The Analysis of Electroacoustic Music: from sources to invariants

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The musicologist is confronted with many situations during the analysis of electroacoustic music, whether on support media, mixed, or real-time. Musical genres and styles vary greatly, and the collection of electronic musical instruments has also proven to be very heterogeneous. The intrinsic characteristics of the electroacoustic parts and their scoring create serious limitations. Furthermore, many sources remain inaccessible or are already lost. Thus the preoccupation with documentary sources related to the acts of creation, interpretation, and technological context becomes more and more pressing. It is now essential to formulate a synthetic vision of this music, which has existed for half a century, and to pursue the search for invariants. This work must be based on a rigorous methodology that has yet to be developed. More generally speaking, the goal is to establish the terms and conditions of a systematic musicology of electroacoustics.

1. INTRODUCTION

For half a century, a huge body of work has enriched electroacoustic music. Over the years, there have been several historical, technological and aesthetic landmarks that cannot go unmentioned. Among the most important are the impact of the studios in Paris, Cologne and Milan, the change from analogue to digital, and the emergence of real time and interactivity. These are so significant that their definition, documentation, interpretation and dating are relatively easy.

Today, historical perspective allows a maturation of electroacoustic musicology. Investigative methods evolve, and the strategies of approach can be refined. Synthesis is possible because the repertoire is sufficiently large and first-hand sources are still plentiful. However, unfortunate events such as the recent loss of Robert Moog on 21 August 2005 and the death of Luc Ferrari the following day, can only inspire musicologists to pursue and intensify their investigative, analytic, biographical and historical work. The invaluable documentary resources provided by the creators of electroacoustic music must be gathered, inventoried, and distributed without delay via institutions such as research organisations, universities, learned societies and libraries. This work, far from being completed and sometimes even still in its preliminary stages, will feed the work of musicologists in the coming years, particularly the work of analysts interested in compositions that combine music and machines.

The difficulties encountered in the analytic approach are found less and less in the segmentation and description of perceived morphologies, especially since the emergence of effective computer tools. On the other hand, a deep understanding of the mechanisms of electroacoustic composition is still difficult to achieve. It must be said that although current methods of spectral investigation by FFT or automatic segmentation permit a certain illumination of the structure of acoustic textures, they remain considerably below the level of precision obtained by the careful reading of a traditional score. Even for sophisticated contemporary pieces, the time-honoured system of representation with notes permits an analytic reading of complex arrangements (doublings, aggregates, polyphony, polyrhythm) while spectral representations and automatic segmentation more often describe the perceived acoustic phenomenon as a global timbre. While traditional notation bears a written representation *a priori*, signal analysis brings representation *a posteriori*.

While the analytic methodology of older or better-referenced music benefits from a large corpus and numerous studies, the same cannot be said for music linked to electronic instruments.[1] Although certain sources are already unavailable due to the rapid technological progress made over the last half-century and the fragility of support media, the works and first-hand documentation are almost always sufficiently plentiful and relevant, thus allowing for significant advances in electroacoustic musicology. There is no single or unique methodology in this domain. Researchers confront a great number of different situations in which they can rely very little on documented or recognised invariants. Genres and styles vary greatly. It is difficult to tackle music on support media, mixed music, and real-time music with the same methods. For synthesis as well as for micro-formal and macro-formal notation, the approach to music made

[1]We are using Marc Battier's expression, '*lutherie électronique*' (collection of electronic instruments), '*Les polarités de la lutherie électronique*', in *Méthodes nouvelles, musiques nouvelles, Musicologie et création*, under the direction of Márta Grabócz, Strasbourg, Presses Universitaires de Strasbourg, 1999, pp. 307–18.

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with the help of computers proves to be different from the approach to compositions conceived of as intuitive or poetic visions or as supple soundscapes. Moreover, the collection of electronic instruments is very heterogeneous and lacks the temporal stability necessary for the emergence of techniques, signs and musical languages that match their diversity.

In spite of these obstacles, analysis is supremely important to electroacoustic music. Obviously, this kind of music must take its place within general musicology and base itself upon the experience of the latter. Introducing the articles of the *Troisième Congrès Européen d'Analyse Musicale* held in Montpellier in 1995, Jean-Michel Bardez stated that

> the analysis, or interpretation in the strongest sense of the word, provokes the disconnection – the rupture – essential for continually creating new links and gives access to the openness of the work, when we would have liked to believe it was a closed territory. (*l'analyse, l'interprétation au sens fort de ce terme, provoquent la déliaison, la rupture essentielle pour créer sans cesse de nouveaux liens et donnent accès à la béance de l'œuvre, alors que l'on aurait aimé croire qu'elle est en territoire clos.*) (Bardez 2001: 8)

A listening score is therefore insufficient because it does not allow the work to be read. The difficulty is, above all, methodological. The increased possibilities offered by electroacoustic technologies involve profound epistemological research – but first, a summary of the situation must be made.

2. SUMMARY OF THE SITUATION

2.1. Contemporary music: complex and explosive

In the study of electroacoustic music, musicologists run up against the complexity of written records and especially against the explosion of styles – as so often occurs in contemporary music.

Virtuosity in writing, such as Ferneyhough's and Lachenmann's, is widespread among composers influenced more or less directly by serial techniques. That which is commonly called the post-serial movement has produced works that are complex for both performers and analysts. Furthermore, computerised composition aids, because of their tendency to nourish and prolong the creative process, give rise to an 'increased' writing virtuosity. The O*penMusic* constraint-programming libraries provide many examples of composition aids that involve the manipulation of symbolic values. These software tools rely as much on endogenous models, coming, for example, from spectralism or serial music, as on exogenous models coming from statistics, genetics, fractals, or neuronic networks.

In addition, every creator explores, during at least one period in his or her artistic life, a favoured model. Granulation with Curtis Roads, tonal modulation with John Chowning, computer performance with Laurent Bayle, global synthesis control with Marco Stroppa, interactivity with Joel Chadabe: these are significant examples linked to strong creative personalities. A phenomenon reducing the musicologist's constraints is the fact that every piece from the repertoire of contemporary music is often unique with respect to its generative process. In a literal sense, every musical work, no matter what its style or to which corpus it belongs, is systemic: it forms an ensemble of symbols and/or acoustic phenomena that is rendered coherent by an organising principle. Since the beginning of the twentieth century, this organisation has become such an increasingly personal part of the act of composition that we are at the point where each work is individualised. Thus, Stockhausen's position as discoverer led him to continually invent new compositional concepts, most notably during his pioneering work in the domain of electroacoustics. Recognised as one of the figureheads of contemporary creation, he always looked towards the future, surpassing each solution with new questions.

For all these reasons, even though assisting the composer can be considered a benefit of an in-depth analysis or stylistic study, other paths are equally available to the musicologist.

