SPACE NOTATION IN ELECTROACOUSTIC MUSIC: FROM GESTURES TO SIGNS

Bertrand Merlier
Université Lumière Lyon 2
Département Musique & Musicologie
Lyon, France
bertrand.merlier@univ-lyon2.fr

ABSTRACT

This article is based on an analysis of the functionalities of many devices and software used for sound spatialization, an original research about space perception modes and finally an in-depth study about musical notation systems. Theses studies lead the author to propose a notation system for spatialization activities, simply based on the paradigm of our Western classical music notation. Various examples illustrate the merits and versatility of this proposal. The present notation is both descriptive and prescriptive. Thus, a practical implementation based on MIDI standard also makes possible instrumental space performances, implementation of algorithmic processes, space writing and structuring, but also offers access to all the existing software such as MIDI sequencer, MIDI computing and score writing. The *MIDISpat* plug-in – developed by the author – has been used for many years inside of Reaper digital audio sequencer.

1. INTRODUCTION

The present paper describes a space notation system based on the paradigm of our Western classical music score notation.

This surprising proposal rests on:

- 20 years of practice and research (see bibliography at the end of this paper);
- an in-depth analysis of various space practices, various working strategies, including an analysis of quite all software available on the market (see Section 2.1);
- listening tests that have highlighted new space perception criteria (confirming the lack of knowledge of space phenomena by developers of most digital audio software) (see Section 2.2);

First (Section 2: Former Observations), we will show that current spatialization tools – as powerful as they seem to be – work on a graphical continuous representation of reality (generally gestural reality), such raw data being unrelated to any concept of notation.

Second (Sections 3 and 4), our reflection will focus on a brief study of Western notation, allowing us to identify 9 elementary principles for a possible notation of spatialization.

Thirdly (Sections 5 to 6), we will propose a theoretical, graphic and practical implementation of this space notation. Several examples illustrate our purpose and attest the validity of our proposal. A simple but efficient MIDI implementation (Section 7) has been used by the author since the mid-2000s in many circumstances such as:

- spatial interpretation of acousmatic works,
- multiphonic studio composition (from 5.1 surround to 16 channels),
- live electronic or mixed music.

2. FORMER OBSERVATIONS

2.1 Inadequate Space Software

In a paper entitled “Reflections on electroacoustic music spatialization in digital audio software” [1], I presented a large panel of software allowing sound spatialization. It summarized various working strategies, various modes of coding and representing space information.

Each studied DAW (Digital Audio Workstation) software provides space information representations build with one or more curves networks. These “continuous streams of data” are physical representations of gesture reality, just like an oscilloscope screen shows electrical signal variations over time. **These representations of space information are remote from any notation system**: they are either imaginary trajectories, or hardware dependent technical curves, or gesture movements directly issued from spatialization gestures that have been practiced for several decades and dependent on gestural organs such as: mixing desk potentiometer, joystick and computer mouse (see examples at Figure 2).

The computer mouse – and consequently the joystick – is the most rustic and reductive organ that can be imagined (especially to control the spatialization!): only XY position detection, no velocity, no energy or speed detection, no polyphony...

This “curvy” mode of representation is similar to tablature notation (look at similarities between Figures 1, 2, and 3), dominated by technical aspects related to instrumental gesture and specifically designed for each "space instrument". It is not at all universal, nor endowed with the abstraction required for a real notation.

In 2005, we concluded that almost all DAW software were inadequate: lack of readability, lack of graphic or intellectual abstraction, difficulties in editing space curves, impossibility or difficulty of simultaneous display of both audio signal and spatialization signal on the same time scale, limitation of virtuosity, impossibility to manage space polyphony or to work on spatial masses because of XY driven sound trajectories, impossibility to work in 3 dimensions... Our paper ended with a set of suggestions for the future:

- liberate space from any hardware contingencies (i.e. related to "instrument" or hardware);
- liberate space from any causality contingencies[1] (i.e. related to gesture);
- build a description system of the produced effect.
- consider a functional approach[2];
- replace continuous curves[3] by abstract objects such as "space event" or "space phrase";
- adopt a common gateway to exchange informa-tion between all the existing software[4].

