Valerio Sannicandro

Space and Spatialization

as Discrete Parameter

in Music Composition

A Space-Oriented Approach to *écriture*:

From Acoustic through Informatics

to Musical Notation

3

Space and Spatialization as Discrete Parameter in Music Composition.

A Space-Oriented Approach to *écriture*:

From Acoustic through Informatics to Musical Notation

vorgelegt von
Diplom-Musiker
Valerio Sannicandro
geb. in Bisceglie (Italien)

von der Fakultät I – Geisteswissenschaften
der Technischen Universität Berlin
zur Erlangung des akademischen Grades

Doktor der Philosophie
- Dr. Phil. -

genehmigte Dissertation

Promotionsausschuss:

Vorsitzender: Prof. Dr. Friedhelm Schütte
Berichter: Prof. Dr. Stefan Weinzierl
Berichter: Prof. Dr. Jean-Marc Chouvel

Tag der wissenschaftlichen Aussprache: 21. Mai 2014

Berlin (2014)

Abstract

In spite of the large amount of theoretical achievements of Spectralism, the role of space in music and sound in 20th and 21st Century has been not deeply explored. Since for spectral composers the main concern of their music was the so-called third dimension of sound (timbre as discrete entity through spectral analysis, allowing gathering information to shape pitch and dynamic), the profound study of this side caused a lack of interest in the reflection on space. In theoretical reflections the word *Espace* appeared therefore as a metaphor (*Les Espaces acoustiques*) and definitely not to intend a musical parameter, therefore the idea of sound depth was seen almost exclusively as intersection of sound colors, while timbre nuances were designed within a frontal acoustic scene.

As a matter of fact, the extreme difficulty to analyze and measure this element (as it was about at the beginnings of Spectralism) was surely an additional factor to make understand space as a merely sound decoration. Because nowadays this problem requires a deeper approach as well as a more consequent analysis (in strict connection with musical and artistic needs), it will be explained a possible path to integrate not only spatialization but also space (and some of its physical properties) into musical writing.

Starting by examine the aesthetic reasons that have been the background for this research (excerpts from music scores as well as theoretical texts) we will identify those possibilities that both musical research and technology offer the composer to explore space and those influences that they could mean on musical language. This enquiry will consequently see how musical material organization can be structured starting directly from space and spatiality, seen not as a metaphor but as acoustic entity, a perspective that will lead the research into the domain of room acoustics and in particular to the resonance modes. Finally, this study will show in which way space, an essential element for the music of our time, can be considered from an inner point of view (that is as a fundamental musical parameter), instead than in its merely topological or architectural nature, providing some musical examples taken from the project *Ius Lucis* (realized at I.R.C.A.M. in 2006/2007).

Foreword

<div align="right">

La musique est : *temps et espace*, comme l'architecture[1].

(Le Corbusier)

</div>

During the time I was working on a new music project (*Ius Lucis*, for two ensembles in two music theaters, composed during 2006 – 2007 for the jubilee of Centre Pompidou in Paris), it was clear that such work demanded a broader introspection into several music topics that it directly or indirectly touched upon. Many questions arose that, if on the one side they may have been answered aesthetically (i.e. with musical decisions linked to personal artistic perspectives), on the other side other questions were waiting for a different kind of statement that needed to be supported by a deeper study on the issues I was encountering. In that period of research, almost every morning I had the privilege to share with devoted people some of these questions, thoughts and visions, trying to put into words an imagination that was, by its nature, very ephemeral.

Ephemeral, indeed, is the adjective that would best label the perception of music in space, as well as space-related phenomena that are of main interest in today's music. As composer, the desire to find a preciser way to notate those physical processes, to control a dimension that doesn't allow a clear standardization in the way it is described (with musical means), rose up dramatically.

My work *Ius Lucis* was assigned – maybe unconsciously – a parallel function: Beside that of artistic and musical expression, it was also an environment where I could experiment and find solutions that would eventually be able to enhance the comprehension (first and foremost my own) of the spatial dimension in musical composition. If looking forward was self-evident through the act of realizing a series of audacious musical inventions, the idea of looking backward to find solutions was much less obvious. In fact, facing a willingness to avoid commonly accepted discourses on sound localization, different examples – different from those we might be familiar with – in fact had to be found within the course of music history; a direction that demanded a rather divergent approach for this kind of scientific and artistic exploration I was about to begin.

Working with a dimension like space (or spatialization, a discrepancy in terminology which is at the center of this present inquiry), introduced to my personal work further interrogations. Some of these were the subjects of long discussions with Serge Lemouton, bright minded researcher at I.R.C.A.M. who accompanied and supported this project intrepidly and with a passion and interest that both struck me and encouraged my work, two reasons for which I will always be grateful. Such work (that started in 2005 and continued later in other places dedicated to musical production with technological means) and the strictly connected theoretical reflection, was shared with other inspiring personalities that I had the honor to make acquaintance and to collaborate.

---

1. Le Corbusier, *Le Modulor. Essai sur une mesure harmonique à l'échelle humaine applicable universellement à l'architecture et à la mécanique* (Boulogne : Èditions de l'Architecture d'aujourd'hui, 1948), 29.

First was the group of researchers at *Experimentalstudio* in Freiburg (Germany), led first by André Richard and later by Detlef Heusinger, a forge of ideas, enthusiasm and energy that supported my work decisively.

The initial step of starting to formulate these experiences in a formally coherent way, giving an order to those thoughts and facts I accumulated during many years, was made first through discussions with Prof. Jean-Marc Chouvel (University of Reims) whose stimulating talks and analysis on this and other subjects corroborated and developed the nature of my reflections.

In order to express at the best this enquiry, that was moving clearly toward an area between scientific investigation (room acoustics) and aesthetic reflection on an artistic discipline (musical composition), I found an inspiring place in the Technische Universität Berlin, and in particular in the person of Prof. Stefan Weinzierl who, together with Oliver Schwab-Felisch, supported my work from the beginning and accompanied this research very actively and with the involvement for which I am still thanking him.

I cannot avoid to mention that in the course of this work, in September 2012, one of the personalities I respect more and that gave me an exceptional model in terms of musical examples, Emmanuel Nunes, passed away, a circumstance that made me think even stronger to his powerful music that I consider a fulgid and timeless example of highest art.

Berlin, October 26th 2012.

CONTENTS

CHAPTER 1

SPACE VERSUS SPATIALISATION

1.1 Defining space

In the last decades of the Twentieth Century, the interest of artists to apply the parameter space to various domains of musical composition has been noticeable.

In addition to the constant and impressive technological development of sound-projection means, a cause of this trend has certainly been a curiosity about a facet of music which, for hundreds of years, still exists as a major question for both composers and theorists. Considering that the nature of the problem touches not only musical fields of study but also several further disciplines (architecture, room acoustics, etc.), it is easy to observe how this involvement and its interdisciplinary quality leads to quite different directions in trying to exit the superficiality that the use of space in music can often reveal. The domains of spatial sound control and related software technology, for instance, are asked to provide only partial answers (each one of them according to their own perspective, base of knowledge and in relation to the practical realization of music composition) and offer rather dissimilar ways to approaching, developing and treating this aspect.

This is why both the practical and the theoretical have been called on to answer a number of disparate questions from the utilization of space in music works to its essential nature and significance. The multiplicity of meanings that the term space can have within the various musical contexts reflects the complexity of the problem: space has been used for many different significations ranging from pure space-related acoustic phenomena, to sound spatialization, up to diverse metaphorical representations[1] (the concept of Tonraum, just to mention one). Such complexity is a crucial point for both musicians and theorists: for the composer, the space parameter is complex in its development and application during the compositional process and for the musicologist this complexity represents a challenge to measure and define.

---

1. It is enough to read the various perspectives according to which this aspect has been investigated in the preface of L'espace: Musique / Philosophie with the resulting conclusion that: *Cependant, à l'heure actuelle, il semble difficile de la circonscrire avec précision. L'espace (musical, mais aussi l'espace tout court) est tout, il est bien plus qu'un simple cadre ;* Jean-Marc Chouvel, Makis Salomos, foreword to *L'espace: Musique / Philosophie* (Paris: Edition L'Harmattan, 1998), v.

So from the outset of this text, it is imperative to clarify that the term space (understood as an element that is – as it will be explained – directly connected to music composition) will refer to a concrete (or virtual) tridimensional room in which sounds are projected.

It needs to be mentioned that, if we look at an actual room (i.e. a concert hall), we can see that, acoustically speaking, such a space does not represent merely one, but a multitude of possible measurable dimensions. For example, room acoustics focuses on both technical parameters (such as reverberation time), and perceptual ones (such as warmth, spaciousness, etc.) just to mention a few.

It will be easy to see, in the following paragraphs, how different the choice of these musically concerned dimensions can be for each of the featured musical examples (and consequently for each composer). This consideration will lead this inquiry to circumscribe the field of observation along a path that has been previously explored and methodologically tested. Underlining this aspect is essential to escaping any misunderstanding based on the use of terms. At the same time, circumscribing a research into a limited, but effective area of exploration will allow a direct connection with a musical view of the problem.

1.1.1 About spatialization

It is clear that, in some of the most recent compositional output that deals with the parameter of space, most effort and attention has been dedicated to the so-called concept of spatialisation. Emmanuel Nunes speaks indeed about spatialization when he refers to a musical dimension that deals with sound source localisation and its eventual mobility in a certain space, a definition that is surely still valid[2]. The term localisation of (multiple) sound sources is the most often used descriptor of this musical dimension, while its eventual faculty to move, as is the case in some major works by Nunes, is also included as a further option. At this point one of the first dilemmas at the core of this research is expressed as: whether, and under which conditions, it is possible to speak about such a dimension or parameter, with all of the implications of both an empirical and a theoretical nature that are consequently implied. The first questions rising from this assertion are the following: If spatialisation is a parameter, in which way is it possible to measure it? Should it be possible to define it in an objective way, what might its nature be?

The treatment of spatialisation as the movement of sound sources in musical scores, as is well known, does not generally follow a ratio of (geometric) distance (since it would be impossible, for evident reasons, to sample performance environments so precisely in the score), but rests basically upon:

---

2. The use of the terms musical parameter and musical dimension in this quotation is still quite changeable, even if Nunes actually measures quite exactly all possible elements (timing, envelopes, etc.) connected to the spatialization process: *Lorsque je me référerai au paramètre musical (ou dimension) ayant trait à la pluralité de localisations des sources sonores et à leur éventuelle mobilité, j'utiliserai toujours le mot* spatialisation - Emmanuel Nunes, "Temps et spatialité," in *Les Cahiers de l'Ircam*, Volume 5 (Paris: Ircam – Centre Georges Pompidou, 1994), 122.

a) a global estimation (by the composer) of a topological nature;

b) an overall knowledge of acoustic phenomena (achieved after various experiences connected to performance traditions and/or praxis, directly or indirectly);

c) some basic notions of psychoacoustics and perception.

Even the extremely meticulous approach of Stockhausen, and his way of describing a single tone according to its various parameters (including an – apparently – absolute distance in degrees and meters) shows instead the forced empirical approach to space.

As a consequence, the use of space in music follows a much more a-posteriori path (linked to psychoacoustics, acoustics or achieved experiences connected to performance) than any other musical element. Moreover, this is made more complex by the fact that an established and commonly accepted way of notating space in a musical score is still missing (except for electronic music where generally each channel – or loudspeaker – already represents a point in space); i.e. there is not a family of generally accepted signs describing, with the lowest possible chance of misinterpretation, a clearly understandable *figure spatiale*.

Instead, and for every particular occurrence, a new system of signs is proposed, applied and explained, both explicit (a space-writing that uses, for example, graphics or other symbols not strictly related to music) and implicit (a space-figure is a result of pitch, time and dynamic notation inside of an a priori defined environment of music sources). In the latter example, the *figure spatiale* is not explicitly expressed but needs to be recreated by interpreting and assembling other signs coming from various information of a musical nature present in the score (text and para-text).

1.1.2 The need for integration: Space-related sound phenomena and musical significance in traditional music notation

As concerns the relationship between space and *écriture musicale*, we can observe two main aspects of music composition whose boundaries are sometimes not so easily separated: First, for various reasons (technological evolution, interaction of musicians with architectonic spaces, etc.) the centre of interest has progressively moved toward both naturalistic, environmental effects and to a definition of (moving) sound sources described in a fixed space with peculiar properties and intrinsic coherence (i.e. a real or theoretical performance environment). Second, for some composers, proposing an advanced writing with musicians placed at several positions in the music hall (or generally speaking in the performance space), a musical score does not only carry the usual information of pitch, time and instruments involved in the performance but, on a more implicit level (depending on the performance explanations – such as instrument placement, for instance), it gives a hidden musical dimension. This means a further level of *écriture*, so that, as Jonathan W. Bernard affirms, by spreading sound sources (musicians for instance) all over the performance room, composers

want to fuse the use of space with the work itself[3].

As history shows, inside every music genre and in every *époque*[4] there has always been a recognizable interest in such phenomena and their latent musical significance[5]. Baroque and pre-Baroque music was characterized by the use of naturalistic occurrences (for instance echo was largely used by Monteverdi – for example *Orfeo* – but also in the form of repeated sections first forte, then piano by almost all composers of the 17th Century and thereafter). Later, with the discovery of broader dynamic ranges (the kinds of orchestra treatments associated with the Mannheim School), even a crescendo – diminuendo can actually become, under certain circumstances, a musical figure connected to spatial phenomena, since it could represent a sound source constantly approaching and retreating (in relationship to a listening point: The audience). Seen from this perspective, what was earlier an expression of affect derived from vocal techniques (messa di voce), becomes in the 18th Century a *figure spatiale*: The sound source (orchestra) does not suggest an environment but tries to represent a bi-dimensional picture (simplification, according the means of the Époque) of a complex three-dimensional phenomenon.

Situations featuring a strong chord followed by softer sounds become a metaphor for resonance. When the time gap between the first relatively short sound (a chord played forte) and its consequence, a stable or decreasing sound (eventually even a melody) is quite short, a model of Impulse-Response is created[6]. This new figure, also strictly related to space, differs substantially from the Baroque echo[7], and its new significance is far removed from any naturalistic description. This represents a new sensibility, toward a more abstract way of thinking of music in space.

Slowly, over the course of decades and thanks to technical improvements of music instruments, many new techniques were introduced to the orchestral palettes of composers that are strongly associated with space-related sound effects. Muted brass instruments, playing *pavilion en air* (above the music stand), different kinds of mutes for strings, etc. connote and suggest multiple differentiations in the inner space that can be recreated within the orchestra corpus. Furthermore, also in relationship with the places (*lieux*) and the

---

3. *"It will probably be helpful to preface this discussion with some attention to the term 'space,' since its meaning in a musical context is hardly straightforward and has never ben strictly agreed on. For most musicians the word signifies, first and foremost,* performance space*: a concert hall of widely varying dimensions, which may be used conventionally (e.g. stage with proscenium) or in any number of unconventional ways. Novel performance directions for new works, encountered more and more frequently as the twentieth century progressed, required players to dispose themselves in arrangements never before seen on a stage; they dispersed forces to widely separated locations within the hall not customarily occupied by performers (in the balconies, backstage, among the audience) with the aim of fusing the use of performance space with the conception of the work itself."* - Jonathan W. Bernard, "Varèse's Space, Varèse's Time" in: *Edgard Varèse Composer - Sound Sculptor – Visionary,* ed. Felix Meyer and Heidy Zimmermann (Woodbridge, Suffolk: The Boydell Press, 2006), 149.
4. *"The idea of unusual dispositions was not entirely new – exceptional repertoires such as the antiphonal works of Gabrieli for multiple brass choirs, or one-of-a-kind pieces such as the 'Tuba mirum' from Berlioz's* Requiem*, are well-known examples from the past" [...]* Ibid.
5. *"Musik zu hören, evoziert grundsätzlich Raumvorstellungen"* - Helga de la Motte-Haber, *Die Musik von Edgard Varèse – Studie zu seinen nach 1918 entstandenen Werken* (Fulda: Wolke Verlag, 1993), 112.
6. For instance see the first two chords of the overture of W. A. Mozart's *Don Giovanni*.
7. The starting bars of J. Haydn's *London Symphony* (no. 104) also simulate a kind of reverberation.

architectonical dimension of music as seen in the past, a musical space or sound source is multiplied in some situations, which have been carefully listed by Nunes[8] – for example the organ placed in cathedrals (multi-irradiation as each tone comes from a different point, depending on the position of the pipes). Also, speaking about some techniques used in the theatre, Nunes mentions (defining them as naturalistic spatialization) not only the echo but also off-stage effects and small orchestras playing on the stage[9].

All examples show the fact that a certain spatial significance is symbolically expressed in musical notation and that spatial[10] content is latent in music at a rather deep level in the *écriture*. This aspect can be taken as the main reason to call for a further examination and reflection on the state of the art today, as well as further possibilities for its enhancement.

At the time when the problem of space arose as an aspect of music composition that needed to be explored (about the Sixties of last Century), most of the technological tools that are readily available today were missing. The first prerequisite, before being able to talk about space and spatialisation was, at the time, inventing new instruments capable of reproducing a space figure (for example a rotation, which was at that time undoubtedly one of the major technical challenges) in order to move toward a growing abstraction and consequently to leave the field of naturalistic imitation.