2.2. Technological progress

The progress realised in the domains of signal analysis and extraction of acoustic and formal parameters using heavily computational methods is remarkable. The latter have long drawn on different principles, such as Fourier Analysis or its derivations (the FFT, for example) for a high-quality instantaneous or dynamic spectral analysis or the LPC for detection of the fundamental. In reality, the evolution of tools is reinforced by the increased power of machines, which in turn allows increasingly efficient calculations and increasingly precise quantitative evaluation of musical parameters.

Major progress is still to be made, particularly in the search for similarity. Although this domain has seen significant advances with regard to the exploration of rhythmic-melodic structures (used mainly for industrial and commercial purposes), the control of indices of similarity, which allow the quantification of the reconciliation of diverse occurrences, is still limited in precision. But the efforts made in musicology and music analysis have already yielded very interesting results within the world of rhythm and, more generally, in the computerised formalisation of musical structures. This is seen in the research of André Riotte, Marcel Mesnage (Mesnage and Riotte: publication pending), and Stephan Schaub (Schaub 2004), for example. At

Ircam, Geoffrey Peeters[2] has been investigating automatic indexation and content description within the context of musical databases, while Olivier Lartillot-Nakamura (Lartillot-Nakamura 2004) has studied automated modelling of listening according to a cognitivist approach to musicological applications. But analysis aids are not sufficient to create a methodology, and we can reasonably ask ourselves how to classify the various approaches of the musicologists.

2.3. Work on analysis

In the work stemming from his doctorate, Stéphane Roy distinguishes among the methods already in use: 'Schæfferian typo-morphological description', 'analysis of composing and listening behaviours', 'analysis of phonological inspiration' and 'structural analysis' (Roy 2003). The author bases his thoughts on the type of viewpoint adopted by the musicologist, emphasising the tripartition of Jean-Jacques Nattiez. He also notes the absence of a theory defining the adopted rules of segmentation and justifiably underlines the fact that the morphologic model 'often favours the study of the states of the musical structure over the processes and functions that form them' (« *favorise souvent l'étude des états de la structure musicale plutôt que des processus et des fonctions qui l'élaborent* » [Roy 2003: 191]).

In taking up the concepts of analysis from a neutral level drawn from Gestaltism, particularly that of the four aesthesic methods (Ruwet's paradigmatic analysis, functional analysis, Lerdahl and Jackendoff's generative analysis, and Meyer's implicative analysis), Roy places himself firmly at neutral and aesthesic levels, but he wisely insists on the importance of an understanding of the poïetic strategies of the composer that would allow a comparison of three points of view: the listener's, obtained by external inquiry; the analyst's, obtained using specific methods; and the composer's. A systematic methodology for the analysis of electroacoustic music has yet to be devised. Such a methodology would lead to a more precise vision of this corpus and would encourage the formulation of general historical and aesthetic propositions, but a certain number of specificities have hindered this research.

3. CONSTRAINTS

3.1. The absence of a perceived instrumental typology

By definition, electroacoustic pieces created with either analogue or digital technologies include fixed, transformed and synthesised sounds. Yet these timbres do not refer to traditional typologies. Classification by predefined categories is made even more difficult because certain sound fragments may or may not be perceived as coming from the natural world, a real phenomenon, a voice or an instrument. Furthermore, accepted technologies permit a perfect continuity between characteristic timbres. For the first time in the history of music, timbre has become independent even of the excitation agent and the resonating body. Not only can we, in theory, produce any sonic phenomenon, but we can produce all intermediate nuances as well. This does not imply sound *morphing*, but rather a non-discretising of the timbral domain into defined subgroups. Musicologists find themselves confronted with a field whose cartography is not standardised, nor is it possible to standardise it – although this assertion must be qualified.

Schæffer's efforts to establish what he called an 'acoustic solfège' (Schæffer 1966) are well known. According to Michel Chion, a classification of acoustic objects from the morphological point of view can be accomplished through the 'identification of sonic criteria or the specification of the structure of sonic objects (« *identification des critères sonores ou qualification des objets sonores dans leur contexture* » [Chion 1983: 171]). But composers and musicologists rapidly abandoned these unreliable methods of differentiation.

The idea of a lack of classification must also be mitigated by a simple observation: certain synthesis or treatment devices or processes are identifiable by a trained ear, such as synthesis by frequency modulation, granulation, reverberation, echo, or resonant filters. The methodological obstacle presented by poorly documented, complex music, whose component parts are difficult to reduce into categories, occurs in notation as well.

3.2. The problem of representation

Within the domain of music in general, notation and representation systems are extremely varied, symbolic or graphic. For works which contain sound on support media, the notation of the electroacoustic parts is often left out of the score, and may even be unwelcome *a priori* by the composer. But certain qualifications must be made.

The process of creation can rely on rough graphic forms intended to help the composer's research. A simple example of this type of notation, taken from the outlines for Jonathan Harvey's *Mortuos Plango*, *Vivos Voco*, has already been published (figure 1). Nevertheless, it is necessary to specify here that scoring and notation are two fundamentally divergent concepts. Scoring is a tool used for creation and allows the generative thought to find its points of reference. Notation, on the other hand, allows the musical contents to be transmitted as precisely as possible to the performer. Notation can, however, aid the scoring process.

With contemporary music, notation has become more complex (new modes of playing, non-tempered pitches, complex rhythms, unstable tempos). Yet a certain number of signs have come from traditional

[2]Particularly within the framework of the Cuidad MPEG7, Cuidado, and SemanticHIFI projects.

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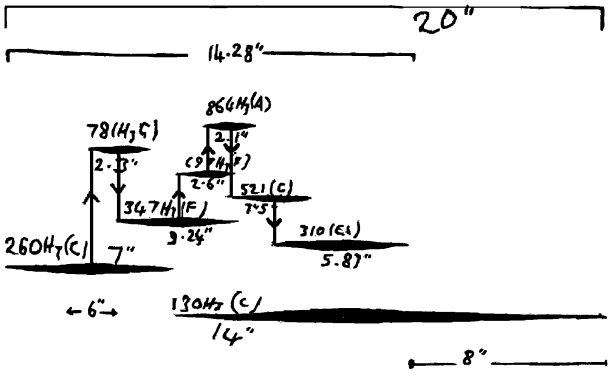

Figure 1. Draft from *Mortuos Plango*, *Vivos Voco* by Jonathan Harvey (Bossis 2004: 132). By permission of Jonathan Harvey.

scoring of pitch and duration, particularly in writing for string instruments. Although pizzicati have long drawn on a unified technique, the 'Bartók pizz.', now known by all string instrument players, and more recently, the 'M. pizz.'[3] invented by Ivo Malec, require differentiated notations. For Jean-Yves Bosseur,

