Technology and musique concrète: the technical developments of the Groupe de Recherches Musicales and their implication in musical composition

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When studying the history and evolution of the GRM, one of its outstanding features has been its continuous energy dedicated to developing machines, systems and, in recent years, software that would better serve composers' views and intentions. Unique discoveries were made that have become the fundamental concepts of sound manipulation and have influenced researchers and developers in the conception of new, but always somehow faithful to the original, tools for composition. Many steps pave this road, some are known and recognised, others were necessary failures that permitted inventors to re-focus and realise their thoughts.

1. THE BASIC CONCEPTS OF 'MUSIQUE CONCRÈTE'

Music, in its historical evolution, has always been concerned with technology – since the appearance of the first instruments and the desire to use sounds other than the human voice. A trend has always existed to improve instruments and make them more reliable and robust. When modern technology, derived from electricity, started to be used to make musique concrète, and later on electronic music, the existing technological objects (mainly record players, then tape recorders, filters, generators and reverberation units) were considered useful, but not completely adapted to the intentions of composers. The same reasoning probably induced the evolution of traditional instruments in times past; for example, the initial discovery that a tense string when plucked would make a pitched sound that would decay through time was progressively improved in order to guarantee a better control of pitch, a louder sound and a certain robustness – technological improvements thus opened the road towards stringed instruments.

But what kind of improvement could be made regarding simple mechanical systems such as a record player or a tape recorder? The use of a record player as a musical sound maker is in fact the result of an accident. When playing a record, the stylus is put on a groove and, from there on, the stylus follows the groove until the end of the track. If an accident appears on the groove, it may loop and read the same closed groove again and again, thus producing a continuous repetitive sound. This was one of the first accidents that caught the attention of Pierre Schaeffer at the beginning of 1948 and led him to using this and other techniques to make music in a different way, which he called 'musique concrète'. However, that historical 'ur-loop' did not occur at a chosen place within the record, it was produced within the sustained resonance of the sound of a bell (and not during the attack), so the result was a bell-sound to which the beginning and the end were missing. To Schaeffer's great surprise what he perceived was not a bell, but an oboe-like sound, which resulted from the absence of the attack.

The loop was continuous, with no audible clicks during the jumps because these were shellac records made with a metal base covered with a soft wax that was marked by a stylus during the recording (these were quite fragile objects). In fact, what is interesting about these loops is not only that the accident may loop a sound at an unexpected point, but also that it generates a repetition: a short sound fragment (up to one second) that repeats 'eternally' with no variation but produces a rhythmic pattern. A famous performance artist (Ben Vautier) once said, 'Repeat an event three times and you have Art!';[1] this could be the strength of the initial discovery by Pierre Schaeffer when exploring radio technology with a musical mind. Repetition gives birth to the first 'genes' of music and shows a path towards musical construction. Pierre Schaeffer explains the contours of the adventure in 1952:

> Any sound phenomena can be considered (as well as the words of language) through its relative signification or through its own substance. As long as signification is predominant, and that we play on it, we have literature and not music. But how can one possibly forget signification, isolate the 'itself' of a musical phenomena?
>
> Two previous actions must be undertaken:
>
> *Distinguish* an element (listen to it by itself, for its texture, its matter, its colour).
>
> *Repeat it*. Repeat twice the same sound fragment: there is no more an event, there is music![2]

[1] www.ben-vautier.com/
[2] Schaeffer, P. 1952. *A la recherche d'une musique concrète*. Paris: Éditions du Seuil, p. 230.

The loop provides two actions: *isolating* the sound fragment from a context and *repeating* an event to create an 'embryo' of music. It is not surprising that during the first years, sound-looping was the essential technique used in musique concrète. It produced an enchanting effect on the listener, mainly when the sounds were recognisable and bore fragments of signification. As an example of this, how captivating is the repetition of unfinished sound and phrases such as '*caff vieux moulin, caff vieux moulin*' or '*et dans la, et dans la*' in the first *Études de bruits* by Pierre Schaeffer, or the marvellous '*Oh … ho hó*' in the *Erotica* movement of the *Symhonie pour un homme seul*[3] by Schaeffer and Pierre Henry. Mysterious voices and mysterious meanings of lost contexts and circumstances!

It is also interesting to analyse the fact that loops are most generally repeated three times; if loops are repeated longer, it is because a new element has arrived and focuses our attention.

1.1 Sound objects and abstraction

As is clearly presented in Jean-Christophe Thomas's article 'Nature and the GRM' (see this volume, pp. 259–65), Pierre Schaeffer did not include in his music any reference to nature, or any recognisable sound – these *diaboli in musica* that 'corrupted' or dramatised the perception of music. In fact, what Schaeffer was seeking was the use of sounds with no relation to a specific meaning, that is, 'listen to it by itself' with no external signification that would pollute the perception. He was in the quest for sounds such as those produced by traditional musical instruments that can be manipulated and assembled relatively freely, with no confusion regarding the sources.

In the first *Études de bruits* this concept is not yet fully operational, which gives a delicate mixture of referenced and 'abstract' sounds to the works. Often the references are to musical instruments (such as the piano in the *Étude violette*), which are referential but to a sound domain that is immediately associated to music. The fundamental concept of 'sound object' that he forges at that period indicates his desire to obtain fundamental material that can be manipulated and combined as instrumental sounds are.

After this first experience, Schaeffer becomes less tolerant with signification and starts his quest for non-referenced sounds. His following work, *Suite quatorze*, in 1949, is mainly made of recorded instrument sounds, thus showing his concern for abstraction. Schaeffer's book *A la recherché d'une musique concrète* reveals the operational frustration he experienced when trying to find sounds appropriate to musique concrète.

This needs to be understood as the starting point for the technological developments: the need for tools that will permit sound manipulation and modification, with the objective of producing sounds that will be perceived primarily as forms and structure and less as anecdotes or language references. Instrumental sounds can be *combined*; however, concrète sounds have to be *modelled* before being combined. There is a need for modelling tools and techniques, numerous and different, in order to permit varied modifications that will produce different effects on sound and not produce results that seem too similar. Tools leave 'traces' on the sounds that they affect, and these traces can be easily detected by the ear. Once again, the 'loop' is a good example, through an accidental manipulation of a record it emerged as a possible music technique; however, our ear immediately recognises this identical repetition of events and its excessive use can transform it into a boring effect.

Technology was the issue for Schaeffer, or to put it in a more poetical way, a new sound-based music needed new instruments for its development. If not, as Schaeffer himself says, it would probably not have succeeded:

> It is probable that without this surgery, musique concrète would have remained in an approximate electronic noise making, sound enhancing or special effect results. However, the loop, which is also a technical procedure, had so huge effects, so radically opposed to any known musical language, that it imposed a new starting point.[4]

The objective is clear: working with sounds, applying to them a compositional thought, implies new procedures, technologies and techniques that need to be experimented, modelled and mastered. If the objective is to 'erase' from recorded sounds any referential allusion, tools must strongly affect the essential parameters of sound in order to create a 'distorted' perception of them.

A sound is a parametrical object that describes a form through time, with a certain spectral evolution. Since sounds, in the real world, are the results of actions on objects (real physical objects), our perception associates sounds through experience, with objects, actions or situations, thus neutralising the perception of the physical phenomena. In order to make sounds adaptable to a musical use, tools must 'detach' the reality associated to sounds so our perception will focus on the phenomena and will not be distracted by the references they may carry.

This was a very strong thought that prevailed through the first fourteen years of musique concrète: there were appropriate sounds for musique concrète ('objets convenables' Schaeffer called them); there were the more general sound objects, not all appropriate for music; and there were musical objects – any sound appropriate for music in its largest possible scopes (including instrumental music). After some years,

[3]Works available on Pierre Schaeffer, l'œuvre musicale, INA C 1006/7/8.

[4]Schaeffer, P. 1967. *La musique concrète*, Collection *Que sais-je?* Paris: PUF.

diaboli in musica finished by being introduced into electroacoustic music, and the first strong rules, and sometimes dictates, slowly disappeared to leave place for a more free and personal way of using sounds, for which every composer designs his personal contour. However, this first period in which many sounds were banned from music making has left its traces in the thoughts of many composers and has strongly influenced the tools that from the very beginning were conceived to achieve this abstraction objective.

To put it another way, even if the operational rules disappeared quite early in the history of GRM and of musique concrète, their influence has continued through time as an important reference thus generating a kind of universal rule: *do not forget that a sound, before signifying something, is a sound, and has to be mainly considered as that*. This idea permits any sound to be considered as a possible sound for music. We should always look for the sound 'itself'!

2. THE DIFFERENT TECHNOLOGICAL PERIODS

When analysing the history of technologies associated with musique concrète and its evolution through time (keeping in mind the evolution of the denomination: *musique expérimentale* at the beginning of the 1960s; *electroacoustic music*, also during the 1960s; *acousmatic music*, since 1974), there have been different technological periods with their specific tools and sound results. It may happen that the same tool or technique has been developed with different technologies; however, the results may not be the same because of the close relationship between the nature of the technology and the results on the sound.