We are at the point that directly confronts the problem of how to integrate more deeply and more precisely other space-oriented dimensions or elements of composition.

1.1.3 Critical statements concerning the use of space in music

In the writings of some of the most outstanding composers (of different aesthetic beliefs) who were experienced and well acquainted with these issues, there appears a critical view of the musical limits of a certain indiscriminate use of spatialisation, showing a lack of musical thought and intention. Hugues Dufourt for example, affirms that this category (referring to the use of space in musical composition) was initially used as a simple metaphor[11].

The use of "category" and not "parameter" points out the fact that Dufourt, aware of all technological achievements (related to spectral thinking researches) of the high degree of precision of spectral analysis tools and their growing application in musical composition, did not see space as quantifiable. He therefore conceived of it not as a parameter, but as category of musical thinking. This position, from quite a different perspective, was also shared by Nunes[12] in some of his writings. This seems to be related to his profound interests and

---

8. Nunes, "Temps et Spatialité", 123.
9. Ibid.
10. This term refers to a broader ensemble of space-related phenomena or acoustic qualities, which are connected to space and which are potentially of use and can integrated in accordance with certain approaches to musical composition.
11. *[…] "une telle catégorie a été utilisée à l'origine comme une pure métaphore" […]* - Hugues Dufourt, "Timbre et Espace," in *Le timbre, métaphore pour la composition, ed.* Jean-Baptiste Barrière (Paris: C. Bourgois, 1991), 272.
12. *[…] "l'intégration musicale des spatialisations, que je considère fondamentale à notre époque" […]* - Nunes, "Temps et Spatialité", 123.

ambitions regarding the linking of spatial movements of sounds to dynamic envelopes of complex harmonic structures, and an idea that the integration of spatialization into the musicality itself is a basic requirement of contemporary music. He warned against the dangers of simulating acoustic phenomena in a frivolous way, since the physical data are not coherently used and transposed into a musical language. Musicality remains for him a priority so as to avoid results that would tend towards the superficial[13].

In this statement, however, the possibility of exploring the acoustic domain much beyond the usual forms of (moving) sound affected by space is not considered. According to Nunes the intentions of acoustics are clearly opposed to those of music (or musicality): A composer approaching the first would produce a mere simulation of a phenomenon; approaching the second is to expect a symbiosis with a musical text.

Dufourt also pointedly addresses the penury of musical significance, asserting that a proliferation of artificial languages and models without theory makes music suffer under the weight of applied logical elements, and space rises up as the place where a certain research prevails over the needs of musicality[14]. This position further underlines how the goal of having a theory that is able to justify the use of space-related elements without oppressing musical needs, can be crucial in the context of a musical work that deals with spatial issues.

1.2 Approach to music composition

After having seen some reflections on the subject, this inquiry will move forward by looking at some aspects of sound spatialization as they appear in musical composition. Basically, when working with space, a gap between full control of traditional musical material (pitch, time, etc.) and a rather partial dominance of spatial elements would seem to always be present throughout the compositional process: There is an objective difficulty in compassing space in a more precise way than the mere movement of sound sources.

Of course, this lack of control does not necessarily mean a lesser artistic value, since we know many musical works, using acoustic or electronic sound sources (or mixed) that are of a remarkable interest and quality. This research, however, wants to ask how this gap between pragmatic decisions and measurable, controlled, space-related elements can be overcome in order to enhance our knowledge of the subject and, possibly, open some paths to artistic imagination.

---

13. *"Si l'acoustique prévaut sur le musical, on est certain d'être en présence d'une conception superficielle et décorative" […]* - Nunes, "Temps et Spatialité", 122.
14. *"Dans une prolifération de langages artificiels et de modèles sans théorie, la musique cède aux prestiges de la logique appliquée et l'espace devient le milieu emblématique de recherches qui mettant au second plan le point de vue spécifiquement musical" […]* - Dufourt, "Timbre et Espace", 272.

1.2.1 Spatialization and *figure spatiale*

Fundamentally, the use of space in the two main fields of concert music (electronic and acoustic music – together with mixed forms) is codified along a series of practical and pragmatic data (position of sound sources and their activation, etc.), as well as empirical estimations of their effects at the moment of performance. It is then evident that, from the point of view of the compositional process (meaning the phase of notation of a musical idea, or generally speaking, of a sound gesture, or a musical action), two different operations are in the mind of the composer: The description of a space-figure and the acoustic result in performance. These two basic points are meaningful exclusively in a pre-defined environment (an acoustic space – generally the one in which the performance is presumed to happen) with peculiar practical features (such as position of players – or sound sources, disposition of audience, etc.).

Musical notation can only be significant given this *conditio sine qua non* (according a spatial point of view) and the two above-mentioned operational steps can be defined and practically realised. Otherwise all notated tones, phrases and eventually polyphony would forcefully lose their three-dimensional attributes and fall without hesitation into the plainness of their flat representation. If we turn our attention to the moment of the compositional process, we notice that generally, the definition of a *figure spatiale* can happen almost exclusively as connected to practical experience:

- In acoustic music the description (notation) of a *figure spatiale* like any other musical figure (or gesture) appearing in the text (score) can be considered only partially as an *a priori*[15] construction since, even if it is independent from experience (it can be defined without being previously performed), there is still a previous practice and knowledge of general issues linked to the spatial perception of sounds;
- In some electroacoustic music,[16] the description (notation using software code and/or realisation on tape or digital supports) of a *figure spatiale* can be conceived as an *a posteriori*[17] construction, since it results from experiences such as simulations, etc. in laboratory.

In both cases however, the use of spatialisation is strictly of a phenomenological nature because an audience becomes conscious of a sound movement by directly experiencing it. Since it is impossible to describe with traditional (musical) vocabulary, the actual phenomenon is the only moment where every spatial construction takes form in the consciousness of human beings (concert audiences).

In accordance with these premises, elements connected to spatiality seem to be musically

---

15 This term designates a certain process without reference to particular experiences.

16. Some electronic works fixed on magnetic tape or other media also have a graphic sketch or plan (e.g. Edgard Varèse's *Poème électronique* for which graphic plans – comparable with a form scheme – have been found) but the final result (algorithms or sounds) are optimized on the basis of experiments (for example sound renderings) for which the final product is the result.

17. This term designates an inductive process that begins with previously experienced facts.

expressed essentially *a posteriori,* because the innate quality of space makes it almost impossible to describe analytically (with available methods) in a musical context. If the musical significance of a *figure spatiale* is linked to an environment (an architectonic space or performance venue – and of course to the human binaural way of listening) how would it be possible to make this physical environment discrete and therefore controlled in order to escape this *a posteriori* condition?

1.2.2 How can space be an autonomous musical parameter?

According to this perspective on the musical text, processes of activating space-figures in the notation and producing or reproducing these in a concert situation actually deal with music elements that are, thus far, partially uncontrollable. Here, the techniques of measuring space are based on phenomenological understandings (more or less accurate) and the ensemble of scientific know-how connected with such techniques is used quite pragmatically, meaning without a measured and broadly accepted method.

In fact, without the option of controlling this aspect on an higher level, space is consequently treated as an additional element, joining other (stronger) musical parameters (or sound objects) to underline their characteristics and peculiarities, as well as the emotional charge of their expression, rather than as something fully conceived as an independent, or even self-referential aspect of music. Only composers' skills will be able, as is the case with Nunes' or Stockhausen's music, to overcome this scarcity of technical means and achieve those well known artistic results (*Gruppen*, *Quodlibet*, *Lichtung*, for instance). Should it be possible to conceive of space as an autonomous entity (parameter), it is self evident that following the path of the mere spatialisation of sounds will undoubtedly be insufficient.

Spatialization is indeed a technique that, in order to be effective, presumes a very peculiar musical substance be projected and revealed through several perspectives in space up to the audience's perception[18]. Only a broader investigation able to include other facets of space could eventually support a more precise definition of this dimension (spatialization), therefore indicating a possible path to surmount this deficiency. Hence, since at this point it seems necessary to deal with a bigger ensemble of musical possibilities connected to space (not only concerning spatialisation but also other space-related acoustic phenomena), the focus of this research will move toward a broader context and it will therefore be imperative to talk about spatiality as a comprehensive, broader group of space/sound relationships and characteristics.

---

18 As we know, spatialized low frequencies, for instance, are much more difficult to perceive than higher ones.

CHAPTER 2

ANALYSIS AND CONCEPTS

2.1 Spatialization and musical examples

In order to give some examples of what spatiality can mean in music composition (and without the aim of giving a full analysis of the quoted music works), in the next paragraphs we will briefly examine how some of these musical possibilities have been used and exploited to artistic ends. In works by Nunes, Stockhausen, Lucier, and Varèse we will encounter the use of spatialisation, the approach to the physical qualities of space, and the metaphoric use of space in terms of compositional space (dimension). Each example emphasizes one particular aspect of spatiality, developing it in different ways (phenomenological, empiric, metaphoric, strictly organised according to superimposed structures, etc.). By describing briefly each of them – their points of interests as well as their methodological limits – we will trace a line, which will lead us to formulate a possible working method that is able to connect space (or spatiality) to the other musical parameters in a stricter way.

The idea of considering space or spatiality as an entity strong enough to shape music (without necessarily depending on other musical parameters) stands in opposition to the general consensus that it can be best perceived when other parameters (rhythm, pitch, timbre) remain constant and unchanged. Moreover, the differential nature of a single sound moving through a certain architectonic environment (direction, frontal, posterior or side position, elevation), as perceived by binaural hearing, can be easily masked if other sounds are joined, summed, or even possibly move around as well.

Although the next two examples (*Gruppen* by Karlheinz Stockhausen and *Quodlibet* by Emmanuel Nunes) are not characteristic of the whole work to which they belong – i.e. they cannot designate an overall attitude or aesthetic credo for the two composers – they represent two typical and interesting practical approaches to space, and for this they will be briefly pointed out in the following paragraphs.

2.1.1 Stockhausen – *Gruppen*

GRUPPEN für drei Orchester is the first composition by Karlheinz Stockhausen where musicians are placed somewhere other than on the stage. The three orchestras are located on the same level as the audience, with the effect that the distances between each musician and the listeners are an important component of the final music result[19]. In order to underline the spacial movements composed in the score, Stockhausen decides to build the three orchestras with similar instruments in order to give the impression in some sections of the work, that the same sound travels around the concert hall (an experience that is surely the result of his work with electronic music).

We can clearly identify two essential points concerning the use of space in this early example of space-oriented music:

> a) Space underlines other music parameters and musical figures are supported by sound movements to increase dynamic effects over the course of time[20] (in some of his early works, movements and trajectories are also structured in accordance with serial thought);

> b) The dichotomy between real and modelled space, i.e. between performance room (which means a series of acoustical attributes) and "musical room" (the word *musikalischer Raum* is very ambiguous and cannot be explained by means other than metaphor – whose definition, field and degree of precision are variable for each artistic experience) is elucidated, according to specific aesthetic positions[21].

At any rate, all acoustic factors playing a role in this example are strongly linked to musical text: A musical figure (a melody or a chord for instance) is projected in space, and therefore perceived under all factors related to that architecture (performance room), but still the musical needs (in terms of pitch order, harmonic structure) are that which dominate the significance of that figure. In this very famous example of a work featuring multiple sound sources (three orchestras, placed in front, at the left and at the right side of the audience respectively), a symptomatic moment (page 95 of the full score, see Fig. 2.2) occurs when the three orchestras (each time a similar group of brass instruments) play the same chord but at different starting times and with different dynamic envelopes[22] (see Fig. 2.1).

---

19. Gisela Nauck, *Musik im Raum, Raum in der Musik* (Stuttgart: Franz Steiner Verlag, 1997), 205.

20. *Ibid.,* 233-234.

21. *"Musik verräumlicht sich, bildet im architektonischen einen eigenen, musikalisch-akustischen Raum"*Ibid., 234.

22. "*Klangbewegungen können jedoch ebenso außerhalb eines melodischen eindeutigen Kontext auftreten, wenn sich beispielsweise mehr oder weniger dichte Texturen in verschiedenen Orchestern als in sich relativ geschlossene Komplexe musikalische Figuren mit einer deutlichen Zeitrichtung eine räumliche Distanz von einem zum anderen Orchester durchmessen"*. Ibid., 223.
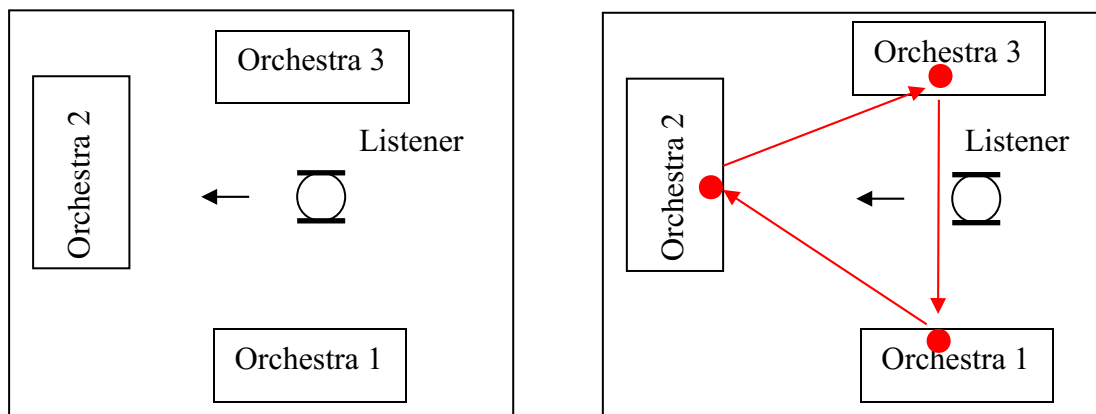
Fig. 2.1. Scheme of the listener's situation for Stockhausen's work *Gruppen*. On the right, the same chord is played in alternation by the three orchestras, creating the impression of a moving sound, a technique that the german composer explored extensively in his electronic works.

Fig. 2.2. Score excerpt from Stockhausen's *Gruppen*. Here (Page 95 of the full score) the same chords are orchestrated from one orchestra to the other, simulating a circular movement. C*rescendi* and *diminuendi* accentuate the effect of approaching and leaving sounds.

What should be pointed out in this extract of the score (Fig. 2.2), is the unanimous character of these sound complexes (brass chords), a resulting harmonic redundancy (repetitions of the same harmony) and a constantly flowing timing of musical figures (regularity of time that provoke the impression of sound-movement). Here, by freezing all pitch information (chords are repeated by all three orchestras and instrumented in the same way), by renouncing a deliberate shaping of time punctually (very long chords), and finally by using dynamics with the aim of simulating an approaching movement (like the crescendo – diminuendo that simulates a sound that approaches and moves away), space perception alone remains and becomes a thematic element.

Auditors can only perceive sounds related to distance (real – depending on which orchestra is playing – as well as simulated – depending on the speed of crescendo or decrescendo currently played giving the impression of a faster or slower sound movement. In the case of a crescendo starting from pianissimo, the impression is that the sound comes from very far away), and position (some sounds are perceived directly from the front, others come from the sides). Additionally, another simple but very effective technique (based on the idea of impulse and resonance) is used to mark even more the room-volume (distances) between sound sources, as occurs at 119 (second bar) between two groups placed respectively at the left and the right of our ideal listener: Orchestra I plays its chord sforzando, and Orchestra II first plays the long chord beginning almost inaudibly and growing in intensity up to the maximum (*ff*). In line with common consensus, the simplest degree of musical writing (where pitches and rhythm do not vary) coincides with the definition of a new paradigm (space) in the musical work, since it allows an elementary perception of this (spatial) dimension.

2.1.2 Nunes – *Quodlibet*

QUODLIBET pour vingt-huit instruments, six percussionnistes et orchestre, dirigés par deux chefs (1990–1991) by Emmanuel Nunes, is an attempt at describing a complex space by changing the disposition of musicians around the audience and revealing a multitude of facets by varying its connotation.

In addition to the displacement of musicians around the audience, the position of some of them changes according to indications written in the score, as explained in the performance notes[23]. Taking constant care to avoid spacial saturation (too many events happening at the same time), the composer creates theatre-like situations with something that he considers invisible personages (musicians changing placement during the performance according to indications written in the score).

Instead of working with one sound's movement through different sound-sources (orchestras,

---

23. *"Différentes « situations » ont été définies pour la pièce quant à la répartition des effectifs dans la salle, «avec un souci permanent de ne pas saturer l'écoute spatiale». Et ces situations forment une véritable « action scénique », créant une « théâtralité de l'espace » dont les actants restent, selon les termes du compositeur, des « personnages invisibles » : « un théâtre sans paroles ni gestes »".[...]* - Peter Szendy and Emmanuel Nunes, "programme du Festival d'automne à Paris, cycle Emmanuel Nunes," http://brahms.ircam.fr/works/work/10871/#program.

as in *Gruppen*), here it is a case of building, metaphorically, an acoustic situation in which the orientation of the sound sources is not only a matter of timbre (or acoustic effects) but also connected to musical material, and therefore significance[24].