> The explosion of trends of aesthetic thought that characterises the second half of the 20th century is evident in the notation systems chosen by individual composers. Never before has the divergence in recommended systems seemed so great, from the most precise scores ever to have existed to the most elastic, which are sometimes reduced to scenarios of very general sonic actions and reactions. (*l'éclatement des tendances de pensée esthétique qui caractérise la seconde partie du XXe siècle se retrouve bien évidemment dans les principes de notation individuellement choisis par les compositeurs. Jamais l'écart entre les systèmes préconisés n'est apparu aussi large, depuis les partitions les plus précises qui aient jamais existé, jusqu'aux plus souples, qui se réduisent parfois à des scénarios d'actions et réactions sonores très généraux.*) (Bosseur 2005: 102)

Many scores refer to a specific method of use and are even confused with ritual, particularly with Cage, Kagel, and Stockhausen. Attempts at standardisation have not really succeeded, even if certain signs appear frequently. Jean-Yves Bosseur correctly states that

> many composers have deliberately reduced notation to the only signs capable of accounting for the most general characteristics of the expected result. (*de nombreux compositeurs ont délibérément réduit la notation aux seuls signes capables de rendre compte des caractéristiques les plus générales du résultat attendu.*) (Bosseur 2005: 109)

[3]These pizzicati, symbolised by square note heads, are played by placing the thumb on a string with a sliding motion. The string stays away from the fingerboard while the middle finger of the same hand pinches the string. Two variants are achieved by either using or not using the fingernail (bright or dull sound). A significant example can be heard in Ivo Malec's *Arco-1*, a piece for solo cello (p. 15 of the score).

Furthermore, extremely precise notation, such as the frequential notation used by Stockhausen for *Studie II*, remains marginal (figure 2). Others such as Rainer Wehinger for *Artikulation* by Ligeti, sought a more intuitive representation (figure 3).

Jean-Claude Risset states that

> to be useful for a musician or a *SACEM* [performing rights] agent, the representation must indicate the major elements of the tape in a recognisable way. And certain graphic transcriptions of electroacoustic music are the subject of particular attention, such as the listening score by Rainer Wehinger for György Ligeti's electronic piece *Artikulation*. Costin Mirieanu notes that such a transcription corresponds to a 'deviant gesture', but also to an effort to rescore and even to analyse. (*pour être utile à un interprète ou à un agent de la SACEM, la représentation doit signaler de façon reconnaissable des éléments saillants de la bande. Et certaines transcriptions graphiques de musique électroacoustique ont fait l'objet d'un soin tout particulier, comme la partition d'écoute réalisée par Rainer Wehinger pour la pièce électronique Artikulation de György Ligeti : Costin Mirieanu souligne qu'une telle transcription correspond à un « geste déviant », mais aussi à un effort de réécriture et même d'analyse.*) (Risset 2001: 132)

He rightfully concludes that 'the problem remaining unresolved, we can't consider listening schemata a satisfactory medium for analysis' (« *le problème restant ouvert, on ne peut considérer que les schémas d'écoute soient pour l'analyse un support satisfaisant* » [Risset 2001: 132]).

Although acoustic authenticity is preferred, graphic transcription is still difficult to decipher due to the lack of recognised norms and an often-excessive simplification of schemata. Yet these listening schemata often do provide meaningful symbolisation. Sounds are no longer noted individually. Instead, the form or shape of a complex acoustic phenomenon is suggested. When the composer controls or is the originator of this kind of notation, it proves to be so much more useful to the analyst that it becomes a higher level of representation.

The sonogram yields even greater precision. It represents both the spectral and temporal aspects of the sonic phenomenon, but not the musical significance. Nevertheless, when the notation designed by the composer falls short, the analyst can only rely on the acoustic evidence and create his own transcription. The principle behind these representations *a posteriori* is based on the segmentation of acoustic events and the symbolisation of their morphology. Thus they enrich the information, and if necessary, they can indicate pitch in terms of note names, as in the example in figure 4 taken from the hypermedia analysis of *Mortuos Plango*, *Vivos Voco*, which is available in-house on Ircam's Médiathèque server. In another analysis, that of *Chants de l'amour* by Gérard Grisey (Bossis 2004), the

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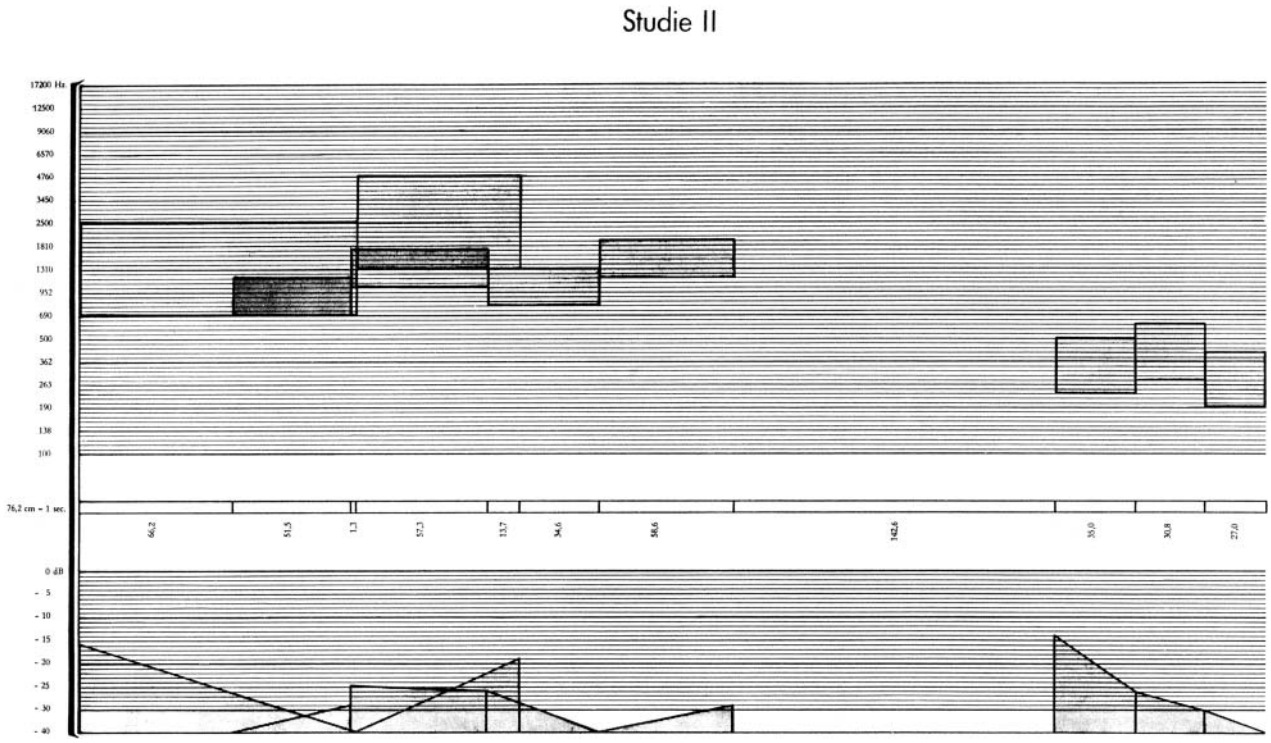

Figure 2. *Studie II* by Stockhausen, p. 1. © By kind permission of Stockhausen-Verlag. All Stockhausen scores, CDs, books and videos may be ordered directly from Stockhausen-Verlag, 51515 Kürten, Germany (http://www.stockhausen.org).