Four main periods are found in the history of technology in GRM: *mechanical period, electronic period, digital mainframe period, personal computer period*. These periods are closely related to the evolution of technology as a whole and its application to the audio domain. For example, the invention of the miniaturised transistor, in 1958, clearly opened the door for the electronic period in our society and in music. All periods naturally overlap as long as the old technology can be maintained and still produce acceptable sound results; obsolescence may then be the result of the machine ceasing to work, or because its result is no longer considered as interesting. A short description of the periods introduces the different developments and their philosophy, which will be explained later:

- *Mechanical period*: ranging from 1948 to the beginning of the 1960s. Uses mainly electromechanical devices such as record players, tape recorders and plate reverberations, some electronic equipment, such as filters and oscillators, is already available.
- *Electronic period*: ranging from the beginning of the 1960s to the end of the 1970s. Introduces the advantages of the transistor, first synthesisers, complex mixing desks, source intermodulation, electronic reverberation and other processing systems.
- *Digital mainframe period*: ranging from the beginning of the 1970s until the beginning of the 1990s. First digital systems for sound calculating, outsourced first, then internally installed. Complex technical systems but the possibility to emulate any kind of sound processing. Non real-time and real-time.
- *Personal computer period*: ranging from the beginning of the 1990s to today. Miniaturisation of computers, accessibility, computers leave the institutions to become home-based systems. Speed and power are their main characteristics, allowing a huge range of sound synthesising and processing capacities (in fact the starting of this period can be placed earlier if we consider MIDI instruments, which appeared at the beginning of the 1980s, however, they were digital instruments more than computers).

It would probably be necessary to add a short perspective concerning our present Internet period. Even if the technology remains fundamentally the same, the way technology is used, through exchange, remote access and collaborative systems, is clearly influencing the evolution of technology even if its benefits may not yet be clearly visible.

2.1. The initial conceptual tools of *musique concrète*

If we turn our technological eye to 1948, the typical radio studio consisted of a series of shellac record players, a shellac record recorder, a mixing desk, with rotating potentiometers, a mechanical reverberation, filters and, of course, microphones for recording.

These machines permitted a limited amount of operations as follows:

- *Shellac record players*: could read a sound normally and in reverse mode, could change speed at fixed ratios thus permitting octave transposition.
- *Shellac recorder*: would record any result coming out of the mixing desk.
- *Mixing desk*: would permit several sources to be mixed together with an independent control of the gain or volume of the sound. The result of the mixing was sent to the recorder and to the monitoring loudspeakers. Signals could be sent to the filters or the reverberation unit.
- *Mechanical reverberation*: made of a metal plate or a series of springs that created the reverberation

Figure 1. A view of the studio in 1953. The two machines on the lower side of the image are the two *phonogènes*: the *chromatic phonogène* and the *sliding phonogène*. (copyright GRM).

effect, indispensable to force sounds to 'fuse' together.

- *Filters*: two kinds of filters, 1/3 octave filters and, high and low-pass filters. They allow the elimination or enhancement of selected frequencies.
- *Microphones*: essential tool for capturing sound.

Musique concrète exploits the functioning possibilities of the systems to allow strong sound modification. Among the techniques used by musique concrète to achieve this are:

- *Sound transposition*: reading a sound at a different speed than the one at which it was recorded.
- *Sound looping*: accidental procedure that created a loop within a recorded sound. Consequently, composers developed a skilled technique in order to create loops at specific locations;
- *Sound-sample extraction*: very skilled procedure that consisted of letting the stylus read a very small section of a record. This was hand-controlled and needed a very delicate manipulation in order to get a clean sample of the sound. Used in the *Symphonie pour un homme seul.*
- *Filtering*: by eliminating most of the central frequencies of a signal, the remains would keep some trace of the original sound but without making it recognisable.
- *Microphone*: used as a tool for capturing sounds, but also used as a magnifying tool to listen to the scarcely audible.

Two main trends appear in this description of techniques:

(1) If a sound has to be by 'itself', then the recognisable aspects of it must be erased, but keep the main characteristics of the sound. Filtering, transposition and microscopic microphone techniques were very effective for erasing the source reference and keeping the essential information available for a musical use. This is what is meant by 'sounds have to be modelled before being combined'. This allows the adaptation of sounds to their future context and the elimination, if wished, of their causal reference.

(2) Two tendencies were developing: non-contradictory and complementary in a certain way. The first tendency is to build a complex machine that will simplify the operations and permit a more regular and controlled result. As we will see, the phonogènes are a clear example of this. The second tendency consists of developing through practice a specific skill in a technique, such as loop making or sound-sample extraction. In the history of musique concrète, the arrival of Pierre Henry to the studio in 1949 brought a person who would develop extensive and new skills in the manipulation of accidents, and be very inventive in the compositional process. At the opposite end, Pierre Schaeffer would promote the construction of new machines that would simplify the operations on sound.

The first tape recorders start arriving in 1949; however, their functioning was much less reliable than the shellac players, to the point that the *Symphonie pour un homme seul*, which was composed in 1950–51, was mainly composed with records, even if the tape recorder was available. To show the duality of the tendencies, this extract from Pierre Schaeffer's journal, in 1948, clearly shows his 'despair' and concerns:

> 4 June 1948: There is no specific instrument to play musique concrète. That is the main difficulty. Or else we should imagine a huge cybernetic machine, capable of satisfying millions of combinations, and we are still not there. As long as I only have two of four shellac players, with which I can only realise approximate junctions, I will remain a terrible prisoner of a discontinuous style, where everything seems cut-off with an axe. Is there any possible compromise?[5]

The first five *Études de bruits* were composed with these limited techniques, however prototypical of the new way of conceiving and composing music. Even if these techniques pre-existed, it was their first utilisation within a compositional context. Moreover, whatever the hesitations of Pierre Schaeffer may have been, they reflect a new attitude concerning musical creation: the composer has the double responsibility of being the creator of his own sounds as well as the creator of his music, within a working situation in which he is permanently listening to sound and using a poorly cooperative technology in relation to his intentions.

[5]Schaeffer, 1952, p. 26.

2.2. The conception of the first original tools

The arrival of the first tape recorder, when it finally functioned in 1950, enlarged the techniques of musique concrète. New actions were possible on sound: the main improvement being to facilitate the manipulation of the media, and simplify operations such as speed variation. A completely new possibility of organising sounds appears with tape editing, which permits tape to be spliced and arranged with an extraordinary new precision. The 'axe-cut junctions' were replaced with micrometric junctions and a whole new technique of production, less dependency on performance skills, could be developed. Tape editing brought a new technique called 'micro-editing', in which very tiny fragments of sound, representing milliseconds of time, were edited together, thus creating completely new sounds or structures.

It is not surprising that Pierre Schaeffer, with the assistance of a very skilled technician, Jacques Poullin, started conceiving and constructing new machines derived from the tape recorder. Schaeffer had foreseen in speed variation an effective technique to modify the causality of sounds, while keeping their essential physical character. Three different machines were conceived at the beginning of the 1950s, each enlarging the manipulation possibilities of sound. The most well-known one was the *phonogène* (or sound generator) of which three versions existed: the chromatic phonogène and the sliding phonogène, both build in 1953; and the universal phonogène, only developed in 1963. The second machine was a *three-head tape recorder* that permitted the synchronisation of three tapes, build in 1952 and used for Olivier Messiaen's work *Timbres Durées*. The third machine was the morphophone, a tape-based multiple delay machine, also started around 1953.

2.3. The phonogènes

As explained earlier, speed variation was a powerful tool for sound manipulation. Since the very beginning Pierre Schaeffer had admired its modification potential:

> I obtained, while making a 78 rpm recorded record, turning at the speed of 33 rpm, completely remarkable transformations. Bringing the record to a speed a little bit lower than half the speed, frequencies go down more than an octave and the tempo is slowed down at the same rate. This change, apparently a quantitative one, is accompanied by qualitative phenomenon: The 'train' element, slowed down twice, is no more a train. It becomes a foundry or a furnace. I say furnace to make myself understood and because always a small bit of 'signification' remains attached to the fragment. However very quickly I perceive it as an original rhythmical pattern, and I deeply admire its profoundness, the richness of the details, the obscure colour.[6]

[6]Schaeffer, 1952, pp. 22–3.

The transformation brought by speed variation is indeed profound. When modifying the speed, we can observe a certain number of modifications in the parameters and structure of sound:

- A variation in the length of the sound, proportional to the speed variation ratio.
- The variation in length is coupled with a variation in pitch, always proportional to the speed variation ratio.
- The attack profiles are modified – either by dislocating it from the following events, or by concentrating the energy of the events.
- The spectral distribution is modified thus changing the perception of the timbre.

The phonogène was a powerful machine capable of strong modification of the sound structure and permitting an adaptation of sounds to the composition context. The two initial phonogènes were subcontracted to two different companies: the chromatic phonogène was built by a company called Tolana, the sliding one built by the SAREG Company. Pierre Schaeffer and Jacques Poullin obtained a patent on both machines, possibly with the view that it would have some success commercially.