The impact of space on musical material – kept intense and fully organised throughout the whole work, as is common in Nunes' compositions – can clearly be seen in the afore-mentioned example from *Gruppen,* as space transforms the perception (same chord coming from different points) and can therefore be treated as a further dimension to be shaped and processed.

Conceived not merely as a medium to transport different musical materials, the rich variety of timbre identities builds a complex topography; space achieves a personality superimposed by the composer.

---

24. *"Et l'œuvre déploie ainsi une géographie du lieu musical, construisant ses méridiens et ses pôles tout autant que son zénith et son nadir : les sonorités s'ordonnent selon divers étagements, pour créer une véritable décantation de l'espace sonore"* - Peter Szendy and Emmanuel Nunes, "programme du Festival d'automne à Paris, cycle Emmanuel Nunes," http://brahms.ircam.fr/works/work/10871/#program.

Fig. 2.3. Score excerpt from Nunes's work *Quodlibet*. Here spatialization is a direct consequence of players' placement in the music hall (and around it). Because the effect of spatialization is strictly connected with sound-source localization, rhythmic and dynamic notation provide themselves information about the way the composer uses sound projection: In this example the extreme fragmented musical text means a dense use of spatialization throughout the whole performance space.

In some other works by Nunes (when we look for instance at one of his pieces that features even greater precision in its use of spatialisation: *Lichtung I*[25]), we will clearly see how important the problem of notation within the parameter space (or spatiality) is, which leads to the problem of connecting the traditional music score and live-electronic programming.

In *Lichtung I* in fact, instrumental gestures and their agogic, according to Nunes, is synchronized as strictly as possible with the computer (using a click-track for the conductor), up to the point that spatialization can shape dynamics and sound envelopes performed by the musicians and even further explore the effects of rhythmical superpositions.

Alain Bioteau, takes this even further when he asks if in *Lichtung I* it would be possible to establish a *solfège des spatialisations*[26] because the main obstacle to sketching out a possible answer is the memory of spacial gestures (*geste spatial*) and its representation in time[27]. Looking at the two main aesthetic streams of the time, instrumental (and mixed music) and pure electroacoustic music[28], we observe a difference in the way these two aesthetics are dealing with the representation of space. According to Bioteau, the fact that in electroacoustic pieces no musician is playing on the scene, each studio producing works for electronic sounds only had to invent its own loudspeaker orchestra[29]. As a matter of fact, if on the one side huge efforts have been made in the technological evolution of sound-projection means, up to now no writing tool has been considered exhaustive enough to represent this parameter in all its

25. *Lichtung* is a work for ensemble and live-electronics, (composed 1988 – 1991):
"Dans Lichtung*, l'écriture instrumentale et le programme informatique sont indissociables dans leur élaboration. Pour le compositeur, il s'agissait de ne pas écrire une partition « à transformer », a posteriori. Une tentative de synchronisation maximale, pour chaque événement, entre l'agogique instrumentale et le discours de l'ordinateur, d'une très grande complexité rythmique. [...]*
Et la partition informatique tend « vers une limite presque inaccessible : un traitement individualisé de chaque moment spatio-rythmique ». *En effet, le son de chaque instrument est envoyé à l'ordinateur, qui lui fait subir des modifications et gère sa spatialisation dans un des huit haut-parleurs disposés dans la salle. Cette mise en espace est conçue selon des rapports rythmiques"* [...]
"En affectant une enveloppe – un profil dynamique – à cette matière sonore qui parcourt le lieu, on peut masquer ou faire surgir ces rapports rythmiques sous-jacents. Et l'ordinateur devient un outil merveilleux pour aller au-delà de l'instrumental, vers l'inconnu du rythme" [...] - Peter Szendy, *"programme du concert Emmanuel Nunes, le 13 février 1992, Centre Georges Pompidou,"* http://brahms.ircam.fr/works/work/10856/#program.
26. *"Peut-on, dans Lichtung I, établir une sorte de solfège des spatialisations? Quels sont les parcours types et quelles relations entretiennent-ils avec les autres paramètres"?* - Alain Bioteau, "Toucher L'espace," in C*ompositeurs d'aujourd'hui – Emmanuel Nunes*, ed. Peter Szendy (Paris: L'Harmattan, Ircam / Centre Georges Pompidou, 1998), 41.
27 *"Le plus grande obstacle, pour esquisser une réponse à ces questions, est la mémoire du geste spatial et sa représentation dans le temps. Jusqu'ici, deux cas se présentaient, rattachés à deux esthétiques différentes".* Bioteau, 1998, 41.
28. In spite of this affirmation, there are many more reflections about space and perception of what he calls sound objects in the so-called *Musique Concrète*. In 1977 Pierre Schaeffer wrote:
"Il est intéressant, dans notre perspective, d'ouvrir une parenthèse sur la spatialisation. Elle fait apparaître un nouveau pouvoir discriminateur qui n'a rien à voir avec les précédents". [...]
"On doit peut-être alors admettre l'existence d'un pouvoir discriminateur particulier – non plus de l'oreille toutefois, mais de l'audition dans son ensemble" - Pierre Schaeffer, *Traité des objets musicaux: essai interdisciplines* (Paris: Édition du Seuil, 1977), 213.
29. *"D'une part, les musiques électroacoustiques ont développé une interprétation spatiale, afin de pallier l'absence d'instrumentistes"* [...]
"Des outils de diffusion ou orchestres de haut-parleurs ont été progressivement élaborés selon des besoins propres à l'esthétique de chaque groupe de recherches et studio en activité" [...] Bioteau, 1998, 41-42.

facets (kind of movement, speed, envelopes) and, most important, parallel to the instrumental notation. In spite of this limitation, much energy has been expended in order to achieve the same level of precision in the score that is demanded of the software tools. But, when (thanks to those sound diffusion tools) the amount of information describing a *figure spatiale* is too large to be codified in a symbol or sign in the musical score (or potentially even fully written) a mere reduction is not only possible but necessary, resulting in a consideration of the programming itself as a *partition informatique* (in the sense of an algorithmic score[30]).

Bioteau also affirms that an algorithmic score (because today, programmed trajectories, for instance, can be easily read using live-electronic programming code) can be fully considered as a parallel score[31] that can be deciphered and compared with the musical text. An accessibility of the algorithmic score that parallels the way that a music score is accessible to musicians, however, does not seem to be essential. Bioteau, in fact, reports that Nunes did not need to visualize the *figures spatiales* used on the score, since he was accustomed to manipulating the simple successions of numbers corresponding to the loudspeakers[32]. This is a further indication that, even when so directly connected with musical needs[33], spatialisation and localisation of sound sources focus mostly on the real phenomenon with its empirical cognitive instruments.

It should be mentioned that sometimes a simple graphic representation of sound movements in space does not differ much from traditional scoring for several voices, where, instead of an instrument, on each (horizontal) line a different loudspeaker activity is placed, temporally ordered from left to right. This is surely reductive information, at least in the case of *Lichtung I*, since many other parameters such as envelopes[34] need to be described and can be studied

---

30. *"Dans ce genre musical où la partition est loin d'être obligatoire, c'est pratiquement toujours le compositeur lui-même qui spatialise son œuvre, […] le codage de la spatialisation elle-même reste toutefois assez réduit".[…]*
D'autre part, la musique instrumentale intégrant l'espace a rarement proposé des systèmes de notation originaux. […] Ibid., 41-42.

31. *"L'arrivée de l'informatique, du contrôle possible des niveaux de diffusion dans chaque haut-parleur et de sa mémorisation, permet aujourd'hui de lire dans les programmes les situations de jeu,les parcours (les trajectoires) et de le croiser avec la partition instrumentale ou la musique fixée sur support (bande)".* Ibid., 43.

32. *"C'est certainement la chose la plus étonnante : Nunes n'a jamais eu besoin de visualiser les figures spatiales qu'il mettait en jeu, la manipulation des chiffres représentant les numéros de haut-parleurs lui suffisait".* Ibid., 43.

33. Emmanuel Nunes writes:
[…] "c'est l'idée de spatialisation musicale *qui me hantais depuis 1965, et qui m'imposa mon premier pas vers l'informatique.* Musicale*, car très vite il m'était paru clair que la spatialisation devrait contenir déjà en elle même une sorte de recomposition du rythme et du timbre, outre sa dimension la plus évidente de* dissémination *et d'encerclement".* Emmanuel Nunes, "Lemmes," in C*ompositeurs d'aujourd'hui – Emmanuel Nunes*, ed. Peter Szendy (Paris: L'Harmattan, Ircam / Centre Georges Pompidou, 1998), 153-154.

34. Eric Daubresse explains that, for the spacial projection of transformed instrumental sounds, a series of envelopes was created, by changing temporal data of the dynamic evolution at the starting point (*tête*), the body (*corps*) and the final part (*queue*), i.e attack – release – decay. Such envelopes are applied to the sounds with regard to their length and articulation. The envelope 0 for instance is described like this: "*enveloppe de base pour les acciaccaturas, profil très serré*"; […], envelope 6: "*enveloppe avec tête importante, sans corps et avec queue minimum*" […], envelope 9: "*enveloppe portato, donne une perception de la durée équivalente entre l'attaque et la chute*" […], envelope 13: "*enveloppe de type trapézoïdale; valable pour des durées qui changent; car se comporte très bien sur des factorisations extrêmes*". Éric Daubresse, "Le projet informatique. De l'élaboration à la collaboration," in *Compositeurs d'aujourd'hui – Emmanuel Nunes*, ed. Peter Szendy (Paris: L'Harmattan, Ircam / Centre Georges Pompidou, 1998), 143-144.

solely in the stocked programmed data (algorithmic score). Proximity between graphic representations of sound objects and their relationship to space on a temporal scale – for those works having real-time electronic processes – and the instrumental score is assured.

Bioteau's analysis of *Lichtung I* remarks[35] that when spatialisation is changed at each note and each corresponding rhythmical value, the closest possible degree of interconnection between the two worlds, music notation and algorithmic score, is reached.

2.2. Precursors

Searching music history for possible precursors to an idea of a parametrized space-dimension within musical composition, and a stricter connection between acoustic phenomena and musical writing, two remarkable positions (and artistic experiences) can be pointed out: Those of Edgard Varèse (1883-1965) and Alvin Lucier (born in 1931). Both offer important points of observation, and therefore appear rather complementary from the particular perspective of this research. If for Varèse the *écriture* is the main protagonist in a way that seems to achieve a spacial quality, it is the physics that emerge for Lucier. In the binomial Varèse – Lucier two extreme positions could not appear more distinctly: Notated music and spontaneous result, discrete compositional process versus happening, a musical structure coming from an arbitrary decision on the one side, an aesthetically developed natural based phenomenon on the other.

2.2.1 Symptomatic methods

The reasons for focussing our attention on the aforementioned composers, out of all of the artistic experiences that were connected with issues of space (even in more recent times), is linked to our primary line of enquiry. By showing these two contrasting positions, we are looking for a way to link space-related acoustic phenomena to musical composition (writing), as well as possible relationships between the phenomenological and ontological aspect of space perception. Looking back to these artistic experiences, it is interesting to point out that such approaches tended to go in different ways and suggested different answers to the main question of architectonical space as a musical parameter.

Although such methods do not allow the dimension space to fully achieve a primary status, or do not bring a satisfying means of measurability, when observed side by side (or possibly even synthesized) they represent an important step forward in the spatialization discourse. The two artistic (and methodological) approaches are even more interesting when considered to be complementary.

---

35. *"Avec l'analyse de la spatialisation dans Lichtung I, il s'agira notamment d'établir différents degrés de littérarité ou de figuration entre les catégories du discours musical. Si chaque note et rythme d'une mélodie déclenche un changement de situation spatiale, nous sommes dans le cas du plus haut degré de littérarité. C'est à dire que la spatialisation, au moins du point de vu temporel, est au plus près du texte instrumental"*. Bioteau, 1998, 44.

2.2.2 Edgard Varèse's example

Varèse's musical output presents two major aspects of relevance here: The first being the experiences with sound-projection connected to new technologies (*Poème Electronique*, *Déserts*) and the second all of the instrumental music (as most representative examples: *Intégrales*, *Hyperprism*, etc.) in which new compositional methods are applied to shape traditional musical material (pitches in particular).

The musical thinking of Edgard Varèse, seen in accordance with these two aspects, can be summarized into a simple proposition: The so-called *musique spatiale* had a much deeper meaning to the French-American composer than a mere projection of sounds into an architectonical space[36].

Helga de la Motte-Haber[37] speaks about Varèse's metaphors describing pitch organization, as providing a modification in the usual categories of pitch setting and a possible relationship with space-related effects. As a matter of fact, the attempt to notate the music – or better the sound actions and figures of *Poème Electronique* – in a score form[38] (with both graphics and traditional music notation signs, see Fig. 2.4), gives evidence of a necessity to compose or define space in a more definite and precise way.

---

36. "*Man darf vielleicht darauf schließen, daß spatiale Musik nicht nur den Realraum meint, in den Musik ja gemeinhin projiziert ist, sondern ein kompositorisches Konzept"* - De la Motte-Haber, *Die Musik von Edgard Varèse*, 1993, 126.

37. *"Seine oft metaphorische Bemerkungen lassen sich erstaunlich gut präzisieren, und zwar im Sinne von Modifikationen der traditionellen Kategorien des Tonsatzes in Hinblick auf mögliche Raumwirkungen".* Ibid.

38. "*Die Skizzen zum Poème Électronique zeigen, daß Varèse überwiegend mit traditioneller Notation, jedoch auch mit graphischen Zeichen gearbeitet hat".* Ibid., 103.
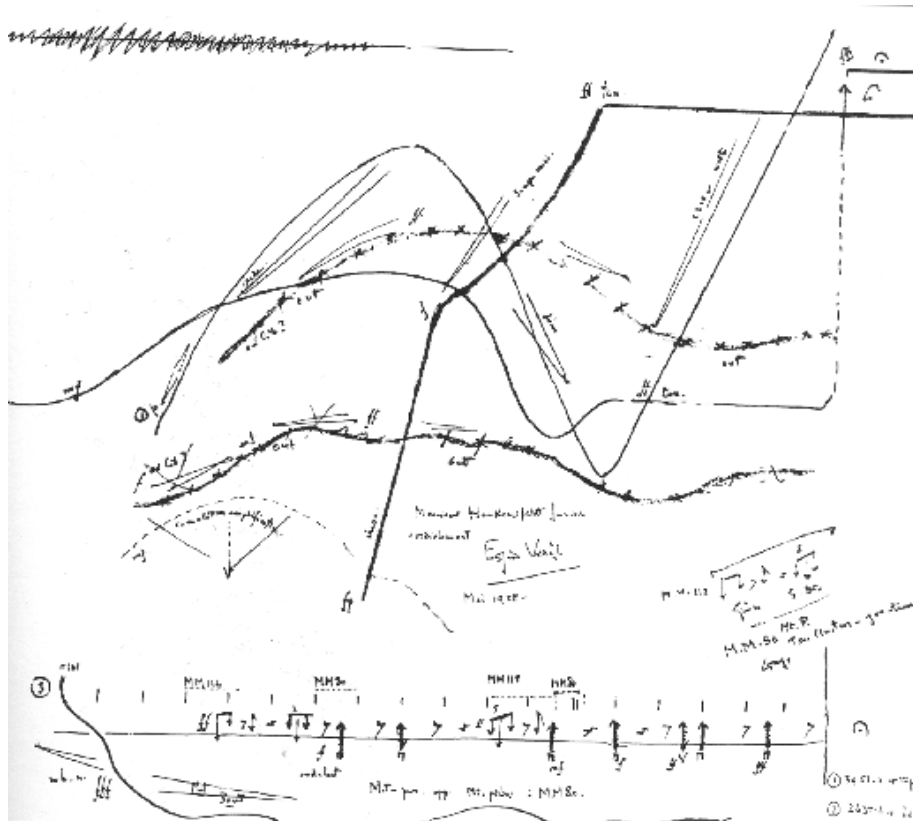
Fig. 2.4. Sketches for Edgard Varèse work *Poème Electronique,* this scheme can be considered as a (working) score, describing the formal evolution of the electronic sounds to the best possible extent given the means available at the time.

On the other side of his musical invention (instrumental music), some metaphors of *Realraum* (to distinguish from a dimension of musical composition, *musikalischer Raum*) are suggested by his unique notation. By way of sapient instrumental writing (that also includes dynamic effects which reproduce a sense of distance) primarily focused on a virtual, space-oriented pitch organisation, Varèse manages to reinterpret the real space[39] (*Realraum*).
The category of *musikalischer Raum* has achieved here a quality of a third dimension of sound, which on the side of a true representation of space inside musical text, we can again only connect with phenomenological impressions[40] (*Eindrücke*), which act upon a haptic

---

39. "*Es handelt sich dabei um einer virtuellen musikalischen Raumbildung in eine komplizierte Interaktion tritt. Der Realraum kann umgedeutet werden, anderseits können jedoch auch realitätsnah wirkende, aber künstliche Entfernungseindrücke durch Klänge erzeugt werden. Der äußere Raum war in den Anfängen der Instrumentalmusik ein instrumentatorisches Mittel, Er wurde musikalisch umgedeutet*". De la Motte-Haber, 1993, 112.