Figure 1. Byzantine religious notation.[5] In the 11th-12th centuries, the first Gregorian or neumatic[6] notations coded small melodic and rhythmic cells. That is to say the melodic (or rhythmic) movements. It seems that space notation is more or less at this stage[7].

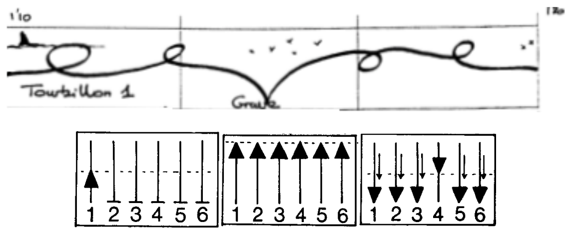


Figure 2. Two examples of spatialization representation. Top: representation of a space trajectory (*in* B. Merlier, *Nebuleuse M42* for cello and tape, 1993). Bottom: spatialization gestures at the mixing desk (*in* P. Boulez, *Dialogue de l'ombre double*, 1985).

2.2 Space Perception Modes

Our paper entitled "Space perception vocabulary in electroacoustic music composed or spatialised in pentaphony" – both presented in French at EMS'08 [1] and in English at SMC'08 [2] – aimed at clarifying or elaborating a vocabulary (a set of specialized words) likely to describe space perception in electroacoustic (multiphonic) music. A battery of tests have made it possible to highlight a collection of words describing spatial listening.

The results suggest five types of spatiality (see Table 1 on left column), 2 types of mobility, 4 or 5 families of adjectives to describe or characterize spatiality or mobility.

None of the studied commercial software (in Section 2.1) is able to seriously generate half of these 5 situations and criteria, proving one more time their inadequacy as regards space.

① sound bath	
② space image	
③ sound plan	localization geometry distance internal agitation movement
④ point	
⑤ demixing or counterpoint	

Table 1. Five space perception modes and associated criteria.

2.3 Conclusion

Only the sound actually produced by **one** loudspeaker is independent from gesture or information coding, and from hardware considerations (such as spatialization techniques and activities, as well as loudspeakers number and position).

If we want to progress into space control domain, if we want to be able to elaborate a real space discourse, to write it, to reread it, to understand it, we have to give up on this representation of reality by a network of curves, in favor of a simpler and more abstract representation.

[1] "Current spatialization representations are not efficient because they are linked to the description of the gesture that produces the effect, that is to say: causality. [...] The sound actually produced by a loudspeaker is independent from gesture or information coding, because the same perception can result from different causes. Even more, it is independent from hardware and – in particular – the number and position of loudspeakers."

[2] A functional approach makes it possible to envisage "compositional transformations on curves: symmetries, rotations, proportions modifications, homotheties, interpolations, smoothing, time offsets, time inversion, acceleration, control of trajectory speed..."

[3] "Instead of using continuous curves driving space without interruption from beginning to end of time, the notion of space object would make it possible to name, identify, record, memorize, duplicate, manipulate... space events."

[4] Only widely spread standard exchange vectors (such as MIDI standard, OSC protocol, OMF (Open Media Framework) files, SDIF (Sound Description Interchange Format) files [4]...) would allow communication between applications, between researchers, developers, composers... [5] As long as everyone remains in singular and idiosyncratic space practices, there will be no hope of having access to a somewhat universal notation; so no hope of seriously progressing.

[5] Courtesy of https://www.pinterest.fr/effiekondopoulo/byzantine-music/.

[6] *neume*: from the Greek νευμα that means gesture!

[7] It is interesting to reread music history ([6] or [7]) and to note numerous similarities between western notation apparition in the Middle Ages and current research on space: various experiments, quarrels of methods, misunderstandings between composers, performers and musicologists. So much so that one can easily imagine such a contemporary electroacoustic musician as the reincarnation of a twelfth century singer, another in the habit of a monk copyist and another in the role of a minstrel.