The chromatic phonogène was controlled through a one-octave keyboard made by twelve reading heads, each associated with a capstan of a different size. A loop was put into the machine, and when a key was played, the related capstan would be put into contact with the associated head and the tape would move along at the defined speed. Only short sounds could be used, always through a loop.[7]

The sliding phonogène permitted a continuous variation of the speed by moving a control rod. The range would permit the motor to arrive at almost a stop position, always through a continuous variation. In fact, it was a normal tape recorder with an efficient system to control its speed, so it could modify any length of tape. One of the first examples of the use of the sliding phonogène (also called continuous variation phonogène) can by heard in the *Voile d'Orphée* by Pierre Henry (1953), where a very long glissando appears that symbolises the tearing of the veil by Orpheus when entering hell.

A final version of the phonogène was built in 1963 and was called the universal phonogène. Its main characteristic was the possibility of dissociating pitch variation from time variation, thus opening the road to two very popular techniques of the digital era: *harmonising*, which implies transposing sound without modifying its duration; and *stretching*, which modifies duration with no pitch modification. This was obtained

[7]See the *Solfège de l'Objet Sonore* series of examples after the *Traité des Objets Musicaux* made by Guy Reibel and Beatriz Ferreyra. It shows a dog singing 'Ode to Joy' in Beethoven's Ninth Symphony. INA c2010/11/12 475602.

through a rotating magnetic head called the Springer temporal regulator, an ancestor of the rotating heads used in video machines.

2.4. The three-head tape recorder

This original tape recorder was one of the first machines permitting the simultaneous listening of several synchronised sources. Until 1958 musique concrète, radio and the studio machines were monophonic. The three-head tape recorder superposed three magnetic tapes that were dragged by a common motor, each tape having its independent spools. The objective was to keep the three tapes synchronised from a common starting point. Works could then be conceived polyphonically, and thus each head conveyed a part of the information and was listened to through a dedicated loudspeaker. It was an ancestor of the multi-track player (four then eight tracks) that appeared in the 1960s. *Timbres Durées* by Olivier Messiaen with the technical assistance of Pierre Henry was the first work composed for this tape recorder in 1952. A very fast rhythmic polyphony was distributed through the three channels.

2.5. The morphophone

This machine, developed during this period, was conceived to build complex forms through repetition, and accumulation of events through delays, filtering and feedback. It was basically made of a large turning disk, 50cm in size, on which a tape was 'stuck', with its magnetic side looking towards the outside. A series of magnetic heads were distributed around the disk, in contact with the tape and their position could be moved along the circle. There were twelve heads: a recording head, an erasing head, and ten playing heads. The principle was that a sound was recorded along the looped tape (four seconds of sound could be recorded) and then the ten playing heads would read the information with different delays in relation to their position around the disk. Each playing head had its own amplifier and a band-pass filter in order to modify the spectrum of that sound; feedback loops completed the system and could send the information towards the recording head. The result consisted of repetitions of a sound at different time intervals, with the possibility of filtering and creating feedback. Artificial reverberations or continuous sounds could easily be obtained through this system.

These machines were quite impressive to look at – they were huge, sturdy and extremely heavy. During this period, most of the technical developments (except the phonogènes) were made internally within the radio facilities. There was a well-established tradition of sturdiness and physical robustness of machines.

Figure 2. A global view of the morphophone (copyright GRM).

2.6. Spatial control systems: the 'spatial distributors'

During the first performance of the *Symphonie pour un homme seul* by Pierre Schaeffer and Pierre Henry at the *Salle de l'Empire* in Paris on 6 July 1951, a spatial control system called 'relief desk' was tested. This system was used to control dynamics during the performance (music was played from several shellac players) and also to create what was called a 'stereophonic' effect, which actually was a left–right control on the position of a monophonic sound. The organisation of the loudspeakers in the hall was quite original too: two loudspeakers were placed at the front right and left sides of the audience; two other loudspeakers completed the distribution – one was place at the rear, in the middle of the hall and another also placed at the rear, but over the audience. The system was controlled from the stage, with the 'relief desk', which consisted of two circular electro-magnets placed perpendicularly – the two hands of the performer moving in and out the circles, or towards left and right and thus controlling the spatial intensity and the localisation of the sounds.

The major concept behind this idea is that music should be controlled when presented to an audience, thus creating a performance situation. This attitude has influenced acousmatic music ever since; the acousmonium is a long-term development of this concept.

3. THE ELECTRONIC PERIOD AND ITS TECHNICAL DEVELOPMENTS

After this first period of mechanical developments, a new era started in 1960. Pierre Schaeffer, whose contribution to the development of musique concrète can be appreciated from the compositional side as well as from the institutional side, had established the GRM in 1958 (previously it had been called GRMC: *Groupe de Recherche de Musique Concrète*), enlarging the research scope and pluralising the word 'Recherche' to 'Recherches' so that music, as a whole, would be covered. Two years later he proposed to the radio administration the creation of a new structure called *Service de la Recherche*, which would enlarge the scope of GRM to other domains: mainly image, technical research and critical analysis of audiovisual programs.

This new structure (see Évelyne Gayou's article in this volume on the history of GRM, pp. 203–11) was intended to facilitate strong transversal actions, with collaborations between sound and image, and specifically designed tools for sound or image processing. Among the major achievements of this period, which ended in 1975 with the dissolution of the centralised broadcast structure called ORTF (French Office for Radio and Television), three were particularly important for the development of the GRM: the *universal phonogène*, already described; the 'Coupigny' synthesiser (Coupigny is the name of the technician responsible of the project); and the *studio 54 mixing desk* (studio 54 was the name of the studio for which the desk was designed).

There was an important change in relation to the past period: while during the electromechanical period developments and experimentation were done mainly by Jacques Poullin and a small team of technicians, sometimes assisted by the official ORTF technical service, experimentation was now 'institutionalised', with teams working on a unique project, with no major financial restrictions, and also without any clearly established time-schedule. That is to say, that after the creation of the *Service de la Recherche* and the creation of the Technical Research Group, several years passed before the results were available within the studio. The phonogène arrived in 1966, but the synthesiser and the mixing desk only at the end of the 1960s!

3.1. The Coupigny synthesiser and the studio 54 mixing desk

These two tools would have a major influence on the evolution of GRM. They are presented together since they were coupled in the same desk.

They were not very original objects in themselves, except that they had been conceived for musique concrète and organised in such a way that they could easily be used by a composer. It should be remembered

Figure 3. Pierre Schaeffer in front of the Coupigny synthesiser and the mixing desk. Schaeffer is actually touching a Moog synthesiser (Photo: Ruska, copyright GRM).

that musique concrète developed within the French National Radio into a highly structured enterprise, with trade unions controlling each category of technicians and production staff defining precise activities for each task. The isolated work of the musique concrète composer went against the existing organisation, since it fused together in the same person technical and creative actions, when these two activities were completely dissociated within the institution's structure! The traditional studio was therefore conceived to have three operators: a person in charge of the machines, a person in charge of the mixing desk, and a person giving instructions to the two others. The structure of the studio was built in order to respect this hierarchical system and not really adapted to a creative and experimental work.

The objective of the mixing desk was to permit a single user to take charge of all the usual studio tasks. Independently of the mixing tracks (twenty-four of them), it had a coupled connection patch that permitted the organisation of the machines within the studio. It also had a certain number of remote controls in order to launch or stop the tape recorders. It was quite simple in its use and easily adaptable to any context, mainly the fact of introducing any external equipment.

The Coupigny synthesiser was a more ambitious project. Even if musique concrète had mainly been based on the recording and manipulation of sounds, synthesis was not excluded as a sound source. Since 1955, Pierre Henry had already started using oscillators to produce sounds for musique concrète. However, a synthesiser meant parametrical control, something completely discarded by Pierre Schaeffer as a procedural approach to music, since it favoured preconception of music, which was against his principle of 'making through listening'. Under those circumstances developing a synthesiser was highly influenced by this concept so that it would work more as a sound event generator where parameters would be globally controlled without actually permitting a very precise definition of their values.

Several trends constrained the development of the machine. It should be modular and easy to interconnect (this meant that there would be more modules than slots in the synthesiser and that it would have an easy-to-use patch). It should include all the major functions of modular synthesisers – oscillators, noise-generators, filters, ring-modulators – but should mainly permit intermodulation, that is, complex synthesis processes such as frequency modulation, amplitude modulation, external source modulation. No keyboard was attached to the synthesiser and a specific and complex envelope generator was associated to it.

The synthesiser was extremely practical for producing continuous and complex sounds through intermodulation (cross-synthesis) and frequency modulation processes; it was less effective for precisely defining a frequency or for triggering sounds. The typo-morphological concepts of Schaeffer were clearly applied here. *Typo-morphology* is the basis of the new description schemes proposed by Schaeffer in his *Traité*, its main importance arises from defining sound as a double based phenomenon for our perception. This cannot be described only by its *typology* (the spectral instantaneous organisation of a sound) but has to be closely related to its *morphology* (the evolution of its parameters through time). In other terms, a single word cannot describe a sound phenomenon: if I say 'dog', I am defining a typology; if I say 'angry dog', I am understating a sound behaviour in relation with its evolution in time.