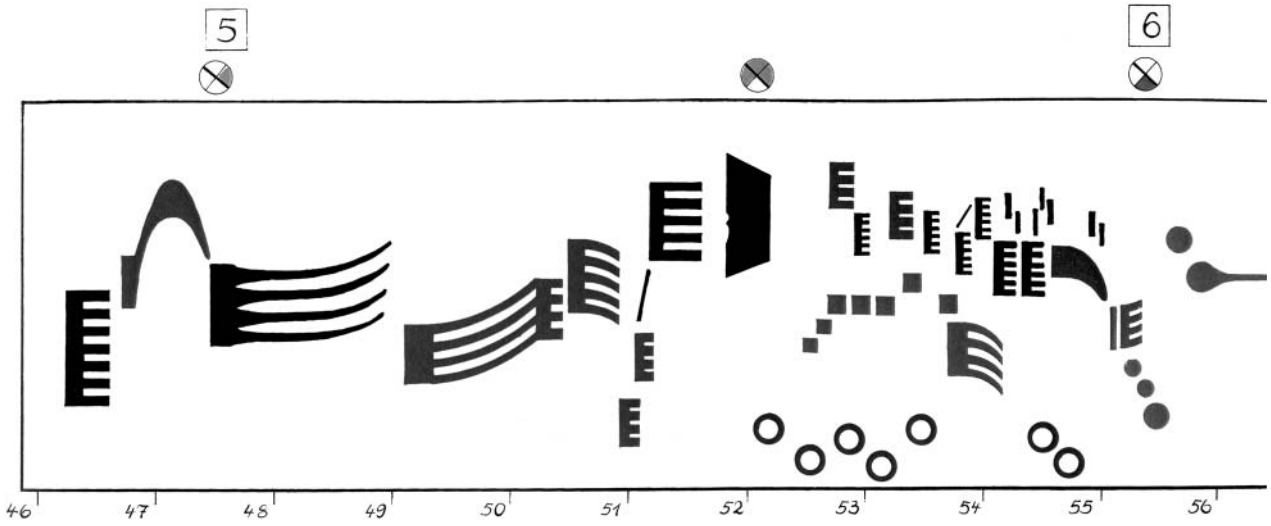

Figure 3. Ligeti's *Artikulation* by Rainer Wehinger, p. 48. By kind permission of the music publisher Schott Musik International GmbH & Co. KG, Mainz, Germany.

sonographic representation enhanced with graphic and alphanumeric comments illustrates the formal construction of the FFT[4] work (figure 5).

[4]*Les Chants de l'amour* by Gérard Grisey are built on the evaluation of the frequental difference between the first two formants of each of the vowels contained in the phrase 'I love you'.

In mixed music, composers themselves precisely note certain important pitches on the schematic notation of the electroacoustic part in order to make it easier for players to locate the sounds coming from the tape. This can be seen in the score of *Chants de l'amour*, but also in the scores of various pieces in different styles such

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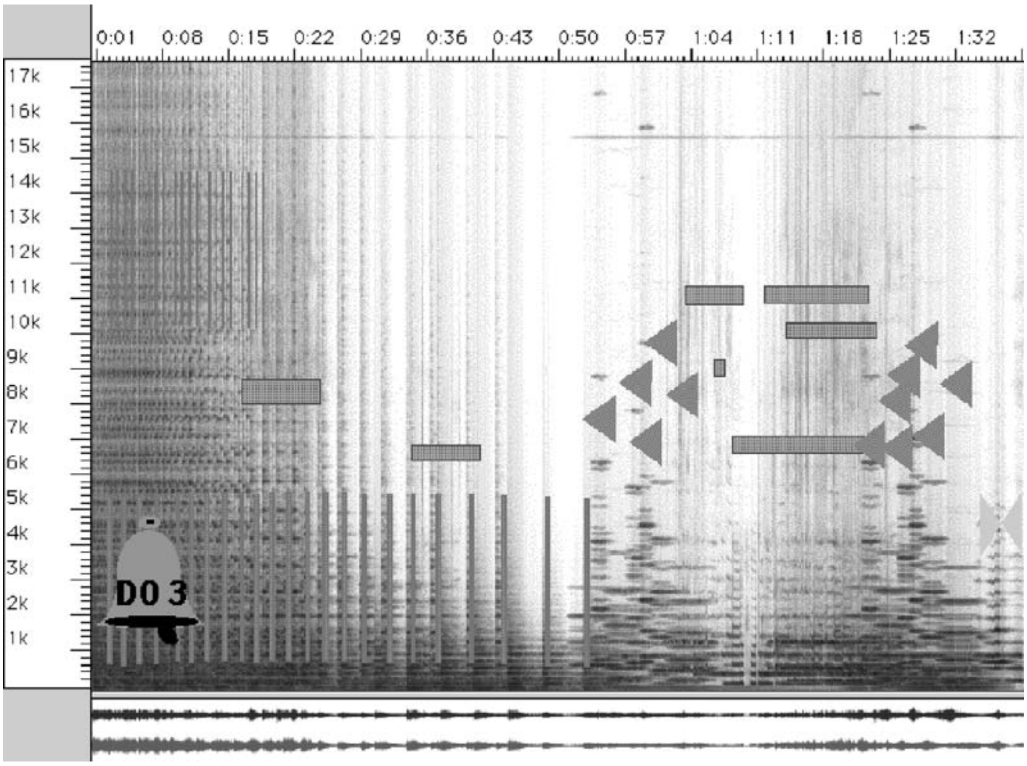
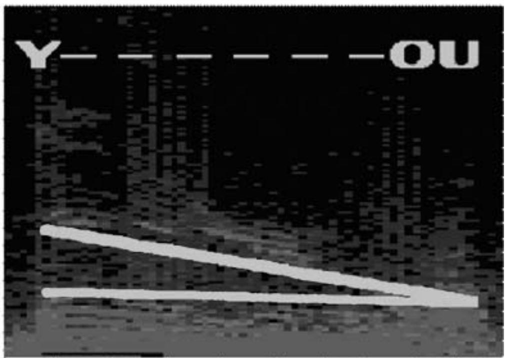


Figure 4. Graphic representation of *Mortuos Plango, Vivos Voco* by J. Harvey (Bossis 2000).