3. ABOUT WESTERN MUSIC NOTATION

Here are some brief historical and functional elements. Western music has pushed music notation sophistication far and wide. Even if in the twentieth or twenty-first centuries, many composers or aesthetic currents – including electroacoustic music – are cramped in these conventions when it comes to noting complexity, timbre or sound objects, even if diversions are frequent and necessary, musical notation remains today a fundamental tool, with its descriptive, prescriptive and memorial roles... (see for example [8], [9]or [1]). Table 2 presents and analyzes score key points.

Score graduations or discretization reduce musical complex reality to simple concepts (height, duration, intensity), that allow easy reading and writing (after learning the codes). This is one of the main reasons for score notation effectiveness (and success). This abstraction also allows building the artificial human complexity of our western music: polyphony, rhythms, sentences and finally all the subtle arrangements of melodies and harmonies... (see for example [6] or [7]).

paper support	fixation on a paper support constrains to find a two dimensions representation of the n musical parameters (height, duration, nuance, timbre, phrasing...). But, this constraint is also a guarantee of easy reading and reprography.
score offers:	- horizontally, a graduated time scale (tempo, measurements and pulsation); - vertically, a scale for graduated heights (tones and semitones).
note	this minimal musical event is a sign likely to graphically bear and express sound characteristics: height, duration.
	Other symbols – usually located around the note – indicate intensity or sound effects.

Table 2. Synthetic vision of Western music notation.

4. THEORETICAL BASIS FOR A SPACE NOTATION

Nine basic mandatory principles for the establishment of an efficient space notation are presented below. These proposals are based on an analysis of several notation systems in use, with the underlying idea that space may not be a bizarre or abnormal phenomenon and that it may not be necessary to invent a new scoring system.

a) Space should be written on paper like any other sound parameters (height, duration, intensity, timbre);

b) Its notation should be independent from any device (such as mouse, joystick, potentiometer, number and position of loudspeakers in space);

c) The proposed notation should be universal and adaptable to any of the following various circumstances, corresponding to the prescriptive, descriptive or memorial roles of score:
   - writing for non-real-time works in studio,
   - writing for real-time instrumental performances,
   - capture and notation of any "instrumental space performances",
   - retrospective reading for analysis purposes;

d) Like any other sound parameters, space needs to be noted as a discrete event[8], represented by a graphic symbol that can be drawn on paper and onto which characteristics can be assigned;

e) Apparent position of sound – as perceived by listeners – is due to a specific blend of sound level of *n* loudspeakers;

f) An elementary space event (ese) corresponds to the sound level on one loudspeaker at a given moment; This level can be zero, constant or variable;

g) An elementary space event (ese) has two main characteristics: intensity and duration, to which can be added certain effects such as attack, release, phrasing, distance, reverberation...

h) A space trajectory is a succession of space events (ese) arranged in time; A space trajectory can be thought of as a phrase or a space melody[9];

i) Simultaneous presence of the same sound on several loudspeakers can be considered and written as a space chord.

5. PRACTICAL AND GRAPHICAL IMPLEMENTATION

Taking the opposite way of all the practices in use, the author decided to rely on Western notation, i.e. get rid of any continuous curve and opt for discretization of space phenomena. We have previously justified our choice as being a trick intended to facilitate notation.

In concrete terms, our notation proposal is summarized in the following points:

- each line (or interline) of a staff corresponds to one loudspeaker[10];
- note faces are used as "space objects" describing each loudspeaker activity; thus, they own a duration, an intensity, several play modes or accentuations...;
- note and silence figures, tempo and measures indications have the same temporal meanings as in classical notation

[8] Which does not mean that space or spatialization are discrete phenomena! Discretization is only a simplification process, a view of mind.

[9] Melody: succession of musical sounds (*Dictionnaire des sciences de la musique*, Honneger, 1976, Bordas). The term "space melody" has already been used by various composers of electroacoustic music, i.e. Denis Dufour in the 1990s.

[10] A priori, at each user choice; this choice may well vary depending on hardware (number of loudspeakers, space layout...), depending on each work or each type of space writing.

