Models of Sound Representation in Electroacoustic Composition

Fábio P. Furlanete
UEL - Universidade Estadual de Londrina

Abstract

Musical composition has always been closely connected to the representation forms used by the composer during the creation process. The development of electroacoustic music, and later computer music, has made possible a huge change in such representation forms; enriching the possibilities of instrumental support, helping the development of the theories that describe the sound and its behavior, and widening the possibilities of writing support beyond paper. Such changes have made the composers reassess the relation between the composition process and the technological support transforming both the elaboration of the musical discourses and their interpretation (listening and musical analysis). This paper proposes a discussion about the specific case of sound representation models that are more used in electroacoustic music as active elements in musical composition; aiming to point some of the more used types, and the possible relations of such models with the composition process.

1. INTRODUCTION

The development of Electroacoustic Music caused a great change in the representation forms used in musical composition. The change in the instrumental support; the improvement in the development of theories describing sound and its behavior as well as the functioning of the sound perception; the widening of the writing support [1] possibilities used by the composer expanding beyond paper, have made composers fall back on representation forms that are quite different from those found in traditional music, quickly

[1] Writing is understood here in the widest sense of representation, in which the traditional notation is one subgroup. In this sense, writing may be developed on other bases and representation systems.

transforming both the elaboration of the musical discourses and their interpretation (listening and musical analysis). Such changes in the representation system have gained great momentum with the development and popularization of the computer, which has allowed sound experimentation to be taken to levels that were unthinkable before. It has also allowed the development and verification of new theories, as well as their implementation in systems allowing musicians to use them in both musical composition and interpretation. With the growing improvement of the digital support "the limitations of experimentation are no longer of technological nature: they depend less on the material, hardware, than on what is logic, software..." (Risset 1993). This paper proposes a discussion about the specific case of the representation models most frequently used in electroacoustic music as active elements in musical composition, and it aims to point some of their most used types, and to the possible relations of such models with the composition process.

2. REPRESENTATION MODELS

We propose a division of the theoretical models used in sound representation into two main categories: Signal models and physical models. Each one of them has own handling methods (analysis and synthesis) of digital audio. It is worth saying that such division and the subdivisions presented as follows are not stagnant and they are far from being definitive, often a model supplies the theoretical basis, or even methods to other models, which may be used in different ways by various models. In addition to that, the synthesis methods derived from such models are often used jointly in order to obtain sound that otherwise would not be possible.

2.1. Signal Models

The signal representation models are not only the most used ones, they are also the oldest - they date back to the 19th century, with the formulation of the Fourier theory.[2] These are the models that currently have the greatest variety of methods of synthesis and treatment, and they are also the only ones that have widely

[2] According to which every periodical wave form may be decomposed into sinusoidal waves with frequencies f, 2f, 3f, etc. with independent amplitudes and phases for each wave.

developed methods, both implemented and tested, of sound analysis.

2.1.1. Frequency/Time Model: it has been the first signal model used, precisely because it is a direct consequence of the Fourier theory. In this model, sound is seen as being constituted by superimposed elementary sounds (traditionally sinusoidal), with different frequencies, amplitudes, and phases.

There are two classical methods of sound synthesis derived from this model: additive synthesis, and subtractive synthesis. In the first, elementary waves (either sinusoidal or not) are superimposed aiming to construct (or reconstruct from previous analysis) the sound; in the second, sounds with a very wide spectrum are used eliminating, through the use of filters, undesired elements. Such methods use information supplied by the STFT methods (described below) to re-synthesize, with or without change, sounds previously analyzed, among which we may refer Phase Vocoder and Linear Prediction.

Due to the fact of being connected to such old theories and to the most common analysis and synthesis methods, this theoretical model is the most widely used, serving even as a parameter and tool to evaluate and describe the other models.

2.1.2 Global Model: it directly manipulates the waveform allowing the generation, in an elegant manner and with few parameters, sounds with rich and complex spectrum. Among the methods derived from this model, the most widely known are those of frequency modulation (FM), amplitude modulation (AM), ring modulation[3] and non-linear distortion. The modulation methods may be described as frequency or amplitude oscillations that, applied to a simple waveform and greatly accelerated, generate side frequencies. The non-linear distortion method consists of submitting a simple waveform to a deformation specified by a non-linear function.

Despite the economy provided, once it has encompassed few more developed methods of sound analysis, the global model results little used as a model of sound representation, generally operating in terms of the implementation of other theoretical models and representation systems.