The typo-morphological concepts applied to the synthesiser implied that sounds would not be constructed on oscillator additions or calculated modulation, but that complex sound materials would be easily generated and controlled globally, from a morphological perception point of view and not as a parametric architecture. The Coupigny synthesiser brought fresh air to the sound of the music composed in the GRM from there on. The first work composed with it was *L'œil écoute* by Bernard Parmegiani at the end of 1969. Many of the masterworks of the GRM's history were composed in the period ranging from 1969 to 1975, mainly using the new synthesiser: *L'expérience acoustique* by François Bayle in 1972;[8] *La Divine Comédie* by Bayle and Parmegiani in 1973; the *Triptyque électroacoustique* by Guy Reibel (1973–74); the *Requiem* by Michel Chion; and the famous *De Natura Sonorum* by Parmegiani (1974–75).

The Coupigny synthesiser and the mixing desk remained active until 1992. When it was transferred to the Music Museum in Paris, still in working condition, about 600 works had been composed on the system; since 1980 new equipment was added around the central system, mainly analogue or digital black-boxes as vocoders, harmonisers, flangers, digital synthesisers (DX7) and the new paraphernalia that appeared during that period. A small 'portable' Coupigny synthesiser still exists, where a dozen modules can be interconnected and twenty modules are still kept, all in functioning conditions. A famous 'form generator module', which was a mixture of an envelope generator and a control sequencer, stopped working in the mid-1970s and never could be repaired (the scheme had been lost). Composers having worked with this module at the beginning of the 1970s swear that it was the most incredible module that was ever built, a kind of ghost from the past for the following generations.

4. THE MAINFRAME COMPUTER PERIOD

Digital sound and the first sound generation software started at the end of the 1950s at the Bell Laboratories under the influence of Max Mathews. It took twenty years for the GRM to produce its first music, calculated in its studios with its own equipment on specifically designed software.

However, the first contacts had started at the end of the 1960s and several articles had been published by Max Mathews' team, including those by a young French researcher and composer Jean-Claude Risset, who had been collaborating with the Bell Laboratories since 1964. He worked as a link between the GRM and Max Mathews' team and brought to France the first works calculated through a computer as well as the first versions of the Music V software.

A group of young researchers from the GRM and the technical research group were interested in these new experiences; however, Pierre Schaeffer was quite sceptical about computers because it was, before anything, a calculator and so a tool for musical speculation and preconceptualisation.

> Composers have to be aware of this: a sphinx guards the entrance of every human domain, of every specific discipline. He who wants to make music, will do it, let him like it or not, with his ear. He who wants to experiment series of numbers or systems will do, let him like it or not, physics or experimental psychology. It still has to be proved that these works do not lead to waste!'[9]

An international conference on computer music took place in 1970 in Stockholm, fostered by Unesco. Many of the leading researchers in the digital domain were present at the meeting, including Mathews, Risset, Zinovieff and Schaeffer as a kind of historical reference. During this meeting Schaeffer gave a speech and participated in a roundtable discussion, where he was

[8]In his article in this volume 'Space, and more', François Bayle gives a very clear explanation of how he used intermodulation while composing the *Expérience Acoustique*.

[9]Schaeffer, 1952, p.141.

extremely critical towards computer-generated sounds and their eventual use in electroacoustic music. Participants at the conference were quite shocked by the conservative attitude of one of the inventors of technological music and the consequences were a certain isolation of the GRM from the digital actors. The GRM composers were quite unconcerned about this – they had the new Coupigny synthesiser, which could make beautiful and rich sounds, while computer sounds seemed harsh and lifeless.

The only perspective left open by Pierre Schaeffer during the Unesco conference was that of using the computer as a sound orchestrator that would produce rich sounds streams, or as a real-time sound processor, thus recreating the essential relationship between 'making' and 'listening'. This event was one of the last involvements of Pierre Schaeffer with electroacoustic music. His interest in the evolution of his invention had lessened sharply after the creation of the *Service de la Recherche* in 1960; it is true that his interests were mainly turned towards image and communication, however, he considered '*musique concrète*' and what it had become as a kind of failure in relation to the huge research project he had build on his discoveries. His *Traité des objets musicaux* is a kind of testament, where all his thoughts and perspectives for sound and music are presented, it is the conclusion of almost twenty years of experimentation and production, but he strongly disagreed with the direction taken by musique concrète and electroacoustic music, mainly based on the musical ideas of composers more interested in composing original works rather than in developing an experimental approach to sound combination with a musical scope, as he thought it should be done.

The Unesco conference was one of the last occasions in which Pierre Schaeffer talked about music; even there he did not lose the opportunity to strongly criticise the pre-deterministic approach to music, mainly represented by the serial techniques against which he had fought all his life. For him it was inconceivable that music could be created without the permanent control and correction of our ear. The computer represented a menace to music making since it represented predetermination and a danger of loss of control of the ear.

4.1. Which road to follow after Stockholm?

The technical team was quite disappointed by the reactions of Schaeffer concerning computer sound and music. However, there was a strong interest among the technicians to explore this new domain. Two trends were then followed: the first tried reconciling Schaeffer's ideas and computer-generated sounds – in order to achieve this a possible issue was real-time synthesis that would give tools to composers similar to the Coupigny synthesiser; the second started experimentation with computer synthesis on Music V software – the objective being to understand its functioning and to analyse its possible applications to musique concrète.

4.2. The real-time hybrid synthesis project

Real-time digital synthesis was a taxing project for the computer world – the speed of processors not yet being fast enough to permit real-time synthesis of sound; however, processors were fast enough to control parameters in real time. The idea developed for building analogue/digital hybrid synthesisers, in which the synthesis would be obtained through analogue modules (oscillators, modulators, etc.) and parametric control would be made in real time through a digital device. This would give very high precision to the voltage control thus permitting patches to be memorised and recalled with great parametric precision (which was one of the main problems of analogue synthesisers: the almost impossibility of recalling a previous organisation of the system). Two parallel projects started: one by Max Mathews at the beginning of the 1970s, which was quite well known and called *Groove*, reproducing the Music V model on analogue synthesis and adding digital control over parameters; and the other at EMS in Stockholm by Knut Wiggen, which, developed in partnership with the GRM, had a musique concrète orientation and was based on the same principles as the Groove synthesiser. These were quite complex projects since new analogue modules had to be conceived and built to capable of being controlled with great precision (a Hz to Hz control was needed on oscillators).[10]

The curious project started between EMS and the GRM took the name Syntom, which meant **SYN**(thèse) + **T**(raité) des **O**(bjets) **M**(usicaux) (synthesis based on the treatise of musical objects). The idea was that some of the basic concepts that Schaeffer had developed in his Treatise, such as '*allure*' (the 'gait' or 'tread' of a sound) or the 'grain', could be modelled parametrically and thus be applied to control synthesis. The result would be that, for example, the 'allure' of a continuous flow of a synthetic stream could be controlled in real time by modifying a parameter that would affect the allure from a minimum to a maximum value. The main difficulty in developing this project was the necessity to parameterise perception values; this would concern the different typologies as well as the morphology ('allure' is typically a morphological concept, whereas a 'homogeneous complex sound' is a typological one). A synthesiser of this kind would have different buttons to create typologies and different controllers to calibrate the morphology, always following the concepts developed by Schaeffer.

This approach was not very different from the one developed in the Coupigny synthesiser, which was

[10]Chion, Michel and Reibel, Guy. 1976. Les musiques électroacoustiques. Aix-en-Provence: INA-GRM, Edisud, pp. 166–7

mainly a sound-stream generator with multiple and rich possibilities of control and modulation. The main difference was the precision of control and the fact that a hybrid synthesiser based on the Treatise would have been much more simpler in its use. The project did not succeed; building the hybrid synthesiser in EMS was more complicated and difficult than expected and Pierre Schaeffer's interest in the problem quickly faded. His team also dispersed and the project was abandoned towards 1972.

4.3. Computer synthesis on the Music V program

Music V was one of the most advanced versions developed by Max Mathews and a reference to all researchers and composers interested in computer sound. It is important to stress that the origins of musique concrète and electronic music, as well as many of the events that took place in the 1950s, happened within radio facilities. The reason for this is the equipment availability within these institutions; in fact, what Schaeffer and his acolytes were doing was diverting radio production technology to other uses before starting a specifically adapted technological development. With computer music, the same evolution applied: it started in the places where computers could be found and where there was available computing time, such as within universities and advanced research laboratories. A new generation of musicians and researchers began working on computers, thus generating a different denomination, which was 'computer music', not designing an aesthetical current but an operational technique (implicitly 'computer music' seemed a more serious domain than electroacoustic or musique concrète, which were more easily associated with experimentation and improvisation).

