them by careful selection, rather than endlessly trying to adjust the parameter settings. This philosophy, remarkable in its own right, is now too often forgotten, given that parameters can again be adjusted interactively in real time and immediately listened to.

3.3 Spatialisation algorithms

Spatialisation tools are constantly requested by the composers. Generally speaking, they are not generators of sound families, but rather enhancers, needed in the final phase of musical production. Nonetheless, unforeseen uses can produce unexpected synthetic effects. The first tools developed on Music V allows controlled amplitude and phase shift on two channels. A major project was then launched, to simulate shifting of one to four sources and recording of them on one to four channels, giving the effect of attenuation due to distance, Doppler effect, etc. (ELR) Versions with random movements, presence filtering, cardioid response, or first order reflection were made. A very real success, despite being penalised by the slowness of the computation, encouraged production of a simplified version for Syter, with two or four output channels, and then a version with echo effect (Doppler, Doprevqd).

The algorithm continued its career on GRM Tools, in a more convincing stereophonic version. A frame representing the shifts and rotary movements of the signal made it particularly fascinating to handle and above all allowed true understanding of the inertial devices proposed, whose effect on the movement parameters was delicately abstract.

3.4 A few failures

Rather than continuously blowing one's trumpet, it is also sometimes necessary to take a humble look at the obvious failures of certain experiments. We would here like to mention some tools which, although finished, no composer was able to use easily or even gain any musical benefit from.

A high *Q* bandpass filter of also unconditional stability, allowing control by frequency modulation was formalised by Bénédict Mailliard and made under Music V. This filter acted as a multiple band filter of height defined by the frequency modulation distribution law (fc, fc±fm, fc±2fm, etc.). In use however, the filter was seen either as a set of broadband filters correlated by frequency modulation, i.e. less flexible than independent filters, or, in the case of exceptionally narrow bandwidths, as nothing more than a simple frequency modulated oscillator. The failure to establish a tangible relationship between a broadband filter and a resonant narrowband filter led to the algorithm being under-used and finally abandoned.

The FLT resonant filter bank was converted into a resonant vocoder by associating a resonant analysis filter, amplitude detection, vocoder resonant filter control (VOC). The resonant filter bank was already seen as a tool revealing spectral movements, and thus a sort of vocoder, so transfer of this imprint to a second bank of resonant filters led to confusing redundancy of the device. The filters are thus used as a non-resonant bank, for which other algorithms would have been more suitable.

Finally, in attempting to meet the numerous needs of the users, some algorithms became so vast and generalised that handling of them became incomprehensible or uncertain. This is the case with several shuffling algorithms, which were overly general stretching, contraction, micro-splicing, mixing, superposition tools, simplified versions of which were often preferable. Elsewhere, other overly-technical tools, such as the linear predicting vocoder (PLI), offer a large number of parameters, which although operative, are never tested.

The example of these failures and analysis of their causes, compared with the real successes, enable us to envisage a few general operating principles for tools intended for composers of electroacoustic music.

4 Concrete attitude and procedures

Before considering a review of the completed data processing developments, it is important for us to recall our acceptance of the terms Concrete Music / concrete attitude, in order to clarify the orientations of the successive developments of the GRM.

Concrete attitude is often compared to collecting concrete or, in other words, real sounds. If, tautologically, sound recording is generally recording of what exists in nature, Concrete Music has from the outset always attempted to eliminate the nature of the source, either through the particular and exaggerated properties of the recording itself, or by successive transformations of the recorded sound. Collecting natural sounds, observing the clues to their origin is comparable to naturalistic or dramatic music and was explored at the GRM by composers such as L. Ferrari and M. Chion. For Bénédict Mailliard [2], concrete attitude consists in empirical exploration of the possible transformations of the sound. This attitude is induced by the medium of work, of sound fixed on a medium, for which no preconceptions are possible and no general method of results exists. All we have is a set of heterogeneous resources, proven and renewed experiments, for a step by step transition towards a finished, satisfactory target sound. Organisation of the sound transformations into a series of instantiations of given transformation operations, with particular and appropriate settings, is a reasonable method of progress in the search for new worlds of sound. GRM's tools have thus always been designed as a set of basic independent transformation elements, either simple or complex, which when combined, constitute the composer's tool.