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[3] The ring modulation may be described as a particular case of the amplitude modulation.

2.1.3. Granular Model: the granular models consider sound as being constituted by a sequence of elementary acoustic objects sequentially arranged along time called grains. The qualities of such grains and their arrangement along time determine the sound timber.

There are 5 synthesis methods derived from this model:

Grids and screens of the Fourier type or *Wavelet*, which directly use the information supplied by the grid analysis methods described above.

Superimposed Grain Flows synchronized with frequency.

Quasi- synchronous flows.

Asynchronous clouds.

Granulation, either synchronous or asynchronous, of prerecorded sounds.

2.1.4. Analysis Methods: The analysis methods of signal models are, mostly, common to all three models: a same method may be used to supply data for either one or another model depending on the type of use made of it. This is possible because they heavily use the digital version of the Fourier transform: DFT (*Discrete Fourier Transform*), herein referred to as grid analysis methods, in which the sound is divided into samples along time, and each sample is decomposed into frequency ranges. Thus, we have a sound decomposition into elementary particles both in the time axis and in the frequency axis, fusing the time/frequency and the granular models, also allowing the obtainment of data relative to the modulation factors used by the global model. There are two main methods of grid analysis: STFT (*Short Time Fourier Transform*) and *Wavelet Transform* , both consisting of the application of DFT to short time segments, also the bandwidth for each frequency range is equal, then the grid is uniform; and in the *Wavelet Transform* both the duration of the segments is proportional to the frequency of each range and the bandwidths are logarithmic. These two sound analysis methods are mainly directed to the description of periodical sounds, and STFT prioritizes the frequency information of the signal, while Wavelet Transform prioritizes the time and phase information.

2.2. Physical Models

Aiming to describe not the nature of sound, but the physical means that produces it, the physical models, under development for quite some time already, algorithmically simulate the vibratory processes of the bodies that produce the acoustical signal.

There are three main methods used in the implementations of sound synthesis through physical model:

a\ Elementary model: its purpose is simulating hypothetical basic elements of any matter that may constitute a vibratory body: punctual masses, springs, and buffers. Through different combinations of these three basic elements, they may become “matter blocks” with different forms, densities, and behaviors, which may be connected to each other and interact with other objects as exciting and capturing elements. This method allows high modularity of the simulated components, but requires a processing power.

b\ Delay Lines: it is famous due to the implementation of the Karplus/Strong algorithm that describes the behavior of sounds of the attack- resonance type. Unlike the previous method, the method of delay lines requires the least processing power, and allows the least modularity.

c\ Mode Simulation: providing the best relation between modularity and processing power, this method aims to describe, instead of the vibrating objects and their interaction possibilities during vibration, the different vibration modes that the object allows. It also has the advantage that there already are well- defined analysis methods through modes.

We could also mention the example of formant synthesis, allowing the sound to be described as a sound source with rich and uniform spectrum which frequencies are either accentuated or attenuated by resonance, as happens with voice sounds or string instruments. Such method may be placed at the border between the signal models and the physical models.

In spite of the difference of means to which the signal and physical models refer to, both try to describe the sound as a unidimensional oscillation of a particle ideally punctual, be it an air molecule or a single point in the surface of a vibrating body.

2.3. A Third Possibility

Each one of these two models proposes to describe a certain point of the circuit of production, diffusion, and reception of sound, being respectively: sound signal, here understood as the representation of the air pressure variation above a point in space, and the physical object that produces the sound vibration. These two types of model suggest the existence of models that treat the last part of the circuit: the cognitive process.

In fact, there are - since the beginning of electroacoustic music - representation models focused on the sound reception that are widely used in musical composition, such as the type- morphology of Pierre Schaeffer (Schaeffer 1966) or the spectrum- morphology of Denis Smalley (Emmerson 1986), but these models only deal with the perception data relative to listening and do not propose to describe the cognitive process as a whole.

Lately cognitive models have also been developed, which are also known as parallel distributed processing models. These do not directly focus on the description of the sound, but on the cognitive processes that organize it. Among these processes we have all the musical activities such as composition, instrumental performance, and listening (De Poli, Piccialli and Roads, 1991).

Still practically at their beginning when compared to the models described before, and using a theoretical support supplied by knowledge branches as different as Philosophy, Psychology, and Biology, the cognitive models aim to the study of the musical cognition through the construction of artificial models. Such models use mainly concepts and methods of Artificial Intelligence that deal with cognition and information processing, implemented through two main paradigms: the symbolic (or computer) paradigm, and the sub- symbolic (or connection) paradigm.