Pierre Schaeffer was not a university researcher even though he developed a very ambitious research project. His research was closely linked to practice and to practical implementation in a non-scientific domain such as composition. In the same way he mistrusted any serial approach to music composition and he mistrusted university research as a road to arrive to any practical result; this also explains the philosophical crises that arose during the Unesco conference. However, since he was less concerned with the evolution of the GRM studios and research, in 1973 a young team of researchers started work with the Music V program, which had been brought to France by Jean-Claude Risset and was freely distributed among different research teams. Pierre-Alain Jaffrennou, Benedict Mailliard and Jean-François Allouis formed this team: the first two had been students of the GRM's course at the National Conservatory; the third was an engineer from a polytechnic school who arrived in 1974.

Their intention was to use experimentation to understand all the possibilities of the program and to develop a project that would permit modifications and adaptations of Music V to make it more compatible with the GRM's ideas. It can seem that this adaptation of Music V to GRM concepts was along the same lines of the Syntom project, however, the reason for this project was a much more practical one.

While the Syntom and the Music V projects were being developed, the GRM as a composition group was living one of its most original periods. As explained earlier, the Coupigny synthesiser with the new mixing desk had arrived to the studios as well as other commercial equipment and this had completely renewed the sound profile of the works. Many masterpieces were composed during this period. Composers felt there was no need for new technology: existing equipment was satisfactory, and the composer's desires were more turned towards building new and better analogue modules.

In 1973 the young team organised an internal workshop for the GRM composers in which the functioning of Music V was explained and some sound results were presented. (There was no computer yet at GRM, it would only arrive in 1978. Sounds were calculated on a centralised computer belonging to the ORTF and then the calculations were sent to the Bell Laboratories to be converted to audio signal!) Composers were very critical of the results and the difficulties of synthesis programming; and after the workshop none of them approached the digital team to experiment or deepen their knowledge about sound calculation. The team was frustrated, however, they understood that if they wanted digital sound to make its way with GRM composers, computer technology had to be adapted to their working methods and not the other way around. The next workshop would take place in 1978, where specific tools, based on musique concrète concepts, were presented and thus immediately attracted composers to this new domain.[11]

The reaction of the composers was not at all surprising; as said before they were working on other rich tools, which seemed much more interesting than the meagre results obtained with the digital examples. Once again the origins of the GRM and the work of musique concrète composers had a strong history in their methodology and procedures: while computer music composers mainly came from traditional composition and university research; GRM composers had mainly started working within the radio environment. They had had to understand techniques and develop skills in tape editing, mixing or button controlling. With the arrival of the synthesiser composers had had to understand the functioning of the modules, connections and modulations. All these actions were always done within a listening environment, in which any action produced an

[11]The permanent GRM composers in 1973 were: François Bayle, Bernard Parmegiani, Ivo Malec, Guy Reibel and Michel Chion.

immediate sound result. Working in an abstract environment, where results were not immediately available, seemed like abandoning one of the main advantages of electroacoustic creation.

4.4. The Syter project

While the Jaffrennou and Mailliard team worked on Music V and its possible evolution towards GRM-based problematics, a new young engineer, Jean-François Allouis, arrived. He contributed to the work of the first team but was personally interested in real-time processing. The existence of small fast chips that permitted short access and response times (even if far from being usable for sound synthesis) pushed him down the road of hybridisation with the idea of controlling sound parameters in real time with a specific 'portable' device. Thus was born the *Syter* project; its first abbreviation signified 'real-time synthesis' and later it would become 'real-time system'. The first version was a simple device that could control sound amplitude. It was used to make spatialising figures during a performance, mainly circles and fixed trajectories from an incoming sound. The project started in 1975 and this first prototype was used in 1977, with the first performance of the work *Crystal* by François Bayle. Several versions followed until the final version, *Syter 3*, was finished in 1984 – this will be studied later.

4.5. The first mainframe computer: the Studio 123

The GRM finally acquired a mainframe computer in 1978, the road to this acquisition was long and administrative, but it was finally possible to have a home-based system. Digital to analogue converters and analogue to digital converters were built by the GRM technicians under the direction of Jean-François Allouis and the composers finally produced the first calculated sounds.

Since 1973 there had been several main changes: the ORTF had ceased to exist as a whole organisation, like the BBC; and different independent societies had been created. Among them the National Audiovisual Institute or INA brought together, under Schaeffer's initiative, some of the previous research activities, including GRM, as well as being the institution in charge of the archives, experimental production and professional training in the audiovisual domain.

Computers were becoming more integrated in different domains of human activity, so it had become clear for François Bayle, the director of the GRM, that in order to renew the technology it was necessary to include this new and promising technology. INA was also providing a strong support to these activities and the GRM had obtained new studios with new adapted equipment.

From the computer side, a new step had been achieved, namely, the possibility of introducing within Music V external sounds through converters in order to be processed. A PDP 11/60 computer was then installed, with home-made converters and a small team of technicians and researchers mainly working on sound-processing software in non-real time, some of it based on the Music V structure. The computer and the team were located at Studio 123 at Radio France, which gave the name to the software developed there.

4.6. What to do with a computer?

The first software developed for the computer was dedicated to import and export sounds in the system. Jean-François Allouis then developed a program for sound stretching and transposing, and a bank of resonant filters. From there on, the team started developing new software while working on the major philosophy of the studio. New researchers had been added to the project, namely, Yann Geslin and Jean-Yves Bernier.

The main questions were: What profile should the studio have? What kind of interface was necessary for the GRM composers? There was for the first time an open environment that could be modelled quite freely; however, the user requirements were not really specified and the research time had to invent them, while making the processing tools. While the Syter project investigated the possibilities of real time, the Studio 123 team worked on the difficult task of making the digital environment attractive to composers and efficient for their work. Their great idea was to go back to their sources; in other words, to analyse what had been the steps carried out since the first experiments in 1948 by Pierre Schaeffer, model them, and start developing contemporary equivalents of the actions on sound. There was a strong difference from that of Schaeffer's approach to typo-morphology: while Schaeffer analysed the methods and music in terms of sound and sound categorisation, the 123 team analysed the operations done on sound and described operational models that could be applied on sound, leaving to the composer the task of deciding which sounds and which results can be considered as 'musical'.

The problem remained of the access to the system by the composers. It was unlikely that composers would learn any programming languages, so intermediate interfaces had to be created that would map the necessary variable inputs with a comprehensible set of questions. Simplified conversational interfaces were then conceived in a question and answer environment, where the questions suggested coherent answers if the user did not know which value to introduce, and open or closed sub-questions would function as a means to specify an answer.

Figure 4. View of the conversational interface screen in the Studio 123 programs.

The results started coming in very quickly. First some GRM composers worked on the system, guided very closely by Jean-Baptiste Mailliard, who worked as the operational interface with the system. *Erosphère* by François Bayle,[12] *Week-end* by Ivo Malec and *L'écho du miroir* by Bernard Parmegiani where the first works that came out of the studio at the end of the 1970s. From then on, the team started to organise very regular workshops in order to explain the techniques to composers and make them practise on the new software, independent of the fact that composers would be working in the GRM studios. It was an extremely positive 'marketing' operation since it brought GRM's image back to modernity. The GRM was no longer considered as an old-fashioned group (Ircam incarnated modernity since 1975); moreover, completely new concepts arrived at the digital domain through the re-visitation of musique concrète's concepts adapted to a modern language. From 1980 to 1987, more than a hundred composers and musicians followed the two-week workshops, and many of them then developed musical projects. More than a hundred works were composed using the system to produce sounds.

The functioning process would be that the composer would bring his personal sounds and introduce them in the computer. The user would then launch calculations for new sounds by using one aspect of the processing software and inputting the necessary information through the conversational interface. If the results satisfied the user (calculation time would range from twice the time of the sound sample to 100 times, in function of the complexity of the calculation), he would record the results on a tape and then go to the analogue studios (Studio 116) and edit and mix his work. A large number of programs were developed, among which are:

ACM: Sequence accumulator, sort of multiple delay with sounds playing at different speeds
ADC: Software for inputting sounds in the computer
DAC: Software for listening to sounds from the computer
BRAGE: One of the most popular programs, later on called Shuffling, which permitted random re-ordering of sections of a same sound
EDS: Editing and mixing software
ELISIL: Silence eliminator based on a threshold
FILVAR: Variable band-width pass-band filter
FLT: Bank of resonant filters, globally or independently controlled (forty-nine maximum)
MODA: Amplitude modulator, voltage controlled
NORMA: Amplitude normalisation program
PLI: Vocoder software, based on linear prediction
PORTE: Threshold noise-gate
RAL: Speed variation
REV: Reverberation unit
RING: Ring-modulator
SPACE: Controllable stereophonic spatialiser
VARVIT: Controllable speed variation
VOC: Cross-synthesis vocoder

Other more technical programs existed to check and correct signal defects, as well as derivations of versions of the existing software.[13] This programming work was essential for the following digital developments in GRM and furnished a list of operational concepts that could be applied to sound, issued from the concepts of the past, however adapted, improved and sometimes originally implemented. Many initial actions on sound are easily recognisable in the previous list as speed variation. Others are more complex developments of initial concepts; for example, shuffling is derived from 'micro-editing' but randomly used on one or two intermingled sounds. The same innovation was applied to resonant filters, a process that was already known, but could here be implemented with a great number of filters and with a large degree of flexibility.