- intensity or nuance symbols (attack modes, vibrato…) have the same meanings as in classical notation;
- phrase symbols (legato, staccato, trills…) generally have the same meanings as in classical notation; Link curves between events will generate continuous movements (thus thwarting graphical discretization);
- graphical abstraction gives access to structural notions such as sentences, chords... And consequently, to compositional transformations on a finally visible structure.

Details:

- A “speaker clef” can be added at the beginning of the score, in place of the traditional treble or bass clefs (see Figures 3 to 7).
- Sharps and flats are not used, as tonality or modality do not make sense. However, in a 3D situation, sharps and flat could very well be diverted from their traditional use to indicate top and bottom.
- In multiphonic music, several coupled staves will be used in order to note several simultaneous independent movements applied to several sound sources.
- For 16 channels, 3 linked staves can be used, depending on the loudspeakers arrangement and the desired readability. At the user's choice, staves may correspond to loudspeakers tessitura (bass, midrange, treble) or to their geographical or spatial layout.
- Example: in a surround configuration, the extra line of C bass can be used for the 5.1 bass channel.

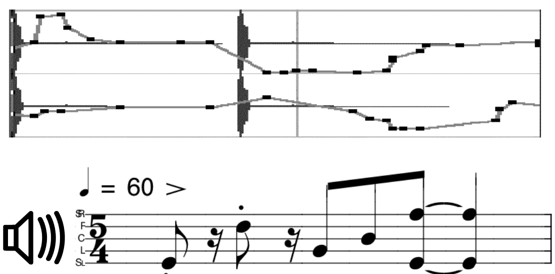


Figure 3. Question: What is the space figure displayed in these 2 examples? Top: Joystick movements representation are uneasy to read. Bottom: with practice, score space notation quickly becomes readable.

6. GRAPHICAL EXAMPLES

Some examples are given in Figures 3 to 7 and commented. Further details about technical implement-tation will be developed in the next section, which will present a practical implementation of this space notation proposal.

All examples correspond to 5.1 listening situations. Each staff line is associated with one speakers as shown to the left of each staff (SL = Surround Left, L = Left, C = Center, R = Right, SR = Surround Right).

Figures 3 or 7 – placing opposite a joystick spatialization representation with the same space notation example – should finish to convince the most recalcitrant on the readability question.

Figure 8 – later in this text, in the next section – displays another possibility of graphic representation or notation, i.e. as piano roll or barrel organ cartons. Practically speaking, this notation is more precise, but intellectually less readable insofar as it does not allow displaying accentuation or liaison criteria.

In practice, combining both notations (score and piano roll) is very powerful, easy to use and easy to read.

7. MIDI IMPLEMENTATION

Using this score system gives access to any musical notation software, as shown in Figures 3 to 7. It also allows access to MIDI encoding, so to take advantage of your favorite DAW infrastructure: effective simultaneous management of audio or MIDI events according to time, efficient visualization of these same parameters in various forms, automations... With a few minor diversions, it is quite possible to respect the double constraint set out in point (c) of Table 3 i.e. both “play what is written” or “write what is played”.

7.1 General Description

MIDI implementation principle is displayed at Figures 8 and 9, at Tables 4 and 5, and explained below:

- each **MIDI channel** corresponds to an input audio track;
- each **volume controller** (Ctrl 7) modulates the incoming audio signal intensity, either statically (balance between the channels), or dynamically (real time performance)[11];
- **MIDI note** codes apply to the outgoing signal, i.e. to the loudspeaker drive: appropriate MIDI height chooses 1 loudspeaker, and its MIDI velocity sets the loudspeaker amplitude. Velocity makes it possible to individually control the intensity of each loudspeaker statically;
- 2 envelope controllers (Ctrl 72 attack and Ctrl 74 release) allow switching from staccato or ping-pong mode to a “continuous” legato phrasing;
- other spatialization features can be modified by MIDI controllers, the use of which is described at Table 4.

Nothing is fixed, as in the MIDI standard; everyone can use its own conventions depending on habits or work to be done.

[11] Which is a brand normal situation used for audio track automation.