3. RELATION BETWEEN REPRESENTATION SYSTEMS AND MUSICAL COMPOSITION

Considering the characteristics of the representation models described above, we may point to some trends in these models and their possibilities to influence the composition process.

Depending on the initial project of the composer and his esthetic orientation during the progress of the creative process, certain characteristics of a model may approach to or deviate from the original project. For example, the physical models tend to direct the composition to a referral of the sound sources, once since the beginning such source is proposed as the start and reference point, even if is hybrid or distorted by hypothetical acoustical spaces projected by the composer. On the other hand, this same approach to the sources allows the inclusion of the gesture in the constitution of sounds in a much more organic way than it would be possible with the signal models. The signal models, on the other hand, focus the composition process on parameterization leading to a dissociation between the time datum and the other parameters, unlike the physical models that allow the inclusion of time as a factor definitively integrated to the sound representation. Regarding this point, we may refer the following passage by Risset (1993): "At first sigh, they [the physical models] are less of a innovation carrier than the signal models, once they take in the computer the acoustic limitations. However, we may imagine other virtual worlds with other physical laws. On the other hand, our perception is well equipped to investigate the external causes of our personal sensorial simulations: thus, the ear is particularly sensitive to parameters that we may control in the synthesis by means of physical models."

Such trends of the representation models may be present in the creation process in different ways, depending on the interaction level between the composer and the technological support. Regarding this interaction, we may refer to the three possibilities listed by Ferraz (1997):

> a\ "Situations in which the support constituted a mere help to accelerate or perform calculations, projections, timber transformations, assemblages previously elaborated by the composer on his work desk.
>
> b\ Limited situations in which the support determines the composition processes and proceedings and the composer only performs a composition already predicted by the designer of such support.
>
> c\ Situations in which both the design of the support is used in a particular way, and the composition mode is reconfigured in order to perform on that environment."

Such possibilities may be easily translated into the question of theoretical models of electroacoustic music:

> a\ Situations in which the synthesis model acts as a secondary element, only supplying the methods necessary to the

materialization of sounds previously elaborated by the composer. In this case, the ideal model is, alike the ideal interpreter of traditional music, that that annuls himself and whose methods translate as precisely as possible the thought of the composer without interfering in the creative process.

b\ Situations in which the models determines not only the sounds to be performed as well as the mode of interaction between them, that is the musical discourse, being the composer in the service of the model and of the methods used in his particular implementation. In such situation, the composer acts only as an interpreter of the model.

c\ Situations in which both the model and the methods linked to it are used in a particular way as the composition process is reconfigured to interact with that model. Here we may say that both the composer in constantly interpreting his own musical discourse through the model and vice-versa.

In these three categories, Ferraz distinguishes the interaction level, which may be either passive or active. In the passive interaction, which occurs in the two first cases, the subject does not recognize the interaction, although it is always present with predominance: now of the composer, and then of the previously established model. In this case, the lack of awareness of the interaction makes the composer work in terms of stereotypes that inhabit the representation system under use (Zampronha 1998), leading to a guidance of the creative process through these stereotypes, here relative to the tendencies of each model as described above.

When the interaction is active, we have a co-determination between the compositional elaboration and the model that the composer is using. Such co-determination occurs through inharmoniousness between the mental representation of sound or the work, and the representation possibilities offered by each model. The composer is aware of such inharmoniousness and takes advantage of the representation play in order to enrich the creative process. Such play is also strengthened in electroacoustic music not only by the possibility offered by the computer as it is constantly auditorily assessing the relation between the compositional project, models and methods employed in the performance of sound: the composer designs a sound or a set of sounds from a certain model and performs such sounds with the methods connected to it; the judgement of the result by the composer determines the success or not both of the composition strategy and of the employment of the model, and the interaction between them is then redesigned and reassessed, an so on. Each new elaboration of the project produces a new inharmoniousness degree leading to a new reassessment in a chain that may extend to the infinite.

4. CONCLUSION

The term “conclusion” is certainly not the most adequate at this time of the research, once it is far from its conclusion, and more than such few lines would be necessary to do so. But, considering the topics discussed above as proposals for future discussions, we may point here to one among several possible directions to the development of this research: considering the strong connection between the musical composition process and the representation forms manipulated by the composer, and that the inharmony between such representation forms involved in the process is unavoidable, the study of such inharmonic relation and its role in the creative process seems to be indispensable.

5. REFERENCES

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