4.1Algorithm and control instrumentation

One is accustomed to describing a signal processing tool in terms of the primordial aspect of the mathematical operation performed, and then execution of the algorithm. The usual success of an algorithm is, in our opinion, as much due to the quality of its instrumentation, in other words the organisation of its adjustment and control devices.

From one platform to another, the same algorithm, produced with exactly the same calculation resolution, does not always produce the same results. Musically speaking, the composers are led to explore variation movements determined by how they are presented with what is possible: parameter names, parameter units, command transfer curves, protection against untimely errors and limit overshoots, they all induce as many ways of understanding an algorithm and inevitably orient the direction of the user's explorations. Hence the importance both of the quality of the algorithm and the quality of what we call its instrumentation. Instrumentation is the set of devices used to present and implement the algorithm: name, number and nature of accessible parameters, choice of representation units, range of variations, variation commands, sometimes associated with (electro)mechanical gestural control properties.

For a better understanding of certain algorithms, it is sometimes necessary to modify the presentation of the settings, which is not strictly speaking a heavy mathematical task, but rather an ergonomic concern, which has often been neglected by the programmers. A transformation software such as shuffling, which covers an enormous time-related range, is exemplary: the result to a large extent depends on the unit and order of magnitude proposed for describing the size of the fragments: with a presentation in milliseconds, the user naturally produces granular synthesis effects, with a presentation in seconds, he discovers crossfading effects, but with a unit based on samples, he has little chance of obtaining fruitful results. On the current platforms, the quality of the computer environment and its memory capacity finally enable the question to be reconsidered and allow recourse to the numerous viewpoints proposed, whether it be through the example of pre-set memories, or by associated graphic representations.

Paradoxically, remarkably open and polyvalent environments such as Max, which are primarily programming environments before becoming operating interfaces, ignore these operating ergonomic aspects, not because they are impossible, far from it, but because the programmer who is often also the user, often no longer has the necessary resources or time for these improvements.

4.2 The studio, a coherent set of tools

We would also like to emphasise a highly specific aspect of sound transformation practice. Any transformation, no matter how powerful, will never equal or surpass synthesis, if it fails to maintain a causal relationship between the sound resulting from the transformation and the source sound. This is in particular obtained by respecting and even revealing the spectro-morphodynamic movements, the natural coherence of which is the most remarkable and interesting property of sound of acoustic origin. In other words, the practice of sound transformation is not to create a new sound of some type by a fortunate or haphazard modification of a source, but to generate families of correlated sounds, revealing persistent strings of properties, and to compare them with the altered or disappeared properties. Some composers attempted to formalise this sound transformation generation concept, for example D. Smalley and the spectro-morphodynamic notion [6], D. Terrugi and the Morpho Concepts [7]. One is rarely given the example of the successive operations required to produce a finished sound, even less the inevitable but ultimately fruitful wanderings involved in experimentation of tools. Better than any theoretical development, it enables one to grasp the unsophisticated, obstinate empirical experimental approach needed to produce electroacoustic music.

The sound generation experiment, whether applied to synthesisers or transformation devices, can only progress by building on acquired knowledge. In synthesis, the formalisation of the devices and resulting memorisable abstraction, offer a stable set of references which can be easily transposed from one environment to another. In sound transformation, no abstraction of the available results is possible and neither is generalisation. The result of an experiment is always the product of an operation and a particular sound to which this operation is applied. The composer must be able to add to the sum of knowledge by reproducing a previously proven experiment. If this is generally possible at a given time in a studio or given data processing environment, it is usually impossible to reproduce an experiment in another environment, owing to the excessive functional variations encountered. And in an environment of the same origin, unflagging research into improving algorithms or their development techniques by the developers makes it highly unlikely that the initial properties will be retained. The composers are at a loss because their knowledge is constantly called in to question and slips further and further way, dissolving into a vertiginous adaptation to constantly changing environments. The conservation of functionalities, however particular, or the emulation of old tools, although unimaginable at the time of electronic appliances, should be the rule in this age of virtual tools and software.