Section	19	20	21	22	23	24	25	26	27	28
You -										
Voyelle	I	y	Y	ø	ɘ	ʌ	ɔ	o	U	U
F 2 (Hz)	2017	1975	1661	1504	1308	570	440	392	370	270
F 1 (Hz)	233	293	329	784	457	260	245	207	150	130

Figure 5. Illustration of the formal structure of *Chants de l'amour* by Grisey.

as Tristan Murail's *L'Esprit des dunes*, Ivo Malec's *Attaca*, and Gilbert Amy's *Une Saison en enfer* (figure 6). In the same way, Ivan Fedele notes the dynamic allocation of sounds in the spatial field[5] through the use of symbols in the form of dice on the score of *Richiamo* (figure 7).

[5]On six points of diffusion.

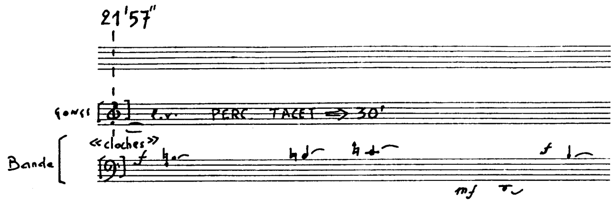


Figure 6. *Une Saison en enfer* by G. Amy, beginning of *La nuit de l'enfer*, p. 29. © By kind permission of the composer.

Analysis of electroacoustic music is particularly arduous due to the complexity of its composition, the constraints imposed by its very nature, the continuity of its timbral dimension, the specificity of the electronic instrumentation, and the difficulties inherent to its performance. Thus an examination of the very subject of this type of work is essential.

4. A QUESTION OF METHODOLOGY

It seems inappropriate to apply the analytic methods which are widely used for music based on scales, timbres and durations to electroacoustic music. The establishment of a universal and unique analytic method for electroacoustics is not immediately feasible, nor necessarily desirable. The framework within which the problem lies must be examined before appropriate solutions can even be proposed. The search for rigorous

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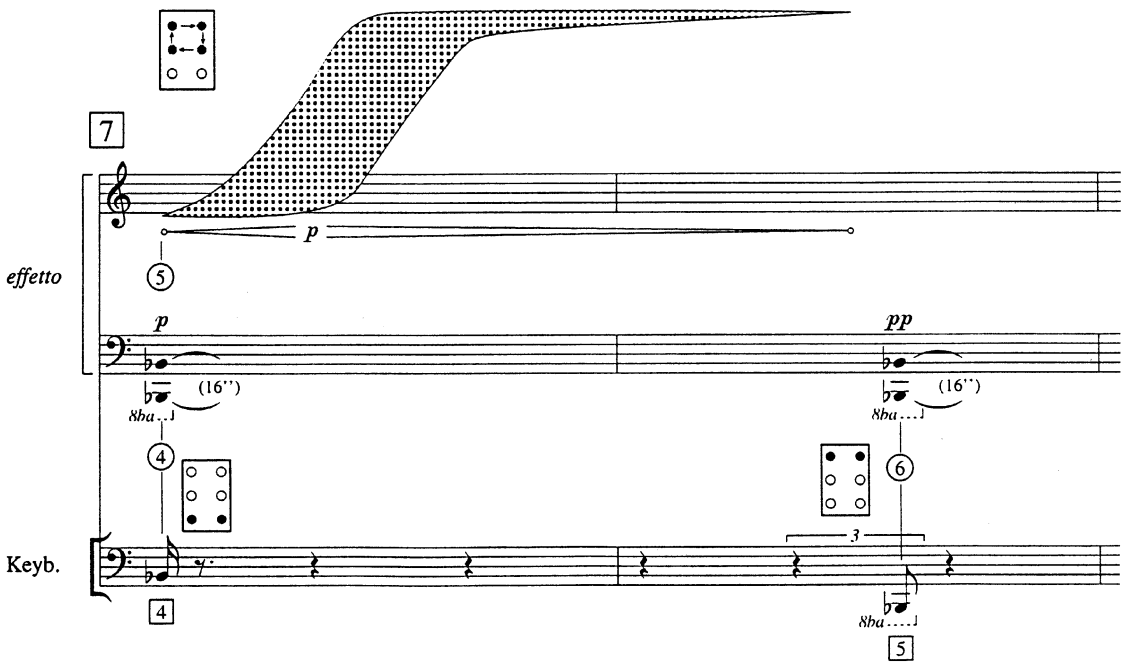

Figure 7. *Richiamo* by I. Fedele, p. 1. © By kind permission of Sugarmusic SpA, Edizioni Suvini Zerboni.

methods with which to approach this music can also be based on exogenous models such as an historical model: investigation of up-stream sources, as demonstrated by downstream invariants.

4.1. Analysis and non-scalarity

Today's analytic methods have been designed for music with discreet variables representing pitch, duration and timbre. Electroacoustic music does not fall within these scalar parameters, although certain tapes or real-time devices can emit real or simulated instrumental sounds in pitches and durations that belong to a clearly defined scale. The textures are thus composed of notes, as they are in François-Bernard Mâche's *Aulodi*, or Jean-Claude Risset's *Voilements* (figure 8), which favours the dialogue between an instrument and its electroacoustic double, as in *Dialogue de l'ombre double* or *Anthèmes 2* by Pierre Boulez.

But the very nature of electroacoustic composition and the various computational processes, their range and their refinement, usually render traditional analytic methods obsolete and unusable. Hence it is imperative to consider other solutions, especially because of the morphology particular to sounds made via transformations and simulations, but also, for example, because of the writing control made possible by computer technology. This dual approach also applies to the analysis of mixed music and requires a deeper study of the relationships established between sounds produced by machines and those produced by traditional instruments. Indeed, although the electroacoustic part of Philippe Manoury's *Jupiter* is based on the automatic tracking of defined pitches of the flute, the sounds do not systematically follow this plan (figure 9). Moreover, the analysis must examine the relationship between the instrument (or voice) and the electroacoustic device; in other words, it must take into account the musical parts

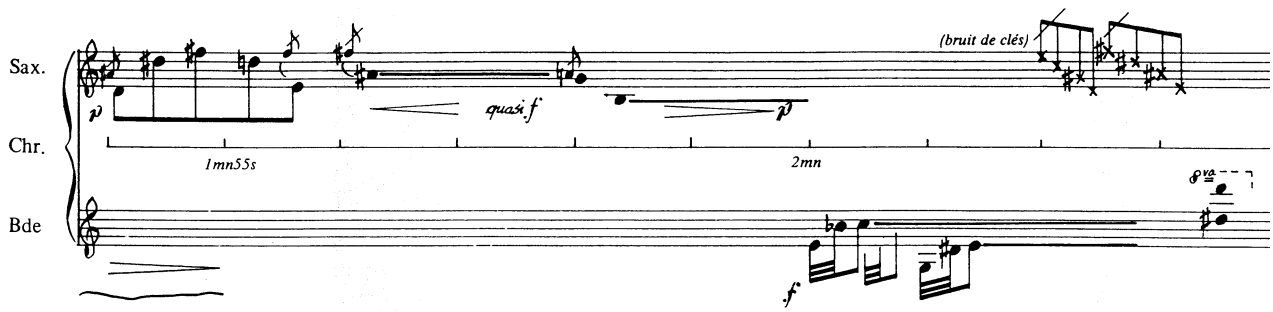

Figure 8. *Voilements* by J.-C. Risset, p. 12. Musique: Jean-Claude RISSET © By Kind permission of Editions SALABERT - Paris - France.