Figure 4. Three simple space movements.
a) Panning effect between rear left (SL) and front left (L) loudspeakers.
If the tempo is 60, this movement spreads over 2 seconds.
b) Ping-pong effect between the 2 same speakers. The sound lasts 0.5 seconds on each speaker.
c) Continuous intensity fluctuation on a single loudspeaker (under each note: velocity indications).

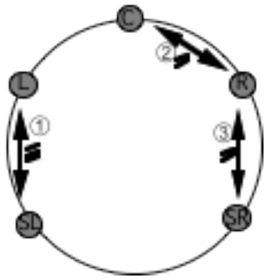
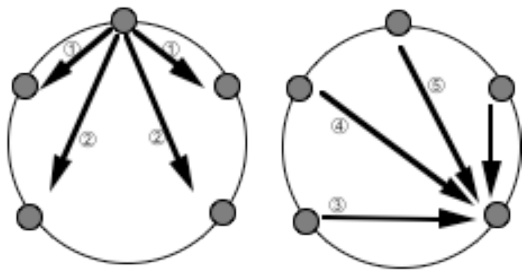


Figure 5. Three space trills . Left: graphical notation. Right: score notation. We note that any musical symbol (silences, trills...) applies to space without problem.

Note 1: if these 3 trills movements should take place simultaneously (instead of sequentially), the score notation would not pose any problem: neither writing nor reading. This simultaneity would be much more difficult to realize (and to read) with a joystick (because of the lack of polyphony of such a device).
Note 2: the reader will note that the left side figure does not allow apprehending temporality.
Note 3: space chords are impossible to realize with a joystick or XY curves.



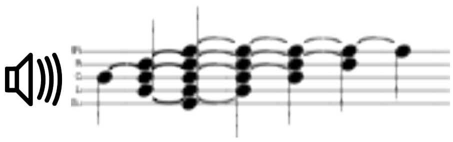


Figure 6. Space crescendo and decrescendo / realized by means of a mass change. Left: graphical notation. Right: score notation.

Note 1: here appears the notion of space polyphony or space mass (simultaneous use of several speakers). This effect is simply written by using notes chords.
Note 2: same remark on the representation of temporality.

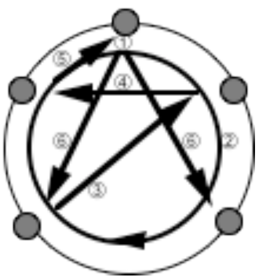


Figure 7. More complex space figures: hold, rotation, then zigzag. Left below: graphical notation. Above: score notation. Description: sound apparition in 1 second on the central loudspeaker and disappearance in 3 s. // 1 second of silence. // 3 full rotations on all loudspeakers in 2 seconds, followed by a syncopate zigzag, then a chord on the 2 rear speakers.

Notation examples can be multiplied at will. Sophisticated space figures notation does not pose any problem (whereas XY representation – or any curve notation – becomes unreadable). Re-reading and comprehension are easy.

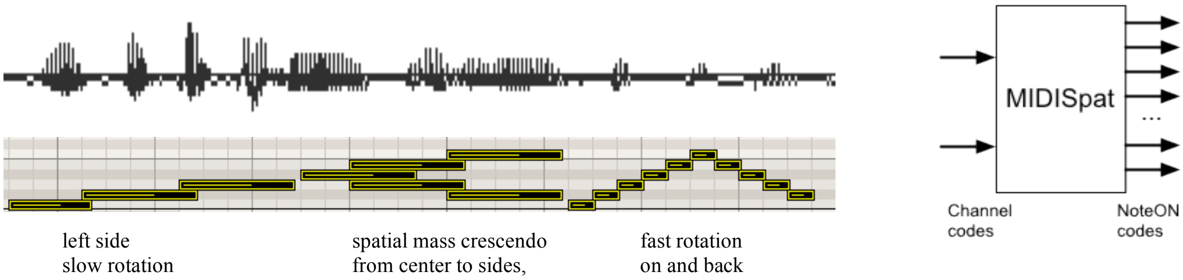


Figure 8. Driving and displaying spatialization via MIDI. The basic idea is to propose an easy edition and easy visualization of a sound space setting up, in synchronicity with the audio signal. Top: 1 mono or stereo audio track to be divided into 16 audio outputs (mono-stereo switching is automatic in Reaper). Bottom: 1 MIDI track to drive spatialization. Channel codes handle signal inputs. Note codes handle loudspeakers outputs.