40*. "Bereits an Tönen haftet durch ihre haptische Qualität eine dritte räumliche Dimension. Sie erscheinen schwer oder spitz, dünn oder rund". [...]*
"Diese plastischen Qualitäten gehören in der traditionellen tonalen Musik nicht zu den zentralen

quality of sound.

Continuing with another kind of metaphorical approach[41] (a parallel with sculpture), sounds that behave ideally like objects seen in space provoke the impression of a certain tridimensionality inside the spacial virtuality of the *Tonraum*, and at the same time they seem to be projected in a real space (*Realraum*).

A metaphor, but one which is consistently developed, since the syntax of chords, melodic lines, up to phrasing, follow synaesthetic categories of thinking more closely approaching geometrical principles (symmetrical chord-transpositions) than the common, traditional ones[42].

Symmetry, finally, seems to evoke a first attempt, within the confines of the technical means of that time, to join the spheres of spatiality with pitch and harmony more tightly together. This geometrical *topos* was, for Varèse, the closest he could come to a way of establishing a coherent connection between pitch organization and space-projections as he would do in the *Poème*; symmetric transformations were, still on a metaphoric level, the most effective method of simulating rotations, translations, movements (and timbre transformations) of sounds in space as we can see in the following picture[43]:
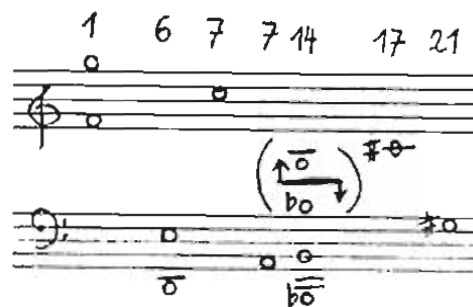
Fig. 2.5. Edgard Varèse's *Déserts*. Examples of symmetrical chord projections. In the section from bar 1 to bar 21, harmony is structured according two major ninths and their symmetrical pitches. The low A and the C (fifths), the G-sharp and the middle-C-sharp (as major thirds respectively up and down), build a symmetrical-interval chord with the minor second B-flat – B-natural (in brackets) as its axis.

Toneigenschaften. Ihnen entsprechen mehrere Faktoren des Erlebens. Dazu zu rechnen sind das Volumen und die Dichte, die beide bei Tönen von der Frequenzen und der Lautstärke abhängig sind". Ibid.

41. *"Die haptischen Qualitäten von Klängen lassen den virtuellen musikalischen Raum mindestens als dreidimensional erscheinen. Sie geben ihm eine perspektivische Tiefe, zugleich aber erscheint dieser musikalische Raum in den Realraum hinein projizierbar, weil sich Eindrücke von nah und fern einstellen"*. Ibid., 123.

42. *"Symmetrische Projektionen in den Tonraum scheinen ein nachgeordnetes Kompositionsprinzip zu sein, das sich anderen Tontechniken der Bildung von Klängen unterordnet"*. Ibid., 152.

43. Ibid., 153.

2.2.3 Alvin Lucier's example

Alvin Lucier has consistently paid particular attention to the phenomenon of space[44].

The general attitude of this American composer differs drastically from that found in the previous example (Varèse), nevertheless, in a different aesthetic and artistic context, the problem of space in composition (outside of music notation), is constantly approached and explored.

It might seem strange that a composer dealing almost exclusively with installations, meaning with music that is not completely possible to write down (in all its details), is placed this close to one of the pioneers of new music (Edgard Varèse). In reality however, given the means offered by technology, introspection on the matter of sound in space could only be made possible as a direct experience by full immersion into the acoustic properties of space.

In his texts though, an explicit reference to the problem of composition – written music – is present as a limitation to overcome[45] (Lucier had composed instrumental music since 1952, before changing his direction in 1965 with *Music for Solo Performer*):

> *For several hundreds of years Western music has been based on composition and performance. Most attention has been focused on the conception and generation of sound, very little on its propagation. Written notes are two-dimensional symbols of a three-dimensional phenomenon. No matter how complex a system of notation or how real the illusion of depth, written music is trapped on a flat plane.*

It is astonishing to see the remarkable affinity between the thinking of Varèse and Lucier, since (at least concerning their artistic needs) both were feeling a lack of control on the space qualities of sound in traditional music notation. They were both concerned with the problem of a (new) musical notation (Varèse), or a way (Lucier), to shape music that could express space in its innate substance.

They were both interested (metaphorically or realistically) in the idea of sound projection, but if Varèse looked at the broad range of possibilities of moving and translating chords and pitches in an imaginary tridimensionality, Lucier followed a more introspective path, being interested in revealing some acoustic phenomena to the listeners that are physically connected to space[46]:

> *Sounds have specific spatial characteristics. Those of short wave length (high frequencies) are directional; longer ones (lows) spread out. Sound waves flow away from their sources roughly*

---

44. Alvin Lucier (born May 14th, 1931) is an American composer of experimental music and sound installations that explore acoustic phenomena and auditory perception. A long-time music professor at Wesleyan University, Lucier was a member of the influential Sonic Art Union, which included Robert Ashley, David Behrman and Gordon Mumma. Much of his work is influenced by science and explores the physical properties of sound itself: resonance of spaces, phase interference between closely-tuned pitches, and the transmission of sound through physical media.

45. Gisela Gronemeyer and Reinhard Oehlschlägel, *Alvin Lucier Reflections, Interviews, Scores, Writings* (Köln: Edition Musik Texte, 1995), 430.

46. Ibid.

> *in three dimensional concentric spheres, the nodes and antinodes of which, under certain circumstances, can be perceived in a room as clearly as those of a vibrating string on a violin. [...] Each space, furthermore, has its own personality that tends to modify, position, and move sounds by means of absorptions, reflections, attenuations, and other structurally related phenomena*

By seeing an immanent vision of space as an intrinsic quality of sound itself, the spatial dimension ascends to a status of equal importance; it is revealed though not yet parametrized, as is shown in the work *I Am Sitting In A Room.*

Space-related phenomena, which are profoundly explored in Lucier's music, appear to be thematic here (the main example taken into account for this research will be *I Am Sitting In A Room*, composed in 1969, because of its direct relation to the topic). Structured almost entirely according to empirical methods, but aesthetically consequent, his compositions present acoustic occurrences in a room that are to be observed (and perceived) by audience.

For him, the relationship between musical material and its perception in space has drastically changed, the sounds generating acoustic effects are less significant than the effect itself[47]:

> *In "I AM SITTING IN A ROOM" (1970), several paragraphs of human speech are used to expose sets of resonant frequencies implied by the architectural dimensions of various sized rooms. By means of a pair of tape recorders, the sound materials are recycled through a room to amplify by repetition those frequencies common to both the original recording and those implied by the room. As the repetitive process continues and segments accumulate, the resonant frequencies are reinforced, the others gradually eliminated. The space acts as a filter.*

The complex problem of the possibility of projecting space-related effects into musical writing, had found two very different solutions: If Varèse had to solve this dilemma by focusing more on music notation and therefore (in the instrumental music) treating it metaphorically, Lucier, limited by technological means but mostly led by his aesthetic criteria, does not take on this challenge and prefers to converge on the pure, naked acoustic effects.

By avoiding undergoing any compromise and refusing to conceive any written music (because space was, at the time, not actually possible to notate except for the mere provenience of sounds that we can call a topography of sound sources), he enters this new field[48] of musical composition by underlining and emphasizing it to listeners, but does not propose any method to control it.

After Lucier, the problem still stands, waiting to be fully solved and explored. However, an important statement has been formulated[49]:

---

47. Ibid., 434.
48. *"Accepted as natural occurrences to be enjoyed and used, however, they open up a whole new field of musical composition"*. Ibid., 430.
49. Ibid., 434.

We discover that each room has its own set of resonant frequencies in the same way that musical sounds have overtones.

How musical this approach can be is clearly expressed in an interview titled *Every room has its own melody*[50]:

Did you notice that tunes seem to start? Every room has its own melody, hiding there until it is made audible, You know, I feel as though we're in the same situation as composers were when they first began perceiving overtones. Musicians were always aware of their effects, I think, but timbre was mysterious until someone could demonstrate their existence. Now we're just beginning to compose with architecture in mind, and I'm very pleased to be in on these first experiments.

If this acoustic phenomenon can be artistically expressed in the form of an installation (without concealing the character of an experiment expressed by Lucier himself), by observing that its result is completely dependent on the kind of room (form, size, kind of materials around the walls, etc.), we can naturally ask what would be the way to control this acoustic effect, to separate it from an actual experience by modelling it, and finally to transpose such results (a melody for example, to use Lucier's words) into a notated musical form.

It is exactly this last sentence that opens a new path to this inquiry on the musical meaning of space: That the technique of spatialisation alone is not adequate to describe and musically develop the whole content of this dimension. Recognising the similarity that an acoustic space (resonant frequencies in particular) can have with a sound spectrum can allow a very different reflection on the perspectives of space in music.

2.3 Further examples from music history

Since this inquiry intends to establish a possible way of understanding how to give spatiality a broader meaning in musical composition, it is interesting to look at some examples from different historical moments, in particular those revealing a similar situation, in the delicate process of redefining an already existing (and historically charged) musical dimension.

For the sake of explaining which dynamics and motivations can play a role in such a subtle passage from one broadly accepted paradigm to a new one that enhances the understanding of a musical aspect, a line will be drawn that starts with some considerations about Dodecaphony, goes further with a few aspects of Stockhausen's work and arrives at Spectral music.

---

50. Ibid., 100.

2.3.1 Enhancement of music parameters

From an historical perspective, the tendency to enlarge the field of possibilities offered by musical parameters can be seen as a natural process, an artistic need. The apparition of Dodecaphony seems to appear as a natural consequence, and as we know, an organic formulation of Dodecaphonic technique came after the chromatic development of harmony suggested by some of its precursors[51].

From a more or less generally accepted empiric tendency, the move from the central idea to the further step of organising it into a coherent system (or method) consists often of replacing or simply changing the elemental hierarchy.

Continuing with the example of Schönberg's composition technique, the main role of the *Tonika* is questioned[52], its primary position in the system of tonality decays, opening the way to a multiplicity of possible harmonic relationships, marked by a moment of passage (*erweiterte Tonalität*) before the formulation of the technique as we know it.

Furthermore, another thought in the formulation of the theory of Dodecaphony points out a main aspect, which nourishes each study and attempt to formalize, in a constructive way, an accepted practice. Those elements that, according to an intuitive working process, transmit images and impressions without any construction, are later incorporated into a system (foreseen in a certain way – but still not formulated – by Richard Wagner) that assures the highest degree possible of *Fasslichkeit*, comprehension, and put together coherently in the form of a *Kompositionstechnik[53]*.

Similar attempts have been made to broaden the field of musical language, therefore of an art, by trying to find a new utilisation of elements or a different order of importance in an area that was previously neglected, or at least considered transitory because of less importance. As Carl Dalhaus affirms[54] referring to Schönberg's composition technique:

> *And in a certain sense the abolition of the difference between central and peripheral sound qualities has meant that a psychological state of affairs which had always existed has been translated into a compositional procedure, a change which initially made it seem as though everything had been turned upside down.*

---

51. *"Die Methode mit zwölf Tönen zu komponieren, erwuchs aus einer Notwendigkeit. In den letzten hundert Jahren hat sich der Harmoniebegriff durch die Entwicklung der Chromatik ungeheuer gewandelt".* Arnold Schönberg, "Komposition mit zwölf Tönen" [1935], in *Stil und Gedanke. Aufsätze zur Musik*, ed. Ivan Voitech (Frankfurt am Main: Fischer Verlag, 1976), 73.

52. *"Die Vorstellung, daß ein Grundton, die Tonika, den Aufbau der Akkorde beherrschte uns ihre Aufeinanderfolge regelte – der Begriff der* Tonalität – , *mußte sich zuerst zum Begriff der* erweiterten Tonalität *entwickeln".* Ibid.

53. *"Weiters wurde sehr bald fraglich, ob eine Tonika, [...] wirklich eine konstruktive Bedeutung hatte. Richard Wagners Harmonik hatte einem Wandel in der Logik und der konstruktiver Kraft der Harmonie Vorschub geleistet. Eine ihr Folgen waren der sogenannte* impressionistische *Gebrauch der Harmonien, wie er besonders von Debussy praktiziert wurde. Ohne konstruktive Bedeutung dienten seine Harmonien oft dazu, Stimmungen und Bilder, obwohl außermusikalisch, zu konstruktive Elementen, die in die musikalischen Funktionen mit einbezogen wurden; sie schufen eine Art Faßlichkeit vom Gefühl her. [...] Dies allein hätte aber wohl noch keinen radikalen Wandel in der Kompositionstechnik verursacht".* Ibid.

54. Carl Dalhaus, *Schoenberg and the New Music* (Cambridge: Cambridge University Press, 1987), 63.

The kinds of order established can obviously be of very different natures, depending on the system itself. For Schönberg it is not really possible to speak of a parameter, but rather a dimension. The twelve-tone series behaves in fact as a set, a *Gestalt* in which the composer can metaphorically move, a musical space[55].

Whereas the term space is, again, used as metaphor as far as it is related to the working environment in which the composer moves. It is this dimension, an operational environment where musical material is forged, that gives a deep musical signification to the final work[56].

The Dodecaphony example seen from this perspective can show in a very understandable way, how new issues in musical composition always change the *status quo* of art languages by revealing new sides of music (or sound), starting with its element hierarchy and continuing with its priorities. Also related to the perception of the (musical) output and not merely to the process of creation, Schönberg himself when talking about the *Emanzipation der Dissonanz,* asserts that little by little, dissonant chords and intervals were sounding more and more familiar, the ear was starting to recognize them, consequently loosening the traditional disturbing connotations and affect[57].

But in order to have an even more limpid instance of how musical parameters surge and transform composition procedures in music history, and to understand the way in which a radical change of those procedures and processes substantially transforms their end result, we shall make a further leap in time. This will mark exactly the moment when the need in musical composition arose to interconnect each factor to the highest possible degree, enhancing the field of methodological possibilities and relationships between musical parameters. This was a phase in which new technologies played a principle role.

2.3.2 A more recent example of musical parameter enhancement

As we look at more recent compositional techniques, especially those that are concerned with electronic sounds, we find a remarkable example of what "enhancement of a musical parameter" can mean. *Kontakte* (1959–60) by Karlheinz Stockhausen, a work that itself reveals much more than a piece of music. The theoretical approach behind the work stands out as a major instance of what we could call obliquity in the treatment of a musical parameter.

---

55. *"The second point Schoenberg stresses evolves directly from his emphasis upon the intervallic succession of the basic set. He asserts that the 'two-or-more dimensional space in which musical ideas are presented is a unit' and stresses that every element of a musical idea occurs in a unified musical space".* Martha M. Hyde, *Schoenberg's Twelve-Tone Harmony – The Suite Op. 29 and the Compositional Sketches* (Ann Arbor, Michigan: UMI Research Press, 1977), 3.

56. "*Schoenberg's notion of 'dimension', which at first may appear to be metaphysical or to have a geometrical analogy, will prove to have concrete musical meaning" [...]* Ibid., 4.

57. "*Das Ohr hatte nach und nach eine Vielzahl von Dissonanzen kenngelernt und so die Furcht vor ihrer 'sinnstörenden' Wirkung verloren".* Arnold Schönberg, "Komposition mit zwölf Tönen" [1935], in *Stil und Gedanke. Aufsätze zur Musik*, ed. Ivan Voitech (Frankfurt am Main: Fischer Verlag, 1976), 73.

In the picture below, this simple scheme tries to show the three main musical parameters (or dimensions):

| Pitch (Harmony) | Rhythm (Time) | Timbre (Dynamic) |
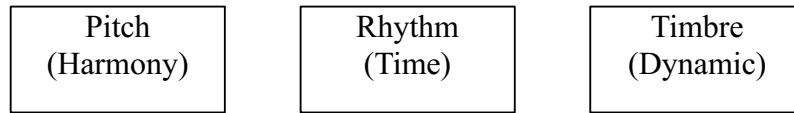
The trinomial Pitch – Rhythm – Timbre describes the three main (generic) parameters that are offered a composer with which to form a music work, including as well their further development into Harmony (a multiplication of pitches), Time (a multiplication of rhythmical structures) and Dynamic (as a way to change a certain sound color).