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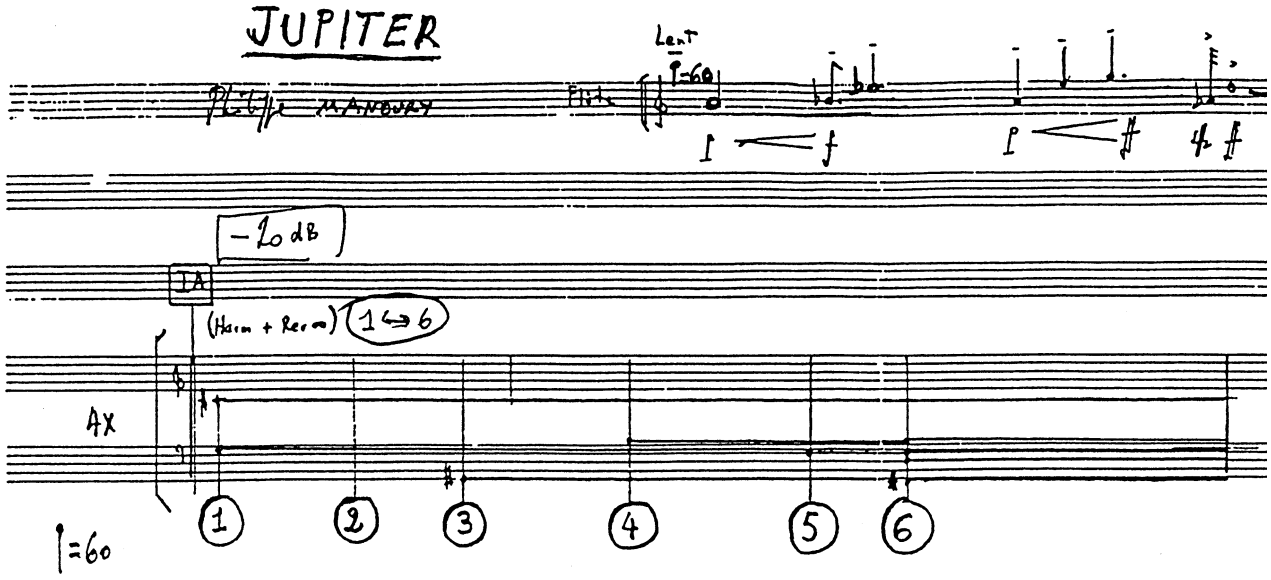

Figure 9. *Jupiter* by P. Manoury, p. 1. Musique: Philippe MANOURY © By Kind permission of Editions DURAND - Paris - France.

comprised of notes, durations and timbres that belong to a standardised nomenclature as well as parts that function on the basis of notes, durations and timbres that continually vary.

4.2. A genetic point of view

In 1984, in an article entitled 'The Analysis of Electronic Music', Marco Stroppa describes the obstacles encountered in his analysis of Jean-Claude Risset's *Songes*. He refers to two common types of sources for works created with computers and recorded on support media: a 'list of operational data' and a 'schematic representation of obtained sonic effects' (Stroppa 1984: 177). However, it is important to note that while the available material is bipartite, it is also true that each of these two source categories pose a major problem. The precision of the first category must deal with its own obsolescence and the reading difficulty inherent to the complexity of computer languages. The second category is closer to the reality of perceived sound but is intrinsically imprecise.

Sometimes, the score – particularly in the case of real time – only indicates the temporal placement of treatments and simulations. The musicologist must then ask the composer for additional information, in the form of patches or Q-lists, for example. Knowledge of the techniques used in the announced events (often given as numbers written on the score) is desirable, if not indispensable, to a proper reading of the score and its associated documentary sources. Whether or not the production is done in real time (and if so, whether or not the triggering is manual or automatically tracked), the transformed and synthesised sounds are the result of the use of an 'electronic orchestra'. Thus, reading the scores of the construction of Stockhausen's *Kontakte* (figure 10) or of the pieces from Philippe Manoury's cycle *Sonus ex machina* and *En Echo* with an awareness of the various patches allows the musicologist to surpass the level of perceptive analysis offered by listening alone.

To a lesser extent, the schematic representations of the envelope or waveshape of the group of tracks of an edited project in a sequencer such as *ProTools* allows the refinement of the understanding of the composer's process. Access to these documents, however, remains one of the most important constraints.

4.3. Searching for sources

One of the difficulties in locating source material is the confidentiality of institutions' archives and composers' private collections. Unfortunately, institutional archives, if they have not been lost, often lack the means to assure proper conservation and strict classification. It is also important to note that there is no standardised method of nomenclature, such as exists for written or printed materials held in libraries. Thus a great deal of work remains to be done.

In the case of a digital support such as the DAT, the ADAT, or the CD, the sonic source is generally of good quality and easily manipulated. The ADAT allows direct multi-track work, but the study of the spatialisation is easier when the *ProTools* sessions are available. Analogue acoustic sources such as the published black records in collections that are hard to find today (the famous Philips '21st century' collection, for example) require a digital transfer whose quality depends both on the condition of the original record and on the

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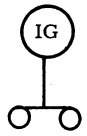
KLANGMATERIAL

Das folgende Klangmaterial ist mit den Daten bezeichnet, an denen die entsprechenden Experimente gemacht wurden.

20.2.58.



Einzelimpulse
Dauer: ca 5 ms

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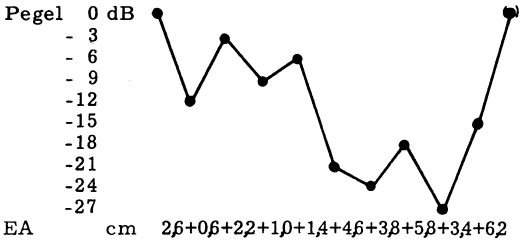

Die Tonbandstücke wurden mit spezieller Klebflüssigkeit auf Weißband geklebt. Diese Schleife (Periode 31,6 cm) transponieren 1:8. Man hört als Hauptfrequenz 95 Hz.

25.2.58.

Wie am 20.2.58.