MIDI controllers		parameters
1	modulation wheel	distance control (by means of filtering + reverberation).
…		
7	volume	input audio track level control, i.e. global nuances during a trajectory.
…		
64	sustain	allows holding notes (space positions)
…		
72		release [0-127] [0.1 – 16s]
73		attack [0-127] [0.1 – 16s]
…		
91	reverb	
…		
	all note off	switch off all the notes
	reset	reset all parameters

Table 3. Use of MIDI controllers codes for sound spatialization control in MidiSpat.

7.2 MidiSpat: a Simple MIDI Controlled Audio VCA

MidiSpat plug-in[12], developed in a snap thanks to the Reaper software JS language, follows many prototype versions written in Max / MSP. The total integration within Reaper (sounds, plug-ins, automations) greatly facilitates the composer's life, especially since Reaper is the most versatile software for routing audio tracks.Reaper also allows creating mixed tracks: MIDI + audio, thus offering a complete entity dedicated to audio signal spatialization. MidiSpat plug-in – used as a track insert – receives MIDI notes that will drive the audio signal to (up to) 16 audio outputs (see Figure 8).

Simultaneous spatialization of several audio tracks is not a problem; spatialization is done source by source, the audio result being automatically summed by the host software.

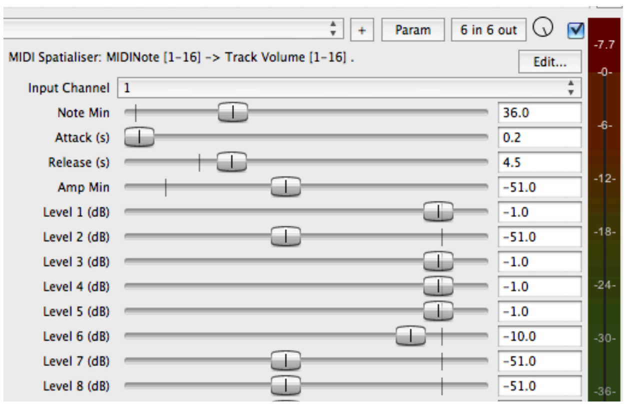


Figure 9. MidiSpat plug-in at use.

noteON [1-16][13]	selects the audio track output opens VCA according to velocity
vel [0-127]	determines output level MIDI velocity is graduated in dB vel 106 = +6 dB vel 100 = 0dB vel 0 = -100 dB
channel [1-16]	selects audio source input

Table 4. Use of MIDI note codes for sound spatialization control in MidiSpat.

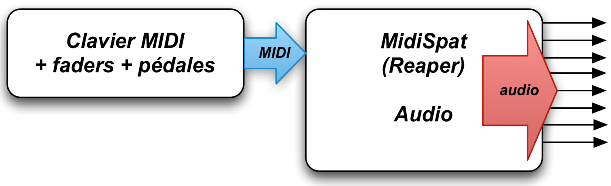


Figure 10. Live spatialization performance with a MIDI keyboard.

[12] MidiSpat plug in is available at: http://tc2.free.fr/espace/midispat.html.

[13] Lowest noteON values were chosen, leaving the opportunity to use a synthesizer or a sampler on the same MIDI channel.

7.3 Space Instrumental Performance and Space Trajectory Memories

The previous presentation (Section 7.2) describes non-real time studio composition work. But the present device is equally usable in live performances or live electronics situations.

Reaper software offers unexampled audio routing, as well as a simple programming language (derived from C) allowing to write one's own plug-ins.