The possibility to work at combining elements (chords, rhythmical structures, complex instrumental combinations) by assembling information coming from these three parameters is self evident. The question would be how to create a stronger integration of these by extracting pitches from rhythm for example. This is exactly the starting point of *Kontakte* as shown in the following scheme:

Compositional process

Rhythm (Time) → Pitch (Harmony*)

Rhythm (Time) → Timbre (Dynamic*)

Rhythm (Time) → Rhythm (Time*)
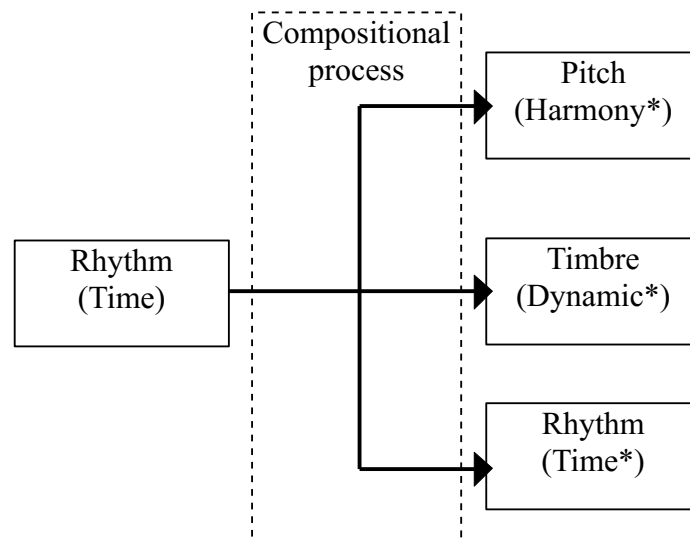
* Harmony, Dynamic and Time are considered like a development of the main parameters: a chord as a overlapping of several tones, dynamic as a factor that can change the timbre quality of a sound, time (intended as duration) as a large-scale rhythm.

In fact, a sequence[58] of ten short impulses (Fig. 2.6) with different amplitude and duration (but with the same pitch), are put together in a symmetrical way. From this elementary (rhythmical) element, further elements (and consequently different parameters) are formed, a possibility that only arises thanks to technological developments[59] (tape music, laboratory

---

58. Robin Macombie, *The Works of Karlheinz Stockhausen (*London: Oxford University Press, 1976), 136.
59. *"The impulse pattern [...] represents on cycle of a wave form. Made into a tape loop, it is accelerated until a*

experiences on the treatment of sinusoids and other synthetic sounds).

We can thus speak about an oblique compositional process as long as the generation of musical structures or musical attributes is not circumscribed inside the same parameter (for instance: Rhythm/time as a further development of already existing rhythm/time data), but is instead a result of a transposition (or reinterpretation) of such data within a different parameter area.

Duration:	5	1	4	2	3	8	7	9	6	10
Amplitude:	1	5	2	4	3	8	9	7	10	6
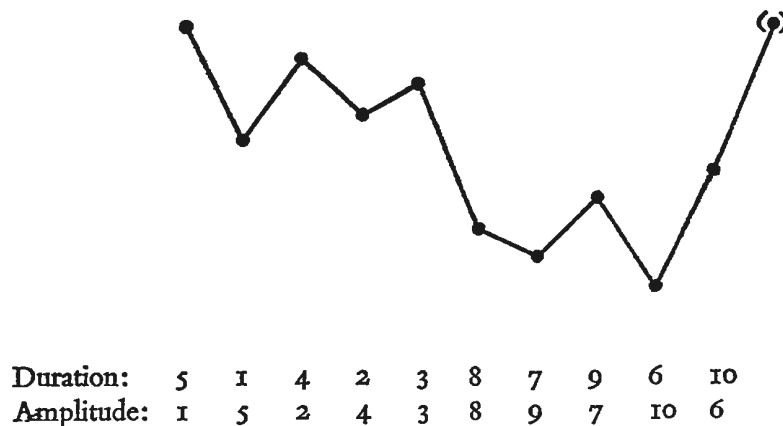
Fig. 2.6. Scheme of ten short impulses (and their dynamic values) for Stockhausen's Kontakte.

A so called obliquity can be expressed as a will to extend – also thanks to technical innovations – a vision that is half way between material and form. As Robin Macombie explains[60], referring to Stockhausen's work: The first creative period of a composer is often marked by the quest for innovation and research in order to make a certain vision as consistent as possible. The point would not necessarily then be what to express, but how to express a work that allows the young artist to create a personal vocabulary, and a strong capacity to shape time (musical forms).

Having seen how the above-mentioned three musical dimensions can be crossed and used beyond their physical boundaries within a compositional process and working method, we shall approach an even further achievement on the path toward the full parametrisation of musical material: *la musique spectrale.*

---

single note of characteristic timbre is heard. […] So we may surmise that Stockhausen may have originally intended to use impulses as mean of transforming percussive, unpitched sounds ('pure rhythm') into continuous timbre ('pure sonority'). Not only does the tape-loop make it theoretically possible to derive tone colour from a series, but it also draws together time and pitch, two separate dimensions of human auditory perception, into a single electronic frequency spectrum". Robin Macombie, *The Works of Karlheinz Stockhausen* (London: Oxford University Press, 1976), 136 -137.

60. *"A composer's first period is usually marked by technical innovation and consistency of vision, for the simple reason that the first problem he has to face is not what to say, but how to say it well. It is in the process of finding a satisfactory mode of self-expression that the apprentice acquires the vocabulary and sense of form that at later stage may themselves inspire him to more practical exercises. But a point is finally reached where that first imaginative impulse is within reach of his technical competence"*. Ibid., 135.

2.3.3 Spectral music, sound as fully measurable

Another experience, much closer to our day than Schönberg's, seems to show very distinctly how an enhanced parametrisation of musical dimensions – or domains – marks a decisive moment in the development of contemporary composition techniques.

The method according to which sounds can be fully measurable, and which is obviously connected to the development of digital techniques, allows composers to analyse, decompose and resynthesise. Along with such technical possibilities, new methods of writing music and of course of forming musical syntaxes are invented. It is however not the aesthetic side of this totally new perspective that interests this research, but the purely methodological acquisitions connected to this aesthetic direction.

Once more, the intention of *Fasslichkeit* as seen in Schönberg's writings and related to the harmonic and melodic organisation of the twelve tones, appears some decades later in the idea of *organisation sonore* (coming from the expression *son organisé* postulated by Edgard Varèse). In order to have full access to all aspects of the sound (i.e. having the highest control of it during the compositional process) those aspects that for a long time were almost impossible to define physically, rise (thanks to scientific developments) as a new domain to explore scientifically and use artistically. Timbre indeed, revealed by new sound analysis technology, is no more a simple musical dimension but a discrete parameter [61].

According Gérard Grisey, one of the foremost exponents of this aesthetic stream, the methodological attitude of considering not the pitch but the frequency, is able to unify timbre and harmony into a single entity[62], and at the same time modify the context of musical parameters.

It gives, together with a new musical aesthetic, a vision of acoustic phenomena that were considered up to that moment as implicit when not neglected, offering an artistic integration[63] of this scientific knowledge into a musical discourse. Science (or acoustics) rises finally as a protagonist in the aesthetic formulation of *Musique Spectrale*, allowing a broader range of musical techniques and its range of artistic expression.

Looking deeper into this composition technique that, without any attempt to imitate previous experiences, can be defined as an attitude[64], we see how the method consists in isolating one or more moments belonging to a bigger entity (the sound itself, as *object trouvé*, for instance)

---

61. *"Im Gegensatz zu einer Definition der Klangfarbe als nicht analysierbare Ganzheit verfolgte die* recherche musicale *die Zielsetzung einer wissenschaftlichen Analyse des Timbres. Die technische Möglichkeiten nahmen im Lauf der Jahrzehnte zu".* Lukas Haselböck, *Gérard Grisey: Unhörbares hörbar machen (*Freiburg: Rombach Verlag, 2009), 153.

62. *[…] "les notions de timbre et d'harmonie sont redéfinies au sein d'une même entité", [...].* Gérard Grisey, "Vous avez dit spectral?". In *insit* (Paris : Lemoine, 2000), 4-5, quoted in Guy Lelong, "Enjeux théoriques," in *Le temps et l'écoute,* ed. Danielle Cohen-Levinas (Paris: L'Harmattan, 2004), 183-184.

63. *"En accédant à de nouvelles régions du phénomène sonore, en repensant les notions de timbre et d'harmonie, en « unifiant » des régions sonores qui semblaient jusque-là inconciliables, en intégrant de nouvelles dimensions de l'espace, l'élargissement du champ musical opéré autour de l'Itinéraire et de l'électronique a indéniablement bénéficié du renouvellement des connaissances en matière d'acoustique".* Ibid., 189.

64. *"L'aventure spectrale permet de réactualiser sans imitation les fondements de la musique occidentale car elle n'est pas une technique close mais une attitude".* Ibid.,185.

and developing it on a different time scale. What physically is a part becomes, after the analysis, the whole[65].

A further essential tool of this composition method, the computer[66], becomes an important agent during the spectral composition process. Far from being a dogma, computational outputs (musical data) resulting from analysis need a strong will to be interpreted, along with very specific and particular aesthetic elements and artistic directions.

2.3.4 Beyond metaphors

The terms *espace sonore* or *Tonraum* as seen in the previous examples pose a remarkable question on the role of space in musical composition: Is it a purely physical aspect (Lucier), a phenomenological dimension that can be revealed during the performance (Nunes), or a metaphor (Varèse) for a music system? The use of space to actually designate other musical dimensions like timbre or pitches, often appears as a trope used to sketch a theoretical description in those cases where an exhaustive exegesis (of the musical text as well as the system) is still looking for a possible interpretation of a new aesthetic attitude. This might be the example of the Dodecaphony and the comparison between dodecaphonic series and space (in particular concerning the so called changing point of view compared to transformation techniques of the twelve-tone-sequence), if Carl Dalhaus had not already contradicted this easy interpretation[67].

Even if in dodecaphonic music it would then be possible to speak about a multiplication of perspectives (*Gesichtspunkte*), as a matter of fact, the integration in musical composition of the above mentioned facets (acoustic phenomenon, dislocation of sound sources and metaphor to form the harmonic and melodic *Gestalt,* all together representing spatiality) is not trivial at all. As it was for the spectral composers at the time of the first steps in the analysis of sounds, there is also a gap today between the physical aspect of a tridimensional space (acoustic effects that are difficult to foresee and organize according a compositional structure) and its control translated into musical (and not only acoustical) data.

Taking the matter further, this spread (also meaning the choice between an empiric or scientific attitude), cannot be simply solved through an extreme control of one sole side of the compositional technique (exactitude of trajectories through orchestration, for instance), because it does not consider the whole potential of what space offers as an acoustic

---

65. *"Insgesamt könnte man sagen, dass spektrale >Figuren< oder >Klangobjekte< in Gegensatz zu motivischen Tonhöhe- und Tondauernstrukturen aus dem Inneres des Klanglichen entwickelt und als fraktale Bruchstücke eines multidimensionalen Formganzen konzipiert sind".* Haselböck, 2009, 154.

66. *"Ein großer Vorteil sei der schnelle und mühelose Zugriff auf eine größere Anzahl von Lösungsvarianten, der dem Komponisten mühsame Rechenprozesse erspare. Letztlich sei der Computer nur ein >Mediator< zwischen Material und Form".* Ibid., 157.

67. *"Umkehrung und Transposition einerseits und Oktavensetzung und Zerlegung anderseits sind Modifikationen, von denen eine reihe manchmal gleichzeitig – und nicht bloß in verschiedenen Augenblicken – betroffen ist, so daß von einem wechselnden Gesichtspunkt streng genommen nicht die Rede sein kann. Die Trennung ist irreal und abstrakt, und der Schein des Konkreten, der von der räumlichen Metapher, dem Wort 'Gesichtspunkt', ausgeht, ist eine Täuschung".* Carl Dalhaus, *Schönberg und andere (*Mainz: Schott, 1978), 196.

phenomenon and what it could mean musically.

Without contesting the artistic quality of music literature featuring such an approach, we suggest the possibility of integration between those aspects that could significantly increase the knowledge of spatiality and its full integration in notated music thanks to appositely designed composition methods.

2.4 Toward space as autonomous music parameter, targets and methods

In the previous paragraphs, we have encountered some musical elements and theoretical topics, across different historical moments and cultural areas, which put special perspective on the main question of our enquiry: How can space be considered an independent parameter? The ensemble of musical examples also corresponded to a series of critical statements concerning space as a musical dimension. In spite of the extreme diversity of such examples, we have seen that a common attitude arises: That of integrating spatiality as much as possible in the compositional context. Although for the mentioned composers, aesthetic and artistic tasks diverge largely, it seems that an overall position of approaching a symbiosis between traditional musical parameters and spatiality is central.

The featured musical examples create a subtile path that, starting from Edgard Varèse, continuing with Alvin Lucier and going through Karlheinz Stockhausen and Emmanuel Nunes, showed different approaches to the phenomenon space and several attempts to include it metaphorically or practically as part of the compositional method.

Additionally, taken as an instance of a possible methodological orientation, some reflections on Dodecaphony and Spectralism have been introduced so as to elucidate a possible path in bringing space toward a status of higher interdependence with pitch, rhythm and timbre. Theoretical reflections have shown how the question of musical parameters (connected with perception and aesthetic valencies) has been urgent from the beginning of Twentieth Century up to today. This need can be delineated with a growing demand for precision in the description of musical elements, since they were not seen anymore in their general and isolated form, but increasingly as interconnected and further explored in an analytical way. Described in their main outlines and according to those aspects that could most directly apply to our inquiry, all examples (musical and theoretical) take us to the point where space also needs to be, as far as possible, measured and explored analytically, that is to say parametrised.

But which method of treating space among those we have seen until now would be the most suitable for this aim? Surely the attitude of dealing with the *Tonraum* can easily allow a composer to shape frequencies and chord structures, but it is still a metaphor that does not (and cannot by definition) enter any aspect of the physical nature of space. On the other hand, Lucier's position represented by *I Am Sitting In A Room* faces the physical properties of a certain actual space (in which performances take place) but – not only because of an aesthetic attitude – does not establish any link with the *écriture*. Again, Nunes' music, which seems to fulfil both a strong connection between spatiality and notation, focuses more on the

movement of sound sources than on the physical nature of space. We can clearly discern how complementary and how different vis-à-vis of space perception these three positions are. As we can see each approach illuminates different sides of spatiality as well as compositional control on the matter space. But it seems that Lucier's assertion[68] ("Every room has its own melody") and Varèse compositional attitude (pitch control according spacial models) are much closer than they would appear, or at least they are symptomatic of a similar artistic need. The next graphic (Fig. 2.7) shows the main points of interest of the featured musical examples and their eventual connections schematically:
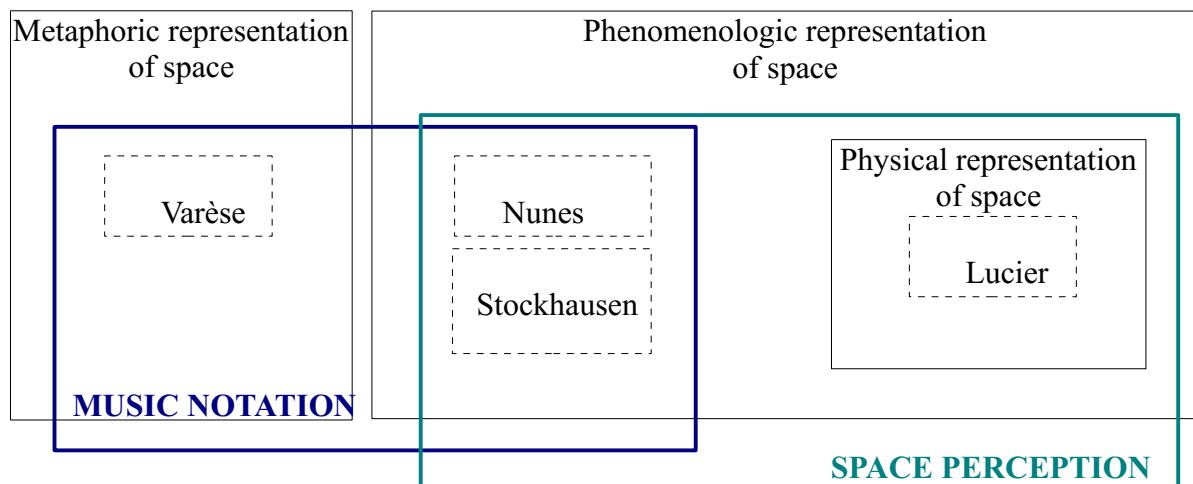
Fig. 2.7. Schematic representation of the four compositional and aesthetic approaches of the previous musical examples (space as a metaphor for pitch organization, space as an element to perceive during the performance experience, space as revealed physical phenomenon).

Suggesting a deeper compositional approach to the physical nature of space, we directly refer to a possible working method requiring some notions of acoustics. Indeed, as difficult as it can be, a stricter relationship between the two dimensions – physics and musical notation – can be considered as a valid answer to the aforesaid question.

It will be essential to describe the principal targets that this exploration of space as a musical parameter will try to achieve. For this reason it will be indispensable to emphasise the fact that at this stage, before any attempt to formulate a definitive solution to the artistic problem of rendering space in music composition (since every compositional process or technique – before its inner coherence – has to be necessarily confronted with the way the result is perceived), this research will attempt to complete and integrate the musical reflection initiated by Spectralism, also covering the aspect of space as a musical element and its analysis as a way to parametrise it (as it was in the case of timbre).