A complete environment of sound transformations should be seen as a traditional studio, that is a set of tools, from the most basic to the most advanced, from the simplest to the most complex, which can be combined and used in successive stages to achieve an unparalleled field of results. We will not therefore take exception to the fact that in any set of transformations oft-repeated, banal operations are proposed. They are always useful at one time or another. What makes the wealth and functionality of a system is the assembly and convergence of the whole, its ability at any moment to answer the questions imagined. Specific tools built for a single experiment, no matter how prestigious, are sterile if they cannot be applied to other purposes. Any set of imperfect tools which suggests the additional use of other environments and platforms is too restricted for any truly dynamic exploration. On this point, we prefer older but complete tools to promising but unoperational projects.

4.3 Tool validation

Strict separation between scientific research time and creative prospecting time lead the GRM researchers to carry out their developments relatively independently of the demands of the composers, and then have their work validated subsequently by trial by music. Even if it is common to describe a synthesising device, to evaluate the technique by comparison with a model and measure the effectiveness of the result, it is hard to appreciate the effectiveness of a transformation algorithm: mathematical elegance does not always justify interest from a musical viewpoint. Thus a few experiments were attempted to test the GRM tools: one was to propose a panorama of clinical transformations of a sound chosen for its polyvalent properties. The drawback was that no musicality could be revealed in this work, of interest solely to the technicians. Bénédict Mailliard in 1984 proposed the creation of a common work by twelve composers, consisting of short studies and called Germinal. For each study produced by free development of an initial musical cell, the tools under test give the key to the origin of all the sounds obtained, exclusively of all other means of generation. The result is a musical panorama, which is of less interest to the technicians...

In addition, we would also like to propose some keys to understanding the needs and expectations of the composers, who are after all those for whom the work and developments in question are chiefly intended.

- Intuitiveness / reproducibility. A real-time system proposes an intuitive approach to experimentation, in the immediate and highly reactive aspects of interactivity. A non-real-time system, controlled by described parameters, is strictly reproducible as it is formalized and abstract. The composer necessarily needs to use both these qualities: access to the experiment, in bearable conditions and with tangible means, but also with possible abstraction and rigorous renewability.

- Innovation / Durability. Proposing new and promising algorithms, offering them to the composers for production, only has a meaning if one wishes to guarantee continued developments and longevity for the tool. No matter how attractive, no innovation can replace a proven tool.

- Particularity / generalisation. The general tool, which deals with all situations, cannot exist, or is impractical. We prefer a network of particular tools, the combination of which offers an answer to a wide variety of cases.

- Arbitrary / rational. Most of the tools offered to the musicians are based on a scientific approach to sound, the signal and even the musical event. Offering the composers theories is to offer them a poisoned chalice of scientific justifications which they do not understand, in an attempt to make them scientists rather than producers of art. We suggest a more arbitrary approach, given that artistic creation is of necessity arbitrary. Some tools produced have nothing scientific about them and can even be seem as completely whimsical: micro-splicing, accumulation, ring modulation, etc. They are nonetheless tools for producing creations which only aesthetic judgement can accept or reject.

5 Conclusions

The construction of operational musical tools is a lengthy task, which to us mainly seems to fall within the remit of the research institutes. They alone can sustain such long term work and guarantee to the composers that the tools will survive. Contemporary creation cannot obey purely commercial considerations and can no longer be measured solely in terms of audience. Otherwise who, in its time, would have backed Concrete Music, frequency modulation, orchestras of loudspeakers, algorithmic composition or interactive environments?

6 Thanks

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