The conversational interfaces also proposed the first version of what would be one of the major trends in GRM's software development: the global control of a large array of parameters. Instead of controlling each parameter independently – for example, the frequency of each of the forty-nine resonant filters (which could also be done) – distribution curves are proposed thus permitting only one or two parameters to organise the frequencies in a very intuitive way.

[12]François Bayle describes the procedure used in *Erosphère* in his article *Space and more* in this volume.

[13]It is important to note that the quite popular software called CDP (Composers Desktop Project) was directly inspired by much of the Studio 123 software and applied to a non-real time PC environment.

The Studio 123 mainframe computer slowly decayed through time, lasting until the end of the 1980s. Most of the team departed from GRM and the only person that remained was Yann Geslin, who transported most of the programs to a new environment. It was a major period in the history of GRM since it transmitted to the digital domain most of the fundamental concepts underlying musique concrète and its further analogue developments.

5. REAL-TIME WAS THE FUTURE: THE SYTER PROJECT

The Syter project closely followed Studio 123. The first fully operational machine was finished in 1984, including a real-time processor (the Syter processor) linked to a host mini-computer (a Bull version of the PDP 11/23 system) and a large hard-disk on which to work. It had two inputs and eight outputs and was controllable in real time through a mouse and a graphic screen.

The Syter system was the result of large-scale work done by Jean-François Allouis, who was the only engineer at GRM and who worked fully on the project for four years to achieve a major processing system. He designed and built the real-time processor, based on a pipeline series of calculation units, as well as the input and output converters and the MIDI interface. He conceived and programmed the software environment and conceived and designed the graphical interface and all the real-time functions. He first transposed some of the existing models of sound-processing inspired in Studio 123 programs, and then developed new processing concepts for processing. He then followed the industrialisation process sub-contracted to the Franch Digitone society, which sold ten units of the system.[14]

The most original aspect of Syter was its graphic interface controlled through a mouse, thus permitting real-time control of the parameter variation. The graphical model reproduced the mixing desk model, with virtual sliders, triggers and joysticks. The different control variables were controlled through a set of sixteen sliders, and a snapshot of the positions of the sixteen sliders could be taken and placed on a different page of the graphical system. The most remarkable feature was that the snapshots could be interpolated, thus generating intermediate values from different spatial positions.[15]

From a programming point of view, the system had a certain number of basic modular bricks that could be combined together to form an 'instrument', which would function in real time through the control of the graphic screens and the mouse. The modules were connected through a programming language that permitted the assembly of very complex structures. Among the modules could be found oscillators, envelopes, delays, harmonisers, noise-generators, etc., common elements in a modern modular synthesiser. However, the innovation was in the way they were combined and the kind of effects that could be obtained.

The same philosophy was applied as with Studio 123, regular workshops were organised for more than 150 composers and musicians and more than 300 works

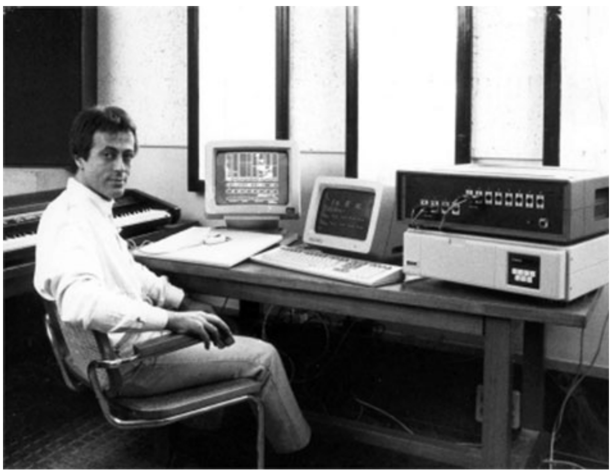

Figure 5. Jean-François Allouis and the Syter system, 1986 (copyright GRM).

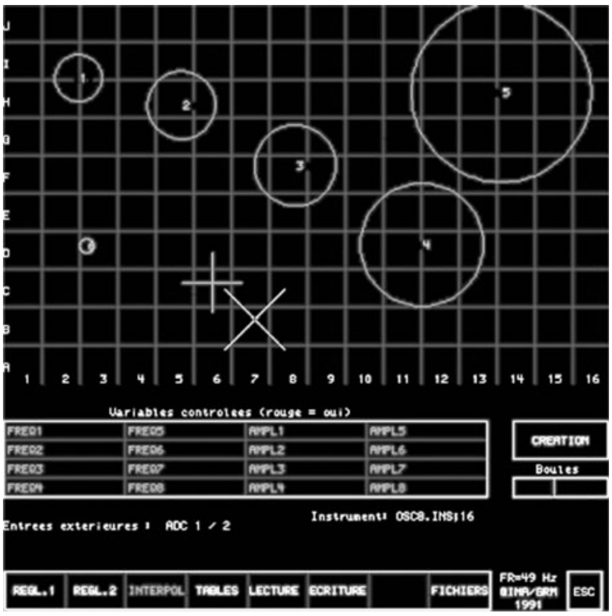

Figure 6. The interpolation screen on Syter.

[14]A full description of the Syter system is given in the PhD work by Daniel Teruggi: 'The Syter system, its history, developments and implications in contemporary musical language', University of Paris VIII, December 1998, Paris.

[15]A philosophical description of the functioning of interpolation and the interface conceptions of the GRM tools can be found in *Interfaces homme-machine et création muiscale*, edited by Hugues Vinet and François Delalande. Hermes Science Publications, Paris, 1999.

have been created using Syter, either in a real-time performance or as a material generator. Real-time performance became a much appreciated issue for many composers because of the reliability of the system and the originality of the transformations. The Syter system worked from 1984 until 1995. A system is still available at the GRM, but has been retired from production.

The different processing instruments include:

ACCHAR: Four harmonisers, four delay lines and a feedback loop (predecessor of *Pitchaccum* in the GRM Tools) – its variant, ACCHARNEW, permitted inverse reading of the harmoniser windows
BRASSALQD: Random shuffling of sounds (predecessor of *Shuffling* in the GRM Tools)
DELAIST: Delay lines with feedback (predecessor of *Delay* in the GRM Tools)
DOPPLER: Doppler effect simulator (predecessor of the GRM Tools *Doppler*)
ENVERS: Real-time sound reverser based on a continuous filling and emptying memory triggered by a threshold
EQUAL8: Eight-band equaliser (predecessor of *Equalize* in the GRM Tools)
ETIRPHST: Stretching algorithm, based on phase detection
FLT8: Bank of eight resonant filters (predecessor of *Reson* in the GRM Tools)
FMCL6: Frequency modulation generator
FORMONDE: Add-synthesis generator
FUSION: Cross shuffling of two different sounds
GEL4: Sound freezer, with four simultaneous loops (predecessor of Freeze in the GRM Tools)
GLISS: Perpetual glissando generator (based on the Risset model)
MODFORST: Amplitude modulator, table controlled
PEIGNE: Bank of resonant filters (predecessor of *Combfilter* in the GRM Tools)
REVGLISS: Reverberation unit with pitch glissando
RINGLFOST: LFO-controlled ring modulator
TRAME: Bank of twenty-four frequency modulation units
VAR: Speed variation

Many variations existed of the same instrument, adapted to a specific project or environment. A close relationship was established between researchers and composers, many of the presented models are the result of progressive elaboration of an instrument in close relationship with the requirements of a composer.

5.1. GRM Tools

The last and the current version of the digital sound processing tools is represented by GRM Tools. Hugues Vinet, who replaced Jean-François Allouis in 1988, when Allouis left GRM for Ircam, initiated them. While continuing the development of Syter, Vinet started experimenting on the new Macintosh environments associated to the Digidesign platforms and the Sound Designer software and card.

The beginning of the 1990s was a difficult transition period for technology; the processing technology on which Syter worked was based in small processors capable of doing very fast optimised calculations with very little live-memory (Syter had only 512 Kbytes of memory!). The tendency for laptop computers was to have slower processors and larger live-memories, thus anticipating today's systems. Within this context it was clear that the Syter model was going towards obsolescence and that development should be oriented towards the new computers. At the same time, it was no longer thinkable of making a specific hardware for sound processing: if Syter were to continue, it would have to be on commercial environments that provided the hardware infrastructure needed for real-time processing. Digidesign provided an adaptable environment, so the first version of GRM Tools appeared in 1991, working on a Sound Designer sound-card. For Syter users, GRM Tools was in regression: where previously seven harmonisers were available, only two were now possible. All the performance possibilities of the interpolation had disappeared and the system looked desperately slow compared to the past.