Moreover, once the frame and the context in which such analysis will move and operate is established, it will provide a possible compositional model (or method), offering a similar

---

68. G. Gronemeyer and R. Oehlschlägel, "*Alvin Lucier Reflections, Interviews, Scores, Writings,*" 100.

approach to that seen in Stockhausen's *Kontakte* (possibility of controlling and shaping other parameters from space-related data).

Finally, as a practical result of an existing artistic need, an apposite software (a compositional tool) allowing a deeper introspection into some facets[69] of the physical nature of space will be presented and illustrated. Over the course of this inquiry we will also examine, on the basis of some practical results, in which way such an approach can be validated by acoustic perception – i.e. if the musical material (output of the analysis) will present some characteristics and peculiarities that could be a direct expression of the method.

2.5 Toward a possible working method

In accordance with these premises, it is essential to focus on a possible working method that could assure within the compositional process, the best possible way to approach space as this research intends to do.

Paraphrasing a well-known statement by Gérard Grisey, we can affirm that if the focus of our inquiry is a tridimensional space (and some relationships between space and sound), it is in this itself that answers shall be found, without necessarily looking at or for any kind of space-metaphor.

Therefore, it is useful to look at some experiences of Spectral Music, because some similarities are evident. In this French musical aesthetic, a strong scientific theory (acoustics) was a foundation for the research and its artistic application in music composition, an attitude essential to our query.

2.5.1 Working methods of spectral music

Many analogies can be drawn between the (musical) situation at the time of the first spectral experiences and the present day: During the Seventies the main task was not only to find an alternative to both the structural labyrinths of serial music and sound manipulations of *Musique Concrète*. At that time, there were many other composers with original points of view, placed aesthetically at various distances from the one or other pole[70].

---

69. This software will not focus on the whole ensemble of measurable dimensions of space but on those that have been taken into account for a specific artistic project. Like timbre, space is a multi-dimensional parameter and for this reason a reduction is necessary in order to form a working model. This has been the working environment used for the project (*Ius Lucis*) developed at I.R.C.A.M. In 2006/2007 in which the aim was to generate a musical structure from a room-mode-analysis.

70. *"Si le développement de la musique spectrale ne se fait qu'à partir des années 70, ce n'est donc pas parce qu'il fallait attendre que l'épuisement d'autres types de musique laisse le champ libre. La voie intermédiaire entre écriture combinatoire et manipulation de sonorités était vaste, et d'ailleurs, plusieurs compositeurs, tels Ligeti, Penderecki, ou Xenakis n'avaient pas hésité à s'y engouffrer, en proposant des équilibres variés entre ces deux extrêmes".* Laurent Fichet, *Les Théories Scientifiques de la Musique aux XIXe et XXe Siècles* (Paris: Librairie Philosophique J. Vrin, 1996), 314-315.

If an alternative way was found in the systematic research of timbre, this was not without a solid theoretical background. It was thanks to the study of acoustics that musicians started to try out new methods and consequently, new musical solutions, an explanation that also explains the relatively late appearance of that aesthetic[71].

Together with a theoretical knowledge of acoustics, the rise of Spectralism would not have been possible without a powerful tool, enabling those musicians to work with a graphic representation of analysis data, describing the sound in a way that the repertoire (as far as pitches and chords in traditional music) could be clearly visible and readily used. It is thanks to the sonogram[72] (graphic visualisation of a sound spectrum), and to software that represents sound in time, that musicians made the essential step toward an effective working method.

Visibility is the *sine qua non* for a composition method to treat sound as tridimensional object. Sound is not a stable identity, and by freezing it at a certain moment of its development, it is possible to look inside it and to observe its deepest structure[73]. At the same time, this observation (which we can call *temps différée*) again creates motion, it reveals sound nuances and dynamic (hidden) inflections by expanding a time-frame into a longer duration.

Consequently, this operational attitude tends to consider itself (once more metaphorically) as a space in which it would have been possible to move and dislocate perspectives.

Nevertheless, like any other complex matter, an acoustic entity like sound (and its timbre) cannot really be understood without discerning its components, i.e. making a simplification of its physical contents with a method of filtering (that consequently reduces the vast amount of data), an operation that, as we will later discover (see 3.2.2), is a crucial aspect of this research. It is important to remark that such analysis[74], and the way it is used by spectral composers, may also require a simplification of working process. The resulting output on a data table (featuring frequency, time, intensity) takes into account not only the first partials of a spectrum, those being mostly perceptible by human hear, but also a whole complex of very high partials that constitute the noise component of sounds (white noise). Such a procedure implies the creation of a model with starting materials, and opens another approach for creating melody lines (separation of partials) and harmonies, which obviously need to be reformatted within a narrower interval range (the one of the orchestra for example). This

---

71. *"Ce qui explique le démarrage tardif de la musique spectrale est aussi ce qui fait la spécificité: c'est la découverte par une génération de musiciens des arcanes de l'acoustique moderne".* Fichet, 1996, 315.

72. *"L'acoustique existe depuis longtemps, [...] mais elle n'avait jamais paru aussi claire aux musiciens que depuis la découverte d'appareils comme le* **sonagramme** *qui permet d'avoir une représentation édifiante du phénomène sonore, et surtout depuis le développement de l'informatique qui, en affichant sur des écrans l'évolution dans le temps de tous les paramètres du son, semblait en dévoiler tous les secrets".* Ibid.

73. *"Les nouveaux moyens d'analyse auxquels je faisais allusion nous permettent, dans le même temps, de porter un regard différent sur les sons, de voyager à l'intérieur du son, et d'observer sa structure interne. On découvre ainsi, immédiatement, qu'un son n'est pas une entité stable et toujours identique à elle-même"* [...] Tristan Murail, "La révolution des sons complexes," in *Modèles & Artifices*, ed. Pierre Michel (Strasbourg : Presses Université de Strasbourg, 2004), 12.

74. [...] *"un timbre peut s'analyser comme une addition de composantes primaires, fréquences pures, parfois bandes de bruit blanc, une harmonie comme une addition de timbres, c'est-à-dire une addition d'additions de composantes primaires"* [...] Tristan Murail, "Spectres et Lutins," in : *Une pensée musicale (*Paris-Montreaux : Edition des archives contemporaines, 1984), 169, quoted in Laurent Fichet, *Les Théories Scientifiques de la Musique aux XIXe et XXe Siècles.* (Paris: Librairie Philosophique J. Vrin, 1996), 317.

approach creates a sort of continuity between timbre domain and pitch domain. In a similar manner to that we observed in *Kontakte*, this represents a methodological obliquity between musical parameters. From the previous examples we can infer that need for new artistic perspectives supported by strong and founded theoretical (and scientific) positions, together with powerful analysis tools, accompanies always a working process based on a modelling of physical structure (in this example - sound). Concerning this inquiry, more and more conspicuous analogies between sound spectra and certain aspects of a tridimensional space can be revealed, but surprisingly enough (although it was often mentioned and taken as reference in several examples and also used as title: *Les Espaces Acoustiques*[75]), spectral composers did not really focus on space as an object but rather considered it more or less a metaphor. When we read that sound was conceived as an organic element, made by different forces working together[76], we could conclude that this may be the moment when composers move from science (the study of acoustics) to an artistic attitude, which shapes an aesthetic.

It could be exactly this direction, considering a tridimensional object as starting material for analysis, that could be taken as an example of organic research. In particular, looking at those possibilities and acoustic qualities that space possesses, could offer interesting paths for research and possible connections with music composition.

2.5.2 Physical aspects of space related to sound

Thinking about the strict relationships between acoustics and music, we naturally shall express the problem by establishing a link between space (tridimensional space) and sound. If this approach explores this duality from a solely acoustic perspective, it takes us away from providing a practical and artistically satisfying answer to the problem. In fact, a strict acoustic analysis of the phenomenological experience of sound and space would bring the discourse back to Lucier's example (see 2.2.4), and not completely fulfil the aims of this study. The right direction will not be offered merely by architectural acoustics since these focus primarily on the auditive experience[77]. An effective solution can be found by considering a

---

75. A series of works by Gérard Grisey consisting of six pieces for different instrumentations from the solo to the large orchestra with soloists (*Prologue - pour alto seul, Périodes - pour sept musiciens, Partiels - pour seize ou dix-huit musiciens, Modulations - pour trente-trois musiciens, Transitoires - pour grand orchestre, Epilogue - pour quatre cors soli et grand orchestre*) started in 1976 and completed in 1985. Among the program notes, Grisey writes: *"rechercher une écriture synthétique dans laquelle les différents paramètres participent à l'élaboration d'un son unique. Exemple : l'agencement des hauteurs non tempérées crée de nouveaux timbres, de cet agencement naissent des durées, etc. La synthèse vise, d'une part, l'élaboration du son (matériau), d'autre part, les différentes relations existant entre mes sons (formes)".* Gérard Grisey, Note de programme Les Espace Acoustiques, http://brahms.ircam.fr/works/work/8954/#program.

76. *"Plutôt que de décrire un son à l'aide de «paramètres» (timbre, hauteur, intensité, durée), il est plus réaliste, plus conforme à la réalité physique et à celle de la perception, de la considérer comme un champ de forces, chaque force ayant son évolution propre".* Murail, "La révolution des sons complexes," 12.

77. We see that in architectural acoustics, among the studied parameters we find reverberation, noise reduction, sound absorption, etc., and those related to the quality of sound, which are called for example intimacy and presence, liveness and envelopment, warmth, loudness, clarity and definition, brilliance etc. Similar features are directed at the listener (or audition moment) in order to best allow music, speech, etc. to be perceived. Christopher J. Jaffe, *The Acoustics of Performance Halls* (New York: W.W. Norton & Company, 2010), 29-36.

tridimensional space as analysable according to its own acoustic properties, as long as these are compatible with a music-oriented analysis. We are now approaching the root of the problem: Looking at the possibility of comparing space to a sort of musical object (what sound ultimately represented for spectral composers), and thus having the chance to analyse it in a way that could allow some kind of working processes similar to those used to musically develop the output given by spectral analysis. The main difference between these two elements, sound and space is probably the fact that the first is immanently musical whereas the second needs to be excited in order to show its musical nature: A room (space) needs a sound to musically exist. For this reason, the use of space in a phenomenological way, as a place in which experiences (sounds) happen and are perceived, prevails above all. Lucier's work *I Am Sitting In A Room*, and Nunes' and Stockhausen's spatial musical works all propose a phenomenological view of this musical dimension. The main differences between them are obviously the degree of interconnection between musical materials and room/space. However, for the above-mentioned composers, space still belongs to the domain of music performance so that, in spite of the precision in linking it to the musical text, it is only fully (musically) expressed during the concert situation. Even with Nunes' extremely precise work on spatialisation, space-related musical elements are constructed in a way that we can call inductive[78], rather than (as is the case for spectral analysis of sound) the result of a deductive analysis. As with the new vision that composers had of sound and its physical qualities, a deeper introspection into space as a (discrete) musical parameter cannot occur without considering it – in spite of its ephemeral acoustic nature – as musical object.

To this end it is of utmost importance to view those acoustic phenomena that would help a similar compositional approach. In particular, we are going to focus on some notions concerning sound fields and later, the resonant modes of a room, which will play a foremost role in this enquiry.

2.5.3 Resonant room modes

A primary acoustic phenomenon that this research will point out in order to find a method to integrate space as a musical parameter (i.e. fully integrated not only in the performance requirements but able to shape music actively as other parameters do – such pitch or timbre), are the so-called room modes. When a sound occurs in a certain space, room modes manifest

---

78. As a result of the combination of various musical information (speed, envelopes, etc):
Afin de générer un déplacement sur des haut-parleurs, il faut avoir un contrôle sur les paramètres suivants:
- le parcours: il est donné par la liste des haut-parleurs qui le composent (parcours_hp.t 0 6 3 4 5 2 1 0   1 2 5 4 3 6);
- les vitesses et les rythmes: ils proviennent du générateur rhythmique qui envoie directement les termes;
- les enveloppes: elles contiennent le trajet d'amplitude de chaque signal affecté à un haut-parleur et sont d'une importance capitale, puisqu'elles déterminent la manière dont les points d'un parcours se lient dynamiquement; elles ont donc une action sur la perception des rythmes et des trajets dans l'espace. Éric Daubresse, "Le projet informatique. De l'élaboration à la collaboration," in *Compositeurs d'aujourd'hui – Emmanuel Nunes*, ed. Peter Szendy (Paris: L'Harmattan, Ircam / Centre Georges Pompidou, 1998), 142.

themselves as standing waves,[79] i.e. sound waves with a stationary oscillation pattern in space due to the constructive interference of incident and reflected waves at the walls of a room[80]. Room modes appear at multiple frequencies above a fundamental frequency corresponding to the longest dimension of the related room. These collections of room modes get more and more dense at higher frequencies, the resulting inhomogeneities of the spatial sound energy distribution are audible mainly at low frequencies below the so-called Schroeder frequency[81]. For each modal frequency and consequently each waveform, it is possible to observe points where waveforms combine producing a maximum amplitude called an antinode, and other spots where nodes (partial or complete cancellations) occur[82]. Such modes[83] can be axial room modes (parallel to two opposite walls), tangential room modes (occurring diagonally) or oblique modes (occurring along two opposite corners of the room), as shown in Fig. 2.8.
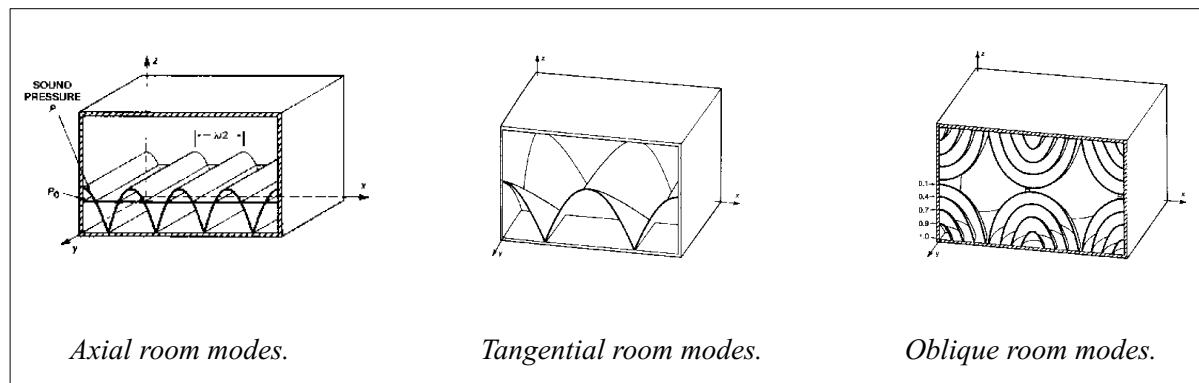
Axial room modes.　　　　*Tangential room modes.*　　　　*Oblique room modes.*

Fig. 2.8. Graphical examples of the three kinds of room modes in a simple shaped room (courtesy of M[c] Squared System Design Group, Inc, http://www.mcsquared.com/modecalc.htm).

---

79. A wave remaining in a constant position. By observing water-waves for example:
In the case of the direct and reflected waves we have necessary two series of waves. We see that the reflected waves cross the direct waves without either set losing its identity. We may also notice that at some points the water is always in maximum motion and at some points it is almost at rest. This pattern, which is difficult to observe because the waves are irregular, is steady, and the water surface is said to be in a state of stationary vibration. The lines joining points of minimum motion are called nodal lines, and those joining points at which motion is a maximum are antinodal lines. Alexander Wood, *The Physics of Music,* rev. J.M. Bowsher (London: Chapman and Hall, 1975), 9.

80. *Waves can travel in the room backwards and forward between any two opposing walls. They can travel also around the room involving the walls at various angles of incidence. If these angles are chosen properly, the waves will return on themselves and set up stationary or standing waves. Each standing wave is a normal mode of vibration for the enclosure.* Leo L. Beranek, *Acoustics (*New York: McGraw-Hill Book Company, 1954), 287.

81. The Schroeder frequency (fs) is related to the room volume (V) and its reverberation time (T) as shown in the following equation: fs = 2000 sqrt (T/V). Manfred R. Schroeder, "The 'Schroeder frequency' revisited," in: *J. Acoust. Soc. Am.* 99/5 (1996), 3240 - 3241.

82. This phenomenon can easily be experienced by moving a microphone into a room where a sinusoidal air flow is produced (a sinus-tone). Arthur. H. Benade, *Fundamentals of Musical Acoustics* (New York: Oxford University Press, 1976), 175.