Die gleiche Anzahl von Impulsen mit den gleichen EA, aber alle gleich laut, zur Schleife kleben und transponieren 1:8.
Man hört am stärksten 254,4 Hz (auch 127,2, 63,6, 31,8 Hz); 4-5-6 Oktaven höher gut verwendbar. Die gehörten Frequenzen treten zurück, sobald man die Ausgangsschleife über 3 Oktaven aufwärts transponiert; neue Hauptfrequenz zusammen mit 254,4 Hz ist 76,8 Hz; bei höheren Transpositionen wird dieser untere Ton immer stärker. Für die Verwendung dieses Klanges gilt 31,8 Hz als die Frequenz, auf die Transpositionen bezogen werden. (Meistens wird dann auf TM mit 31,8 Hz Steuerfrequenz aufgenommen und transponiert).

Figure 10. K. Stockhausen's production score of *Kontakte*, p. 5. © By kind permission of Stockhausen-Verlag. All Stockhausen scores, CDs, books and videos may be ordered directly from Stockhausen-Verlag, 51515 Kürten, Germany (http://www.stockhausen.org).

mechanical and electronic quality (RIAA equalizer, preamplifier) of the material available to the analyst. The discovery of unpublished tapes either of complete works or of work fragments is certainly a cause for concern. Aside from the tape's condition, the analyst must deal with the scarcity or the poor condition of tape recorders that are compatible with the recording format.

The listings reproducing the computer programming code are often very useful because of their intrinsic precision. A musicologist who knows the language would find *Stria*'s Fortran routines understandable and helpful; their usefulness to a composer is invaluable, particularly for understanding the names of variables. Similarly, an understanding of Q-lists derived from the work done by Manoury's team for his opera *K.* or from patches used in Tristan Murail's *L'Esprit des dunes* is indispensable to in-depth investigation.

The only perceptive analysis of John Chowning's *Stria* lends a merely superficial understanding of how the piece works. With this type of approach, even the general segmentation is difficult to assess on the sonogram. Only the reading of computer routines on listings yields a precise understanding of how the music is structured and how to approach a pertinent semantic field, with regard to each 'event'. These routines function as actual scores since the precise parameters of each event are accessible, but reading them is rendered difficult in the absence of a temporal axis. (figure 12)

Still, it is not customary to publish these listings, even though traditional scores have been circulated ever since musicians have felt the need to have a written record available for the memorisation of an oral repertoire. The emergence of musical creation through written composition favoured this evolution. The reason behind this confidentiality undoubtedly stems from the fact that these partitions are intended principally for interpretation and not for analysis. Nevertheless, the creator's thoughts – whether gathered in interviews, conversations, and published writings or not – belong to different genetic sources. They are essential to the illumination of the process of creation. This 'primordial' source material must be considered to be endangered by its dispersion, its confidentiality, and the progressive disappearance that has already begun. The time has come for consideration of the source materials, the

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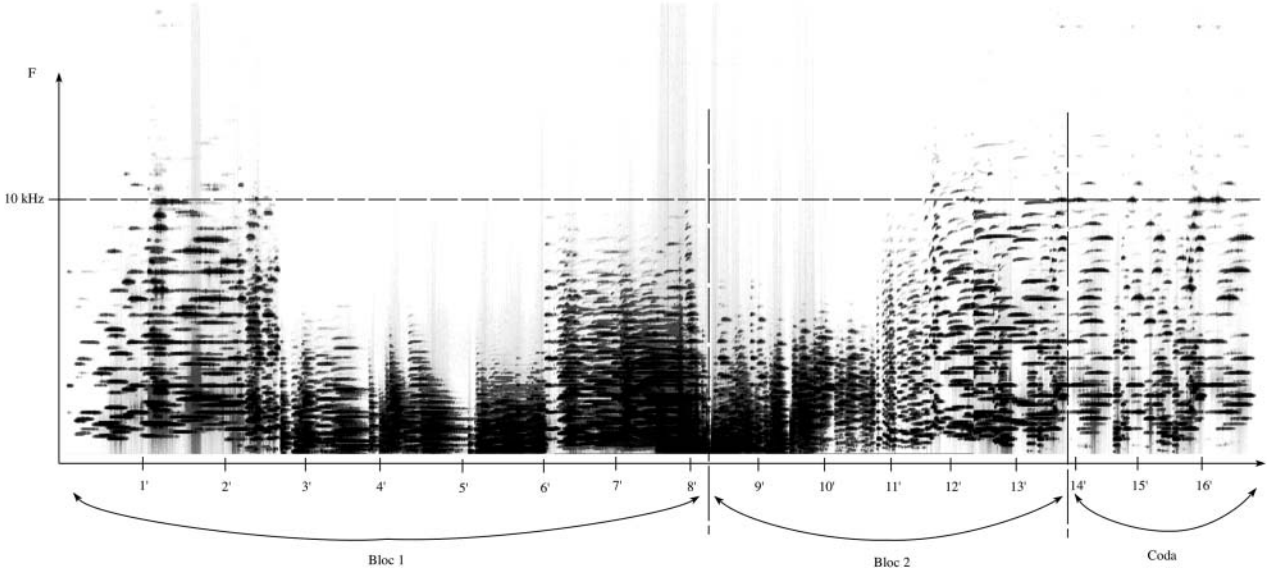

Figure 11. Sonogram for *Stria* (Bossis 2005: 102).

```
5 Oct 1977     9:36          T0.MEM[ PC, JC]              PAGE 1-1

Event types are blk-tapered→0
stat-pnts→1
recursive→2
Type 0 - 1 - or 2 →2
Type Begin time of event   → 1
Type Duration of event   → 55
Type Attack Duration of event   → 47
ext =   .750
Type <cr> or ext where .5 ≤ ext ≤ .75 (.85)  → .45
Type <cr> or 1 for At Switch att prop to freq → 0
Type <cr> or ] for reset of Freq tab →
Freq.=   .000
Type <cr> or new base frequency   → 2618
Freq. space=   .000
Type <cr> or new power for ratio  → -2
Freq. space=   .382
```

Figure 12. Fragment of the *Stria* listing (Chowning: private document).

conditions of their collection, identification, classification, conservation and dissemination, and the way in which they are made accessible.

Clearly, it is essential to know how to read a document in order to understand it as an essential component of the research. A schematic transcription and the resolution of abbreviations and variable names, routines and sub-routines are indispensable. The composer or musical assistant can collaborate with the musicologist, but the pioneers of computer music will not always be available to analysts. Thus it is essential that sources are collected, documented and made accessible. Paradoxically, advances in computer technology – and in technology in general – make analysis of certain sources difficult. The establishment of a veritable archaeology of technologies and of works that employ those technologies is slow. It is imperative not only to conserve and analyse this body of work, but also to preserve the memory of the period's technologies. As is true with certain systems of musical notation or with the spoken languages of ancient or extinct cultures, the obsolescence of technologies must give birth to a paleography of computer science. Technologies and the works they produce must be preserved not only so that they can be heard but also so that they can be understood and their origin and composition be appreciated.