A MIDI keyboard with a modulation wheel (distance), a volume pedal (nuances), a sustain pedal (hold) and various faders (attack and release envelopes) makes it easy to spatialize any live audio signal (see Figure 10). The MidiSpat plug-in lets you turn any played MIDI event into volume curves controlling audio output levels of each Reaper track. A space-performer requiring more virtuosity can profitably use any MIDI sequencer to record space sequences step by step, correct mistakes and thus refine its performance. Using a MIDI sequencer allows memorizing an interpretation and visualizing it either in score mode, or in “piano roll” or “grid edit” mode. Possibilities of creating, reading, understanding, manipulating a spatialization performance are excellent.

This “instrumental keyboard spatialization performance” has been used by the author on several occasions in various public concerts. This surprising new practice is similar to the interpretation of acousmatic music using a mixing desk console. For a mid-level keyboard player, learning keyboard spatialization requires only a few days of practice, for a result that is otherwise rich and virtuoso than the one obtained using a mixing desk console (or a joystick).

It should be noted that virtuosity can be further enhanced by preparing MIDI spatialization sequences (trajectories or spatial mass changes) in advance, storing them in memories or presets and triggering them during performance. Ableton Live software is particularly well suited to this kind of work.

8. CONCLUSIONS

8.1 In summary

The term notation refers to a set of conventional signs by which sounds of music and how they should be played are written: letters, figures or graphic signs, representing musical phenomena, which are transcribed on paper in an universally admitted format. Notation by signs requires segmentation and discretization of musical phenomena; that is to say a simplification of reality. Only this “sacrifice” makes notation possible, but in return it offers access to the complexity of a language, to abstraction.

Regarding this model, the author proposes to discretize the space phenomena and to abandon the curves network representation. This choice is justified as a matter of course, if one accepts to look at musical notation adventures and history (ekphonetic notation, neumatic notation, interval notation...). Current spatial representations – when they exist – are strangely similar to early Middle Ages ones (see Figures 1 and 2).

This score notation is much more readable and understandable than representations by curves networks presently proposed in all digital audio software. The two essential concepts adopted are: discretization of space phenomena and creation of an elementary space event (ese) carrying 2 main characteristics: intensity (of a loudspeaker) and duration.

These simplifying choices make it possible to hook on the Western notation score paradigm, whose benefits are immediately apparent.

8.2 Advantages

This simplification of reality for scoring purposes has many advantages:

- readability and comprehension are far superior to the representations proposed in digital audio software;
- temporal organization is clear, thanks to time spread events on a horizontal axis;
- synchronization with musical events is obvious;
- gripping durations is easy, thanks to the usual symbols;
- space polyphony or work on space masses pose no problem of notation nor representation.
- and finally, the multi-secular habit of using score does not entail new learning.

This last point reinforces the idea that space can be considered as a fifth parameter of sound, in the same way as height, duration, intensity and timbre.

8.3 Validation

In a 1998 paper [10], the author accurately described – on about one page – the essential space notions, in form of a physical or phenomenological description.

In a paper dated from 2008 [1][2] (and following a former study [11]), the author highlights 5 modes of space perception, with various families of adjectives to describe or characterize spatiality or mobility (see Table 1).

The present notation proposal and its software implementation fully respects all this knowledge; and allows engaging without constraint all types of space activities, with any spatialization modes, real time or deferred time. In no case does this change perception.

By taking into account space events attack and release, discretization either becomes imperceptible because it is smoothed or becomes perceptible (which is a new situation impossible to realize with continuous curves); the proposed notation is perfectly compatible with any current spatialization practices and even allows considering instrumental performance of space.

It is thus easy to use the past experience and know-how, as well as the numerous existing notation software, with very few diversions.

The musicologist will also find his account by the existence of a written support giving access to space analysis, structure extraction of compositional thought, ideas formalization.

8.4 Future studies

The main problem with this proposal is essentially psychological or symbolic. Will composers issued from concrete music agree to use the fundamental tool of abstract music?

The first presentations of this notation in France suggest that the answer is NO!

Yet the step to a great progress is a tiny one, when one think that all the computer tools described here are at everyone's fingertips in all digital audio sequencers (Cubase, Logic Audio, ProTools or Reaper).

Acknowledgments

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