83. Jacques Jouhaneau, *Acoustique des salles et sonorisation (*Paris: Lavoisier, 2003), 16.

Stationary waves are, in room acoustics, a phenomenon to avoid[84] because they provoke an unequal energy (in fact concert halls are built according irregular geometrical forms), but this is exactly the point where this research, which is musically oriented, differs from a purely acoustical study on room property. The main point here is not the most efficient architecture. Rather, it will be shown in which way the study of room modes can be helpful in musical composition. After having considered these observations and mentioned some notions about their physical nature, let us again focus on the fact that each room mode corresponds to a fundamental frequency, evidence suggesting a strict analogy with sound spectra as we can infer from the following table (Fig. 2.9).
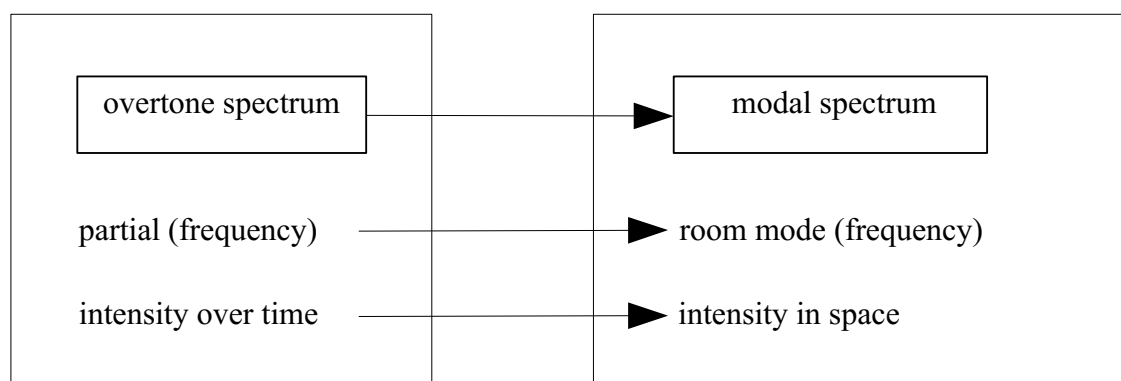
Fig. 2.9. Schematic representation of analogies between a sound spectrum (analysis) and a room-mode analysis. These two models present strong analogies: Each partial frequency of the sound spectrum can be compared to a room mode (each one of them is associated with a frequency). Their loudnesses (intensity) are a function of time for the spectrum (spectral envelope), and a function of space (intended as position in the space) for the room-mode model.

Consequently, as a series of frequencies called partials (corresponding to a fundamental frequency) build a sound spectrum, a collection of frequencies that are the room modes will correspond to each room. With respect to the intensity[85] (loudness) of each partial/mode, the difference between those two models consists of the fact that for the first (spectrum) intensity is a function of time, whereas for the second (room) it is a function of position in space. This difference will be crucial in the definition of our working method, and will also prove an essential point in establishing a stricter relation between space (as discrete parameter) and those phenomenological elements of music composition that we can collectively call spatiality.

---

84. Ibid., 20.
85. The loudness of each mode changes gradually from the point of minimum (node) towards the point of maximum (antinode) and vice-versa.

2.5.4 Room models for working purposes

Surely, the highly advanced technological development of spectrograms and similar tools has permitted a high degree of precision in the visualisation and description of sound spectra. Many technical developments have been made since the times when the first composers were working with very simple modelling of instrumental sound spectra, or even with an invented[86] series of partials as we find in Grisey's work *Dérives* (1973–1974, pour petit ensemble et grand orchestre), as shown in the following picture[87].

Fig. 2.10. Imaginary sound spectrum used as starting musical material for Grisey's work *Dérives*.

As concerns our inquiry and the hypothesis of using space as a sort of sound object, particularly as far as this pertains to a possible methodological application in music composition, the actual state of the art is more reminiscent of the circumstances in which spectral composers were working at their beginnings. Not only new tools, but also a strategy, if not an aesthetic direction, must be examined for this purpose. Because it will be the subject of the next chapter to describe some possible tools designed for this aim, and of the fourth chapter to describe existing (and possible) musical applications, we shall now see what the boundaries of our working model will be.

The first question is: What form can our room model have? Unlike sound analysis that is possible for any kind of sound, room mode analysis happens to be limited at the present moment to certain forms. While for rectangular rooms the frequency distribution of room modes can be calculated analytically, the calculation for rooms with irregular shape requires

---

86. *[…] le modèle instrumental peut aussi devenir un simple point de départ pour une dérive imaginaire vers des spectres totalement artificiels" […]* Gérard Grisey, "Structuration des timbres dans la musique instrumentale," in *Le timbre, métaphore pour la composition*, ed. Jean-Baptiste Barrière (Paris : Ircam - Bourgois, 1991), 356.

87. Fichet, 1996, page 323.

computationally expensive numerical solutions, which are, at the moment, limited to very low frequencies. The second question faces a more aesthetic (or musical) issue and refers to the consideration that a room mode analysis would not deal with its temporal development, because it would refer to the analysis of an experiment.

This causes a drastic change in the way we are going to think from now on about the temporal relation of time when speculating about space. As we know, sounds are developing in time, and even a short portion of sound (a spectrogram analysis) tells us that partials do not come at the same time but according to what is called an *enveloppe spectrale*[88], i.e. the succession of loudnesses of partials that is responsible – among other factors – for the peculiar timbre of an instrument. This aspect[89] suggested considerable methodological means to spectral composers in founding original criteria for shaping a time *Gestalt*, in the definition of a whole musical form and on the rhythmical basis, as is the case in Grisey's work *Dérives.*

This noteworthy aspect once more tends to underline composers' attitude to link, on a global level, different musical data gathered on the basis of an analysis, melting coherently the aforementioned three parameters of pitch/harmony – rhythm/time – timbre/dynamic but using them as a reference to explore artistically different degrees of change and variation[90].

Similarly, when focusing on vibration modes, it is possible to observe that dynamic fluctuations (change of intensity) occur, quite interestingly for our purposes, as a function of space (that is, localisation inside a three-dimensional space, see 3.1.2) an aspect that allows us to establish a direct methodological connection between space (localisation) and intensity (dynamic).

---

88. *Certains compositeurs n'hésitent pas à se baser sur l'analyse de l'enveloppe d'un son (c'est-à-dire l'évolution de son intensité entre son apparition et son extinction) pour déterminer des durées ou des rythmes en multipliant le résultat de ces analyses par un facteur plus ou moins important.* Laurent Fichet, *Les Théories Scientifiques de la Musique aux XIXe et XXe Siècles* (Paris: Librairie Philosophique J. Vrin, 1996), 323–324.
This aspect, essential in the musical transposition from analysis data, will also be discussed later in chapter four.
89. *[…] "le principe d'une arrivée progressive des partiels, les plus élevés arrivant en général avec un certain décalage par rapport au son fondamental. Les indications de nuances s'inspirent aussi en grand partie du développement dans le temps de l'intensité des partiels."* Ibid., 322.
90. *"Le jeu sur la simultanéité ou le décalage des attaques des différents composants d'un son, le rapprochement ou l'éloignement par rapport à l'exemple harmonique, tout cela contribue à rendre plus floue la distinction entre harmonie et timbre."* Ibid., 323.

CHAPTER 3

TOOLS FOR MUSIC COMPOSITION

3.1 Working with resonant modes, a compositional concept

In the preceding chapters we briefly summarized and categorized some of the spectral techniques used in music composition. In this chapter, we are going to compare the spectral music compositional approach with a methodological proposition facing the need to consequently link space (seen as an autonomous parameter – i.e. measurable and able to form music) with traditional compositional writing formats, which we can call *écriture* (and therefore the entire range of parameters such as pitch/harmony, rhythm/time, timbre/dynamic).

In fact, this research will follow a kind of parallelism between the two methods and approaches (spectral music – spectrum and resonance-mode analysis – room modes), as they will demonstrate similar characteristics.

3.1.1 Design of a possible methodological approach

Once the common operational points between a sound spectrum and a collection of resonant room modes are explained, all possible ways of extrapolating musical information will be demonstrated in a manner strictly connected to spectral composition techniques. An overview of such similarities can be inferred from the following scheme (Fig. 3.1).
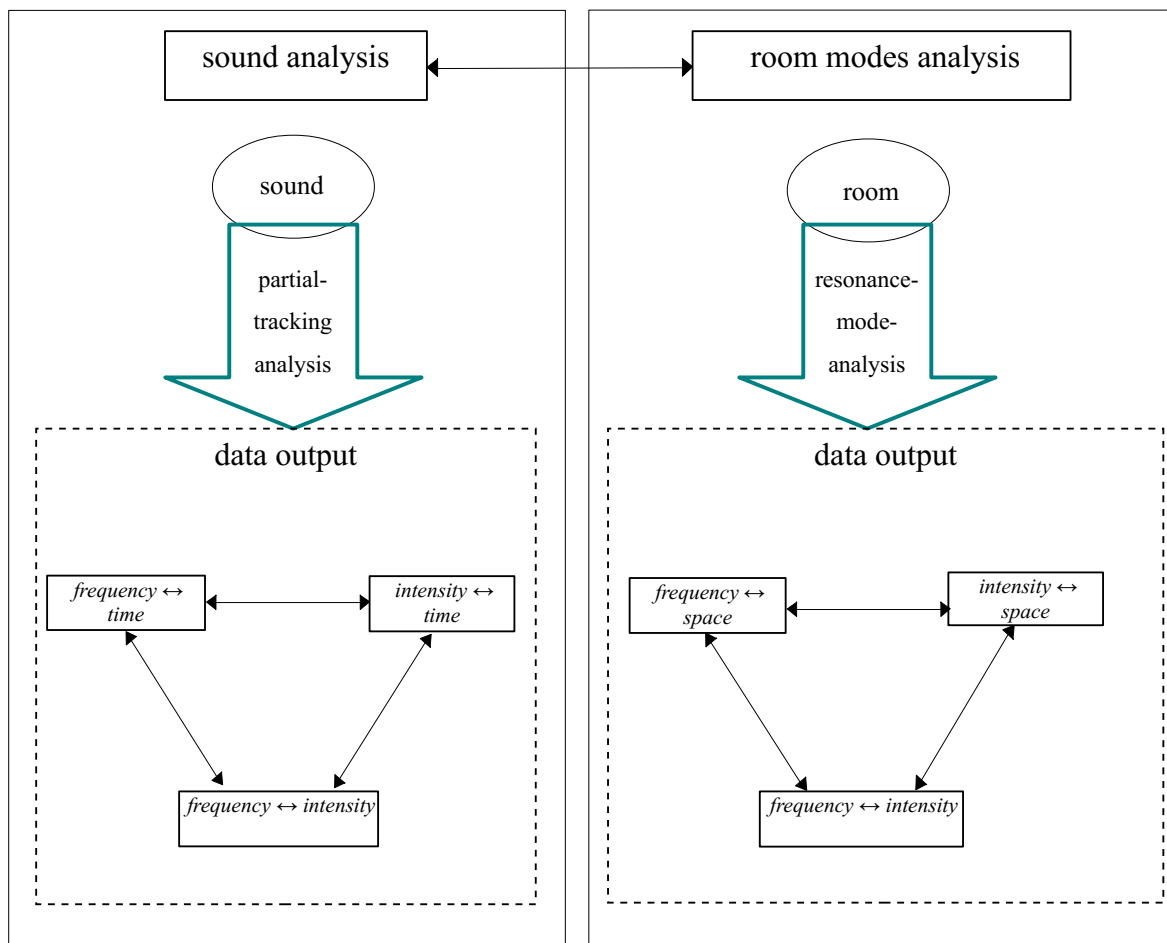
Fig. 3.1. Scheme showing certain similarities between a sound-spectrum analysis and a room-mode analysis. This is to underline the fact that, by treating a tridimensional space as a musical object, it is possible to proceed using a parallel working method, similar to that used by spectral composers.

3.1.2 Data extrapolated from room-mode-analysis

The previous graphic shows similarities between two compositional methods, treating each in accordance with the specific boundaries of its matter (sound for the first, space for the second). As observed in 2.5.3 (Fig. 2.9) in the room-mode analysis, it is possible to create a mapping between frequency (corresponding to a room mode) and intensity (the amplitude of the same room mode at a certain point of space). With the spectral method, the mapping was between frequency (of a spectrum) and time (time-frame inside a sound used for analysis). Following this analogy, the relationships between intensity (of a frequency) and time (the amplitude development of that frequency in time) broadly used by spectral composers to achieve time (and rhythm) information for musical composition, will provide a mapping in the room-mode analysis that consists of a list of loudnesses corresponding to a list of points in space (a space-frame between node – the minimum point of a room mode, and antinode – its maximum point of intensity). Moreover, by considering the whole complex of room modes (and therefore the whole cluster of frequencies and their amplitudes) at each point in the room, we will approach something similar to the spectral envelopes (intensity over frequency) of a sound at different times.
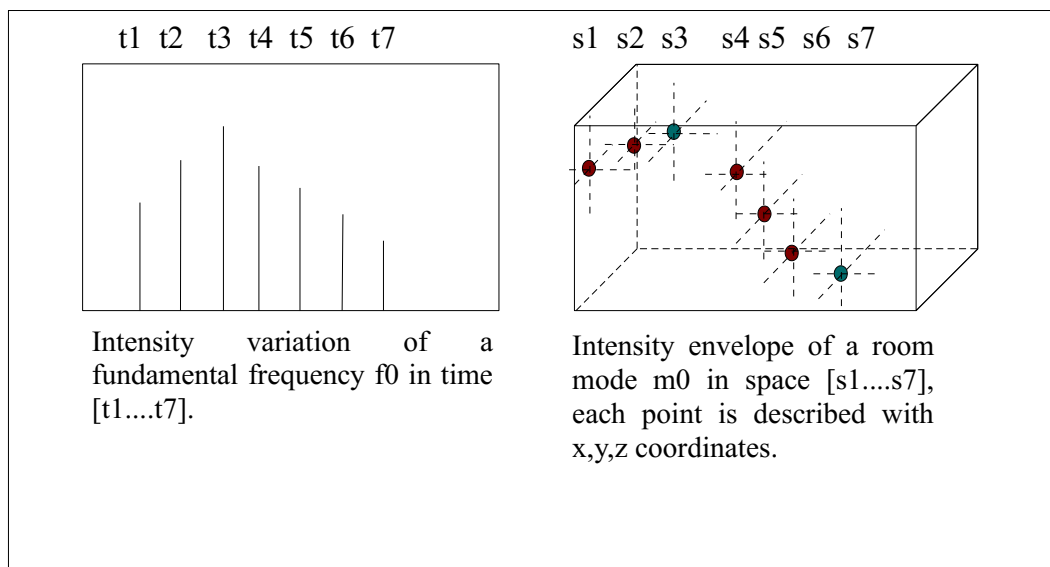
Fig. 3.2. Analogies between a single frequency envelope (over time) and the spatial distribution of a single room-mode. For the first, intensity changes as a function of time, for the second the variation of intensity (loudness) is a function of space (position).

A broad series of derivate data (combining time/space, frequency and intensity information) can be gathered from both methods. The most significant of which is a mapping between frequency and intensity, i.e. the loudest and the softest frequency in a spectrum at different times (*t0, t1, t2*) versus the loudest and the softest frequency (corresponding to a room mode) in a room at a certain point in space (at different points *s0, s1, s2*). This facet will be particularly important when deducing pitch data from the room-mode analysis.
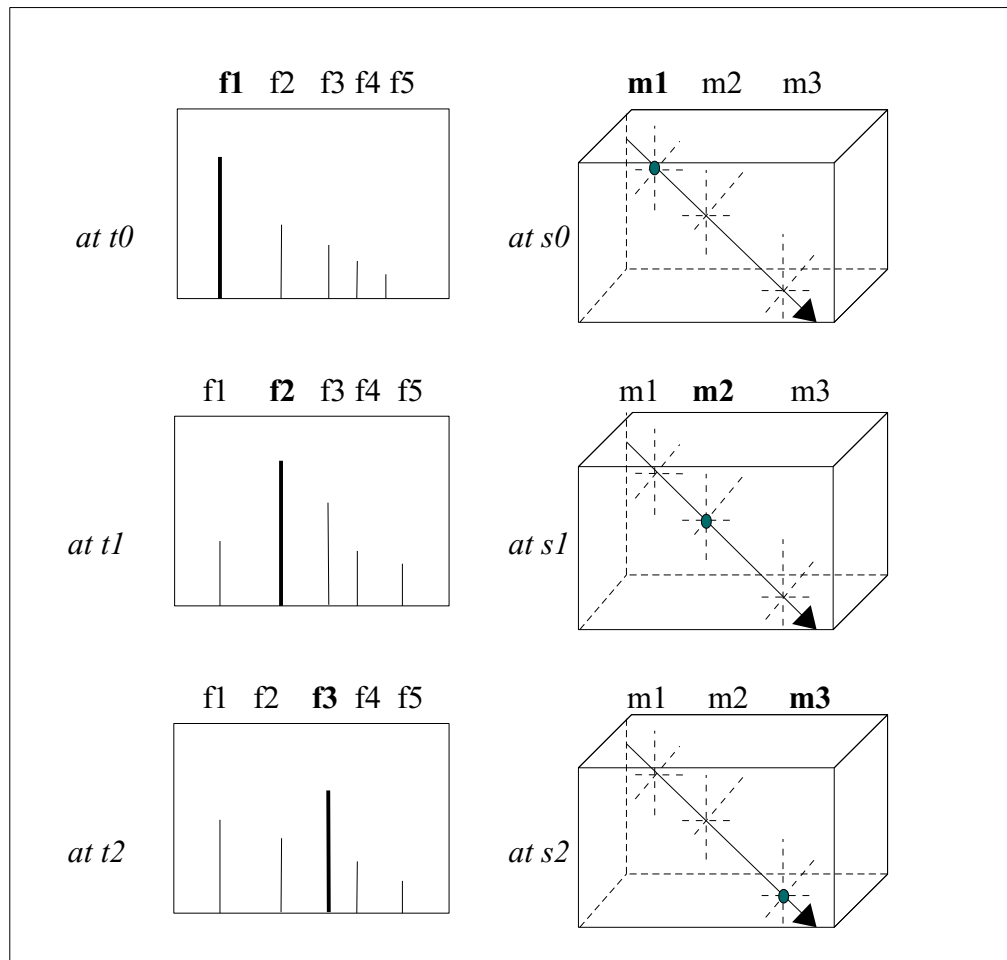
Fig. 3.3. Schematic representation of three sound spectra (at three different times), compared with three room-mode analyses at three different positions in space. Further analogies between partial frequencies and room-modes (corresponding to frequencies) show the similar methodological approaches.