A philological approach, which operates on three different levels, is appropriate here. Philologists first examine documents in their physical reality, studying and evaluating the support media. They study the linguistic aspect and, finally, the literary aspect of the documents. Although etymologically, philology is concerned only with grammar and the exegesis and criticism of texts, it does more generally refer to everything which aids in the restoration and illustration of the past. In the same way, the musicologist must first of all determine the language of the music, which is sometimes very difficult considering the abundance of musical styles of the past century. S/he must then situate the musical expression within the context of music history in general. Babbitt's works take their place principally within the lineage of serialism while some of Harvey's pieces combine the influence of serialism and spectralism. The musicologist must also reconstruct the source's history, situating and precisely describing it. Generally speaking, a true scholarly apparatus is indispensable.

Finally, interactive devices pose specific problems. To date, there have been very few experiments done that are useful to music analysts. In this domain, musicological research is still exploratory. Simple on-off switches are far from mechanisms designed to capture continuous values, such as ultrasound, laser, and radar devices, but the association of several of these resources is very productive. The composer can develop a writing system that precisely integrates the

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movement and the instantaneous position of the performer's body part in real time on stage. Creators have more than just a virtual symphony that allows a new virtuosity: they also have new means of expression. Musicological work must continue to explore and develop a precise knowledge of these interactive devices whose history is being written before our eyes.

Whether or not they are old or currently under development, the heritage of electroacoustic music should inspire the musicologist to critically analyse the source material. Only a systematic evaluation of available documents will allow musicological work to be carried out on a sound basis. Nevertheless, this work presumes the availability of the greatest number of documents. Unfortunately, many sources remain inaccessible or are already lost. Hence the indexation and preservation of acoustic events as well as written and computerised documents is of the utmost importance. For this reason, the collections currently being built, such as those within the framework of the MINT (Paris IV-Sorbonne),[6] are very important.

4.4. The historical model

Future progress will certainly be made at the crossroads of research into source material and its musicological use. In general, the idea of a line beginning with collection and leading to the determination of invariants becomes clear in the light of historiography. Whereas history signifies both the event and the telling, historiography studies the different ways history was written throughout the ages: it therefore asks fundamental questions about the collection of documents, their evaluation, and their use in a discourse which develops generalising concepts.[7] Similarly, research into stylistic and aesthetic invariants can only happen after a real critical review of sources has been undertaken.

In her *Introduction à l'historiographie*, Marie-Paule Caire-Jabinet emphasises medieval historians' interest in what she calls 'the search for sources' (Caire-Jabinet 1994: 15). She also states that the historian does not depend solely on written sources but enlarges the corpus to include 'auxiliary sources' drawn from archaeology, accounts, and oral tradition. Finally, she describes a methodology that infers a progressive chronological adjustment and prescribes a critical view of documentation. This was only made possible by the improvement of work tools during the Middle Ages, such as the division of texts into chapters and paragraphs and the creation of tables of contents. The creation of a true historiography thus required the establishment of a scientific method and useful tools for examining sources.

The need for investigation into documentation continued. In the preface to the 1869 edition of his *Histoire de France*, Jules Michelet states:

> As a corollary, until 1830 – even until 1836 – the notable historians of the period had never before felt a greater need to seek facts outside of printed books, from primary sources, most as yet unpublished, from manuscripts in our libraries, from documents in our archives. (*Au reste, jusqu'en 1830 (même jusqu'en 1836), aucun des historiens remarquables de cette époque n'avait senti encore le besoin de chercher les faits hors des livres imprimés, aux sources primitives, la plupart inédites alors, aux manuscrits de nos bibliothèques, aux documents de nos archives.*) (Michelet 1971: 3–7)

This imperative applies to all domains; historical and analytical works on the corpus of electroacoustic music cannot ignore this 'search for sources'. Consequently, the results obtained through the study of the history of civilisations, as well as in musicology, are never definitive. Results benefit from advances made in the collection and examination of sources. In his *Naissance de l'historiographie moderne*, Georges Lefebvre stresses that 'history is not written once and for all, […] it is not made from dead matter, petrified for all time' (« *l'histoire n'est pas écrite une fois pour toute, […] elle n'est pas faite d'une matière morte, et figée pour toujours* » (Lefebvre 1971: 15).

4.5. Invariants

The systematisation of research allows invariants to be revealed through rigorous documentation and a coherent analytic corpus. These common elements are useful to a reasoned vision of styles, genres, and a topology of electroacoustic musics. Many in-depth analyses and historical studies follow rigorous procedures, such as questioning the status of sources, and understanding their importance can nourish the understanding of this heritage. In the same way that ancient Western music has been re-categorised according to time periods (Middle Ages, Renaissance, baroque, classical, romantic), electroacoustic music can be included in different bodies of work. In any age, research must rely on first-hand documents while keeping them in context. The invariant is not invariable in and of itself, but only in relation to its context. The context consists of a certain number of external factors that are themselves, like the musical repertoire studied here, subject to the researcher's critical interpretation. As a result of this method, the vocabulary used will

[6]Particularly with the participation in the *Ears* (*ElectroAcoustic Resource Site*) project. This project is led by Leigh Landy in collaboration with the MTI Research Group at de Montfort University (UK). He brings to his work the documentary resources necessary to the musicological investigation of electroacoustic music and computer music (http://www.mti.dmu.ac.uk/ears).

[7]The historiographers mention Herodotus, who in the fifth century BC, already conducted a serious investigation of the countries of the Mediterranean basin and rejected a strictly mythical history. He gathered his information from the source itself. He was not alone in Ancient Greece. Hellanicos of Mytilene also insisted on factual accuracy, and the erudition of his *History of Attica* prevailed over legend.

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become more refined and will avoid the pitfall of imprecise definitions hastily assigned. In any given corpus, the invariant illustrates general and permanent features that possess certain characteristics. These are the constants, the observed similarities within a group of precisely inventoried documents.

The methodology of experimental science requires the examination of facts, the observation of their relationships, and finally the formation of laws. First, the subject of observation must be defined and then the methods of observation can be determined. The analyst must then show a method of writing and of formal models for each piece studied, but this same method also sets the piece within a larger context through its associations through a search for invariants. More precisely, these invariants place the piece in its musical environment and promote the identification of trends, genealogies and complementary influences.

Musicology must include a full history, historiography and analysis of electroacoustic music; it demands systematic study of sources and rigorous investigation of the invariants that emerge. The analysis of electroacoustic music also implies the questioning of the various musicological points of view with regard to the technologies created by electricity, electromagnetism, electronics and computer science and their relationships with other scientific disciplines.

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