At the same time, it was now possible to give a much larger diffusion to the GRM products; for new users, the concept was completely innovative and the product received several awards for its performance and originality. The new road advanced very quickly, processing power was always greater and the product could now be seen as a long-time perspective. New versions appeared and also new volumes and new adaptations to the Digidesign platforms and subsequently to VST environments.

In 1994, Emmanuel Favreau became the engineer responsible for its development. He continued improving and adapting GRM Tools to new environments and he optimised the graphical interfaces in order to simplify their use and make them easy to learn. A first series of eight algorithms was launched called Classical bundle, which was mainly an adaptation of the Studio 123 and Syter models to the new environments, with improved graphical controls and performances, and sometimes with new possibilities.

A completely new set of four algorithms was subsequently launched called GRM Tools ST, which explored the large possibilities of spectral rearrangement and analysis-resynthesis of sound signals. With these last algorithms, Emmanuel Favreau offered new opportunities within GRM Tools, concentrating on the spectral modification of sound and its huge possibilities, while previously most of the algorithms had been based on manipulations on the time dimension as well as hybridisation of synthetic sounds with recorded sounds.[16]

New algorithms will continue to be developed in the future, thus continuing a well-established tradition in sound manipulation and better user-oriented interfaces. Global approach is preferred to single parametrical control since it permits an immediate action on sound and thus a response to an action, continuing with one of the premises announced by Pierre Schaeffer.

5.2. The 1990s and their new tools

Another interesting project was developed at the beginning of the 1990s called the Midiformers. The development of Midi systems enhanced parametric control through keyboards and discreet organisation of the frequency domain. It was difficult under these constraints to freely work on sound processing, even if there were very powerful synthesisers and samplers that produced very interesting sounds. The idea was launched by Serge Delaubier, a composer and machine inventor, in order to apply the note-control approach proposed by Midi instruments in a global way – instead of thinking of making complex sounds, the idea was to generate complex structures of sounds starting by simple notes on a synthesiser or sampler.

This was the main idea of the Midiformers, which were event generators based on conceptual models such as bouncing, or fortune-wheel such as sound grapes. Based on the software called Max, each Midiformer would propose a Syter-like control screen, with sliders and buttons (and here interpolations were possible). They were very easy to use and generated complex patterns that could easily be controlled by the sliders or any external device. Utilising the detuning possibilities of MIDI permitted users to generate the illusion of continuous pitch control. The Midiformers where freely distributed from 1992 until the end of the 1990s, at which point their development was stopped.

5.3. The Acousmographe

The Acousmographe, a graphical annotation tool started in 1991 and now one of the major development projects of GRM, developed in relationship with the French Education Ministry and represents a completely different kind of project. It is a framework for the analysis and comprehension of musical phenomena, based on a sonogram calculated on the sound's signal on which graphical annotation sheets can be placed. A set of original graphical creation tools permits the annotation or transcription of the sound elements into graphical symbols. It is considered a highly educationally oriented tool since it permits teachers and students to work on any kind of music, particularly popular music or electroacoustic music.

For the GRM it has become a major tool for musical analysis, continuing the tradition of understanding musical phenomena. It was started by Olivier Koechlin, then continued by Hugues Vinet and Emmanuel Favreau (who is responsible for the project), and more recently Adrien Lefèvre.

5.4 Beyond 'musique concrète'

Recently new technological projects have been launched that are connected to the activities of the GRM and its opening to large communities of users, as the Webradio or the Acousmographe. Other projects are less clearly associated to activities and should be seen as experimentations to prepare what could be the tools of the future. As efficient and reliable as today's technology may seem, there is a permanent quest for innovation and new possibilities brought about by new environments and user tendencies. It is therefore necessary to explore other issues, sometimes distant to any immediate use or application. Among the different projects recently issued or running today, five of them are presented below: *Sound-Spotter, the interpolar Webradio, Preservation of artistic works* and *Sound manipulation interfaces.*

5.4.1. Sound-Spotter

The Sound-Spotter was developed through a joint project with the University of Hertfordshire between 2001 and 2004, carried out by Christian Spevak. Its objective was to investigate the possibility of searching for sounds within a document once a reference element was given. The difficulty was that while it is relatively easy to compare sound signals in order to find identical elements, it is more difficult to find variations or deformations of a given sample. The way it was used was quite simple: a section of a sound document was chosen (in the case of electroacoustic music this could be a simple sound or a series of sounds) and then identical or similar sounds were found on all the document.

The Spotter was conceived to assist and accelerate the use of the Acousmographe, where it is important within a musical document to identify similar or identical sounds, even when used in a different context. The difficulty is that while an identical sound in a different environment is easily recognisable by our ear, when analysed as a signal, it is quite different. The same perception differences apply with commonly used procedures in composition such as transposition, stretching or superposition of sounds. An experimental version of the Sound-Spotter exists that shows promising results in sound recognition and could eventually be applied as a complementary tool within the

[16]GRM Tools are available through www.emf.org/grm.

Acousmographe in order to accelerate the search and recognition process.

5.4.2. The Interpolator

Another interesting application was developed with the University of Hertfordshire, which received the name of the Interpolator. This is a graphical interface conceived to control complex situations within the GRM Tools. It can be defined as a multidimensional general controller, based on the interpolation model developed in the Syter system and applied to simultaneous parameters of up to four different plug-ins placed on a special player. The first version was developed by Martin Spain and was based on a gravitational interpolation model with rich coloured graphics and an intuitive interface.

5.4.3. Webradio

The Webradio is a publication tool intended to simplify the production of web-broadcasted programs. It was conceived and developed by Dominique Saint Martin at the GRM and is currently used to present the regular concerts of the GRM as well as historic radio programs (the project is currently presented in the article 'The GRM: beyond the walls' by Dominique Saint Martin and Solange Barrachina in this volume, see pp. 233–9). It is a multimedia integration tool for audio and graphics that is easy to use and implement.

5.4.4. Preservation of artistic works

The GRM, as any production and research institution, slowly but steadily has accumulated material and built an archive. Since it is a musical archive, the works have a specific value, as works of art, for which regular and voluntary actions have to be undertaken to assure the longevity of the works. The 'Acousmathèque', or general archive of the GRM, has been in charge of this task, which, since the beginning of 'musique concrète' and recently with the transfer to digital formats, assures the good conservation state of the originals (in a controlled environment) and the preservation towards a digital master format and then the digitization within an information system. Particular concern has developed in recent years regarding complex and multimedia works and what means should be undertaken in order to assure the reproducibility of the performance of a work in the future.

An important research work, under the direction of Yann Geslin, has been undertaken in order to identify and organise the collection of elements needed to assure an effective conservation of all the necessary elements that constitute a work of electroacoustic music. Furthermore, the aim of this research is not merely to produce a description and collecting environment, but also to advance towards self-description systems that automatically organise and structure the elements that constitute a musical work during the production process. This project, based on the OAIS environment, is complementary to similar concerns that appear in all the domains of artistic art, where the preservation of works is a much more complex task than the task of keeping the independent elements that contribute to the performance. An integration of the results of this project within GRM will permit a much simpler process and effective from the point of view of being able to reproduce a performance in the future.

5.4.5. Sound manipulation interfaces

The main results in recent years regarding the tools developed in the GRM concern sound processing and graphic representation of music. These two projects have followed the evolution of technology, and also the development of users' tendencies. The close relationship with the French Education Ministry, essential from the GRM's point of view to develop the concern and the knowledge of sound manipulation and musical composition from early age, continues as a strong trend for the future. The existing tools of GRM concern the production of sound on the representation and analysis of the results. In the middle, what is missing is how to bring the sounds together in compositional environments that propose different forms of representation of sounds and different controls on the actions that are done in order to make the sounds live together and become music.

A project is being undertaken with the De Montfort University in Leicester, an institution highly concerned with educational issues for electroacoustic music, to conceive and develop these tools that will permit an effective representation and manipulation of sounds in order to have systems that more efficiently structure the work of young and less young composers. One of the main issues concerns the interfaces and the way sound can be represented in correspondence with the internal images and representations of sound.

6. FIRST CONCLUSIONS

Pierre Schaeffer definitely gave an initial impulse that had the strength to influence the destiny of the GRM. Technology has changed, music has changed and society has changed. Seen from today, when so many things have happened since, his approach and the survey of his discoveries seem an extraordinary event that marked and even shocked his environment. While he kept the institutional responsibility, he attracted composers, researchers and the public to his ideas and to the GRM, thus creating and maintaining the initial momentum. His first discoveries and conclusions became research projects of great ambition that can be explained as the seed for the understanding of music within humankind.

However, even more astonishing is the fact that his quest has been subsequently taken over by younger and new generations of researchers and composers. Pierre Schaeffer opened a door of understanding which immediately attracted composers who shared the same concerns and questions. Other musicians have enlarged the initial scope and tried to make it evolve, adapting it to the evolution of concepts and of technological and musical environments. Michel Chion has contributed greatly to the understanding of the main concepts of Schaeffer, while enlarging it to the analysis of listening; François Bayle has developed strong operational models to explain how images act on our perception and how the modality of acousmatic is rich in philosophical implications.

Technology, as seen in this article, has been a powerful tool for forging concepts and making them applicable. The construction of a phonogène implicitly makes operational concepts become real, which will affect sound and music. It is the result of an intellectual action that seeks to extract from experimentation the main trends that may permit a generalisation of a procedure. The electromechanical machines of the 1950s seem like technological dinosaurs in relation to their physical volume and complexity; only the arrival of digital tools has permitted not only a simplified modelling of the work on sound, but also an experimental modelling of the concepts, with continuous improvements and operating adaptations.

The development of digital tools within the GRM marked a strong change in its history. Not only was it the first major technological project in the post-Schaeffer era, but it was also preceded by a deep reflection on the operational models and on the sense of creating a new environment to match pre-existing concepts and their necessary adaptation to a different musical situation and musical objectives. This kind of back-analysis of accomplished concepts and models has taken place regularly, in particular whenever the technology shifted in such a way that there was a danger of losing some operability or because a completely new environment was affordable. It was and it is necessary to measure the consequence of any change and to foresee the possible evolutions it will bring on concepts and models.

At the centre of concerns we find the users: from a GRM point of view, mainly composers, but also other categories of users such as sound designers. Their concern is for an essential feedback to the conception and the development of new tools. They have since the beginning been the final recipient of any tool. It is difficult to find transversal trends underlying the philosophy of the tools developed by the GRM that would take us from the first years to today. However, three main trends have persisted that have conditioned every development made at any period by different research teams:

(1) Tools are made to be controlled through listening and during listening. The basic concept issued from the 'making' and 'listening' duality by Pierre Schaeffer.
(2) Tools should be easy to grasp and manipulate.
(3) The user should be independent and not rely on an external operator.

6.1. Morphological concepts

From a more practical point of view, a certain number of operating categories have been established that summarise and structure the actions done on sound. These categorisations were produced at the beginning of the 1990s, and continue the work done when the first digital studio appeared in order to specify the particular operational approach used in GRM. They received the name 'morpho-concepts', a name forged by Hugues Vinet and François Bayle to describe the common trend that would unite a machine from the 1950s to a contemporary digital system:[17]

(1) Sound isolation and observation
Recording, listening to sound images
(2) Sound editing
Cutting-out, incrustations, loops, time inversions, substitutions
(3) Dynamic modifications
Amplitude modulation, actions on potentiometers, noise reduction or elimination, compression, expansion
(4) Speed modifications
Speed variations, phase variations, Doppler effect
(5) Time modifications
Time stretching, time contraction, time freezing, loops, time inversion
(6) Spectral modifications
Filtering, resonant filtering, harmonisation, ring modulation, spectral interpolation, analysis-resynthesis
(7) Density modifications
Shuffling, feedback, multiplication
(8) Order of events modifications
Shuffling, editing, sound inversions
(9) Space modifications
Panning, circling, Doppler effect, reverberation
(10) Sound addition
Mixing, sound interleaving

These operating categories are extremely useful for understanding the evolution of technology in GRM and elsewhere, and they constitute an important framework

[17]Teruggi, D. 1994. *The Morpho Concepts: trends in software for Acousmatic Music composition*. Denmark: ICMC Århus.

for future developments. The categories are a reflection of the history of GRM but they should not be analysed from a historical point of view – all of them are always operational and summarise the actions currently performed in the composition studio with today's tools.

6.2. Necessary failures along the road of development

In the light of this technological evolution, it is important to analyse what did not succeed in the long history of GRM developments. The most common reason underlying failure is that something did not function as expected or had some side effects that made its use impossible. Other reasons may appear, related to users' disinterest of a finished development (one says then that the user requirements where not clear), or the fact that, after all, the result is not as interesting as expected.

With digital systems, the failures are less visible: they are virtual failures and can be easily recovered. With hardware equipment, failures are more difficult to admit since they generally imply a major investment in time and equipment and are, of course, very visible! Failures should not be interpreted completely as failures; within the domain that concerns us failure means that there was an investment that did not lead to a 'return on investment' which is, when discussing electroacoustic music, the fact that the development was not very popular among composers or that few items were sold.

In the case of GRM, failures have often been a necessary step to clarify technical options or to clarify composers' projects and intentions. To end this historical overview, a short list of failures is provided that may give a different perception, if this was not clear enough yet, on how certain ideas succeeded and others were abandoned or had to be suspended until the arrival of a adapted technology.

6.2.1. Three-head tape recorder

This was a very interesting and innovative machine, its main record being its use by Messiaen, which immediately gives to it the perspective of having been selected by a famous composer. However, the system was not very practical or effective. First, it was inconvenient: the capstan motor that needed to drag three tapes was so big that it induced a magnetic field that would record a 50Hz frequency on any tape put on the machine, while twisting the tapes because of an excessive pull on them. Second, it was inconvenient: the machine was so heavy it could not be moved. When the first performance of *Timbres Durées* took place, three telephone lines had to be rented in order to transmit the information to the concert hall. It was practically never used again.

6.2.2. Morphophone

This was a very complex and rich machine, however, it was almost impossible to make it work. It was very difficult to stick a looped tape on the turning disk and since the magnetic heads had to be in close contact with the tape after a few turns, a head would detach the tape. Some experiments were done on the machine but it was never really musically used. The concepts of the morphophone could only be applied on GRM Tools.

6.2.3. Syntom project

As suggested previous, this project was a failure; its objective of matching psychoacoustic listening criteria with synthesis parameters was far from being realistic and the project very soon showed its limitation. Fundamentally, there was an operational confusion: the typo-morphology was conceived as a framework for sound analysis, subject to interpretation and ambiguities, and trying to make it become an operational model was completely beyond its possibilities.

6.2.4. Syter 2

Between the first prototype of Syter, used to distribute sound in space during the performance of *Crystal* by François Bayle, and the Syter that finally was finished in 1983 (called Syter 3), there was an intermediate prototype made of small processing units linked together but without a central control unit or host computer. The idea was that simple processors could be given specific small functions and the results combined together and controlled by external devices. This project was a complete failure – it never worked but it did serve to show the necessity of a central unit that would control and supervise the functioning of the processors.

6.2.5. GMR: grand manche retroactif (large retroactive handle)

This was a kind of huge retroactive joystick designed to control the Midiformers. Since many of the models of the Midiformers were inspired by physical behaviour, such as the bouncing of an object, the idea was that a retroactive joystick, with adjustable reactions and counter-reactions, would be very efficient in piloting the Midiformers. A real two-dimensional prototype was built with motors compensating or reacting to the efforts put on the handle of the joystick; the precision of the motors was very high, as well as the power of the motors, and the retroaction was somehow 'aggressive' on the user. Some weeks after the first demonstration, somebody visiting MIT in Boston found exactly the same concept already operational in a joystick. This discovery made the developers of the project lose interest in the joystick.

There are probably other hidden failures in the digital era, but, as said before, since there are no traces of them, all that is left consists of testimonies about them. The failures were probably necessary steps towards what can be considered success. In any case a machine or a system have never been the guarantee of musical success: very poor systems when in the hands of virtuoso composers can produce completely unexpected results. When composing, the difficulties are always the same; what changes is the complexity in the implementation of a system so it may produce acceptable results.

FINAL CONCLUSIONS

In 2008 the GRM will be fifty years old and *musique concrète* will be sixty. Three non-dissociable aspects have contributed to its longevity, each dependent on the other but achieved by different actors. The *composers*, always seeking new perspectives in music and in the technological environment in which they work, have been the main motors of the activity, always looking forwards towards a possible new world. The *technicians* have continuously contributed to the enhancement and evolution of the technical systems, often with original ideas that have enhanced the perspective of composers. The *theoreticians*, who with their permanent quest for understanding underlying structures and schemes, have provided the necessary conceptual environment to help concepts, theories and points of view to evolve.

Technological research in GRM's existence has always been closely related to production. Composers were the final users; they often formulated in an intuitive form their needs and their 'dreams' of what they would like to obtain or achieve through sound processing and control. Research has thus always been very closely related to production, and more concerned with developing effective solutions, ready to be applied in production. In the last ten years, a strong shift was been taken in order to work more closely with university research, through effective collaborations between research centres and a specific user environment such as the GRM, which proposes new and original problems and seeks strong feedback from its users. In parallel to this expansion, important actions undertaken in the educational field have spread the ideas and concepts dear to the Group towards the younger generations and other communities of users, thus attaining notoriety quite unknown in the past. The growing interest within the musicological community for sound-based music supports this, in particular regarding the theoretical implications of sound manipulation. An increase in interest for electroacoustic music studies (apart from technical studies which were already widely known) demonstrates how this growing interest is already bearing fruit.

The road linking the rich tradition and modernity is always active, as well as the actions and the will to investigate the new trends for music. The institutional continuity has constituted the indispensable background on which all the history and actions have been developed. Longevity has given a common scope to all actors: that of contributing to a major project that has influenced to its very roots music and musical composition. Past and present members and participants to the GRM's activities have been and continue to be united by this sense of contribution to the evolution of human understanding.