An observation can be also made about the similarity between linear time (the natural development of a sound in time) and linear trajectory in space (points of analysis). The sampling points (for both spectral and space analysis) do not need to be chosen absolutely on a linear basis (discontinuous time/space points are also not only justifiable, but also possible in a composition process). Moreover, we notice that in the room analysis model a space trajectory (series of analysis points) is additionally described by a third dimension, which is time; a trajectory in space indeed is a sequence (i.e. a movement) that happens in time.

3.1.3 Relationships between space, spatialisation, and *écriture*

After the general overview (second chapter) of some of the most prominent aesthetic compositional approaches, we can affirm that if on one side (spectral composition technique) we see a high degree of introspection into the sound (considered as compositional object) that allows a wide parametrisation of almost all of its components, on the other side (Nunes' approach to spatiality for instance) we notice a broad control of spatialisation and its correlated parameters. It would be interesting at this point to see if any possible integration between these two approaches to musical composition might be possible. Meaning, how might one create a working method that would be able to link physical data (sound/space) to phenomenological elements (like spatialisation, moving sounds in space). One suggestion, expressed here graphically to better underline the sequence of the different operational steps, is offered in Fig. 3.4.
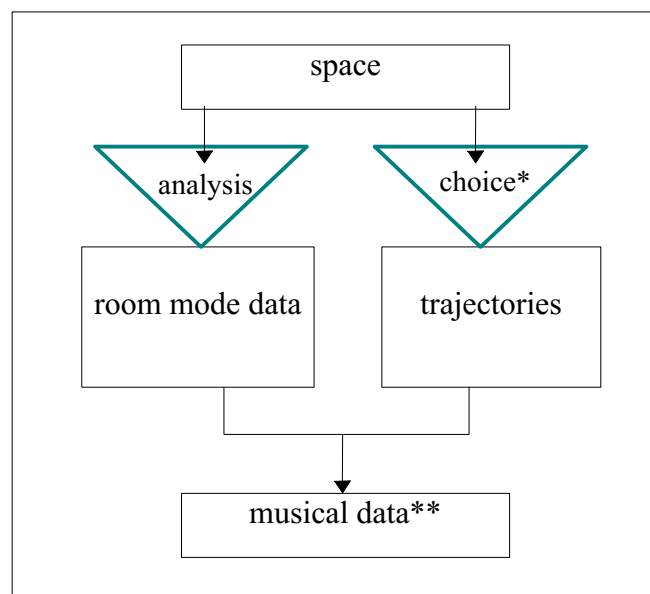
* decisions made in the compositional process
** output can be a list of frequencies, dynamics, rhythms
   or time relations

Fig. 3.4. In room-mode analysis, by starting from a tridimensional space as compositional material, two facets interact: the objective collection of modal data used for the analysis, and arbitrarily chosen trajectories, along which such analysis will be triggered.

From the previous graph (Fig. 3.4) we can infer that:

- Space (an arbitrary room, an existing space or a virtual model) is taken as a starting point, or starting object that triggers the whole compositional process (in the same way that a sound/spectrum is for spectral composers);
- Two parallel paths are required, one analytical (analysis of room modes), the other as a result of decisions made freely – according different criteria than those suggested by the analysis – and in accordance with the needs of perceptibility (as is the case with

spatialisation);

- As the result of a free artistic decision, trajectories (later used – or not – for spatialisation purposes), in the strict case of this virtual working model, behave as filters in discerning and selecting musical material (to be used in the compositional process) from the wide amount of data given by the room-mode analysis[1].

With this method the two sides, spatialisation and physical nature of space, converge to guarantee both methodological coherence in the use of space (thanks to its parametrisation) and artistic freedom in making discretional decisions (in the compositional process).

Concerning the last step of the analysis (and working chain), the *écriture* is needed as a further tool for the transcription of such data into musical text (as described in 3.2.2). It gives an ensemble of musical material, expressed and notated with traditional music signs (featuring pitches, durations/rhythms and dynamics) as output. As we will see, such material will appear as raw material (not musically or aesthetically structured), as a continuum of musical text requiring a strong artistic approach with which to form it and put it into a musical *Gestalt*. The way this is done, depending on the user sensibility or aesthetic direction, is perfectly open, without any musical or aesthetic dogma.

3.1.4 Software overview

Often, a new tool (or musical instrument) is designed or invented as a response to a precise artistic need or even utopia[2], which for Alvin Lucier is embodied by a vision of modulating performance rooms:

> *I often dream of performance spaces specially designed for works based on the three-dimensional characteristics of sound. Paraboloids, spheroids, and other similarly shaped rooms with movable walls could be constructed to position, move, and modulate sounds. Walls, floors, and ceilings could be thought of as acoustic lenses whose focal points are determined by reflective time. It is also possible to create imaginary spaces by means of computer simulation.*

As the musical analysis and theoretical reflections from the previous chapters have shown, composers' attitudes seem to converge into a growing precision in the definition of the dimension space, as well as its most possible exact representation (notation). The tool we are presenting in this research is an informatics platform (running on Max 5[3], previously designed

---

1. Actually, a sound spatialized along a trajectory in space modulates the intensities of single room modes within the fixed mode spectrum determined by the room form.

2. Gisela Gronemeyer and Reinhard Oehlschlägel, *Alvin Lucier Reflections, Interviews, Scores, Writings* (Köln: Edition Musik Texte, 1995), 436.

3. Although other programs (based on physical models) like *Modalys* are also able to work with resonant modes and also offer 3D room simulations, there were various considerations in choosing to work with a Max 5 platform: firstly the fact that Max 5 provides a better "user-friendly" working environment because it is less focused on program codes (than *Modalys* actually is); for the peculiar artistic needs of the software and the composition itself, this room-mode analysis was intended to also work in real time (see 4.2.1, Fig. 4.77 for more

in Max/MSP) that allows the composer to move into a virtual space (tridimensional model). Up until now, because of its virtual nature and therefore its approximation with real acoustic rooms, this simulation focuses on certain aspects of room acoustics – probably the most simple to analyse like room dimensions and form – but also allows (as it is intended) a precise analysis on room modes, which as we will see will lead to a compositional working method.

Especially designed for the *Ius Lucis* project[4], started in 2006 and realized in 2007, the software consists of two main cores, one programmed[5] in Max/MSP (now in Max5), the other in Open Music (from version 6.1). The first is used for both live-electronic purposes (synthesis with room modes sinusoids – a technique that will be explained in the fourth chapter) and to gather data (in form of a text file with *.txt* file name extension) that will feed the next one programmed in Open Music[6]. The latter is used to transcribe (approximately and according certain thresholds arbitrarily placeable according to artistic and/or operational needs) this room-mode data into musical text. It is indeed important to remark that the output

explanations); finally, since Max 5 seems to be more widely in use and a more developed software for musical purposes, we were confident that this research could enjoy further development.

4. *Ius Lucis* (2006/2007) is a musical work conceived for two instrumental ensembles playing synchronously in two separate concert halls. The first performance of the work happened on June 6th, 2007 in Paris, at *Grande Salle* (*Centre Gerorges Pompidou*) and *Espace de Projection* (I.R.C.A.M.). In the program notes for the concert the work is described as follows:

Ius Lucis *is a work conceived for two instrumental ensembles playing in two different cable-connected concert halls. Each ensemble is used in different ways for a real time transformation of the other one, the degree of interaction creates in each "perspective" extremely various sound-synthesis combinations, for this aim the work needs to be performed two times, one for each ensemble/room. After the intermission, audiences (listeners are divided in two groups, one for each room) change concert hall and listen the second part that is both complementary (since many recognizable musical elements and situation are interacting and overlapping in listeners' memory) and new (a radical change in spatialization and instrumentation nature) at the same time. The form of the work is essentially created as a palindrome (mirror-like); the middle section "*des Schattens Lob*" is the centre of its symmetry, a turning-point after that ensemble 2 reiterates (with consistent changes) the music played by ensemble 1 but in opposite motion. This moment marks at the same time the beginning of a temporal and metric "de-phasing" between the two instrumental groups. Written for the peculiar concert halls of centre Georges Pompidou (Grande Salle) and Ircam (Espace de Projection), this work is deeply immersed into the idea of architectonic space. First of all the construction of ensemble 1 (stereophonic) and ensemble 2 (musicians placed around the audience) allow an "orchestrated" spatialisation. Second, sound movements realized by electronics (loudspeakers) are strictly connected with music (accents, envelopes, articulations are "translated" into spatialization combinations) and even with instrumental directivity of the clarinet (producing a timbre variation when moving); enhancements of these processes are several exchanges of sound movements between the concert halls that represent an extended form of counterpoint. Finally, the exploration of room acoustics (analysis of resonance modes), used in the composition structure, has served as a true harmonic and rhythmic "*Gestalt.*"*

5. The software was primarily programmed by Serge Lemouton, musical assistant (R.I.M.) at I.R.C.A.M. during the production of *Ius Lucis*.

6. *"Open Music is a visual programming language based on CommonLisp / CLOS. Visual programs are created by assembling and connecting icons representing functions and data structures. Most programming and operations are performed by dragging an icon from a particular place and dropping it to an other place. Built-in visual control structures (e.g. loops) are provided, that interface with Lisp ones. OM may be used as a general purpose functional/object/visual programming language. At a more specialized level, a set of provided classes and libraries make it a very convenient environment for music composition. Above the OpenMusic kernel, live the OpenMusic Projects. A project is a specialized set of classes and methods written in Lisp, accessible and visualization in the OM environment. Various classes implementing musical data / behavior are provided. They are associated with graphical editors and may be extended by the user to meet specific needs. Different representations of a musical process are handled, among which common notation, midi piano-roll, sound signal. High level in-time organization of the music material is proposed through the maquette concept. Existing CommonLisp/CLOS code can easily be reused in OM, and new code can be developed in a visual way."*
Ircam - Centre Georges Pompidou, "Open Music – Description," http://repmus.ircam.fr/openmusic/home.

from Open Music programs (there are several different patches giving different outputs as result from different data analysis) shall be considered as rough data, and therefore needed to be re-interpreted and re-worked manually (as much as desired or needed by the composer) in order to be finally transcribed into a musical score or instrumental part, as shown in the next graphic (Fig. 3.5).
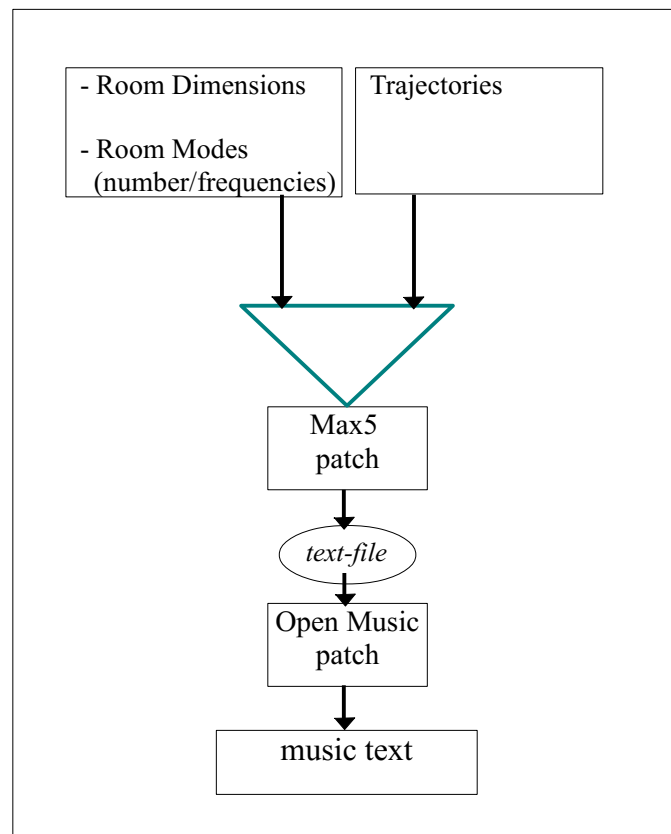
Fig. 3.5. Flow diagram of a working method with room-mode software: Starting with a tridimensional model of a virtual room, Max/MSP software extrapolates data in the form of text-file(s). These are used to feed a program (Open Music software) that transcribes them into musical text.

3.2 Compositional work with software platforms

Once the composition method is designed, the next step would be to describe how musical ideas and compositional needs meet the programming work on the two main software platforms, Max/MSP and OpenMusic, which should be considered as work-in-progress platforms. The original Max/MSP software used for the composition of *Ius Lucis*, has in fact not only been upgraded, but also developed for further musical applications.

3.2.1 Room-mode analysis as first step to compositional work

The main patch, originally written in Max/MSP has been used to define a working environment based initially on two virtual rooms (corresponding in dimensions to the two concert halls in which the piece was to be performed) that have been analysed and explored according to their room-mode contents. Since this analysis was intended to be restricted (for musical needs) to a defined number of room modes (up to 64) and, for the same reason, to those modes being the closest possible to a certain chord structure determined in advance[7], the program was structured in order to respond to this need.

In order to represent modes graphically, an already existing applet[8] has been implemented inside the *modebox* object, which is the most important part of the software. This additional window is automatically generated each time the object is created or re-instanced and, by opening the patch with *modebox,* a window with the applet opens automatically on the left side of the screen. It provides, in addition to a graphic interface for *modebox*, an interface that can be used for test purposes (on an intuitive basis): It displays the shape of the virtual room and below it eight squares in which resonance modes can be activated by clicking on each small square (which turn green when activated).
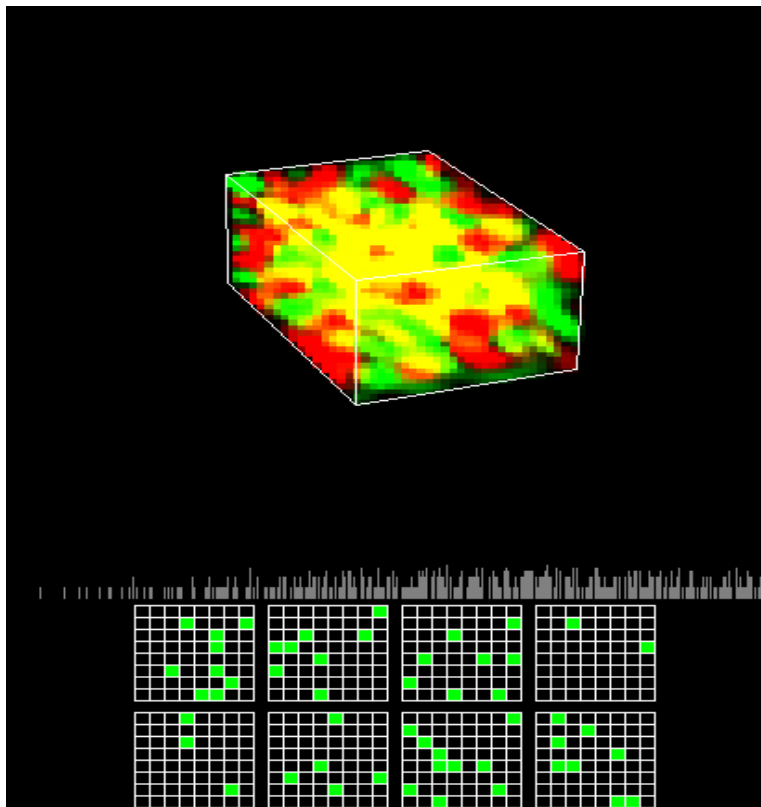
Fig. 3.6. Detail of the applet-window implemented in the Max/MSP software for room-mode analysis: visualization of a virtual room (up), visualization of a frequency range and at the bottom a schematic representation of selected room-modes.

A spectrum appears between the virtual room and active modes when the *Show Spectrum* option on the right is activated (without any information of frequencies). By clicking on one

---

7. In the peculiar case of *Ius Lucis,* room modes have been selected in advance in order to control the harmonic contents.
8. The tridimensional applet was taken from: http://www.falstad.com/modebox.

of the small vertical lines (representing partial frequencies of the spectrum), a collection of modes (small squares) corresponding to that frequency become yellow (border lines). These may be activated manually, if so desired. The graphic representation of the room modes is also displayed in the form of waves inside the virtual room. These waves are represented by red/green alternations of colours, indicating the opposite polarity. In the example below (Fig. 3.7), a sole mode (7, 0, 3) is selected and seen from above.
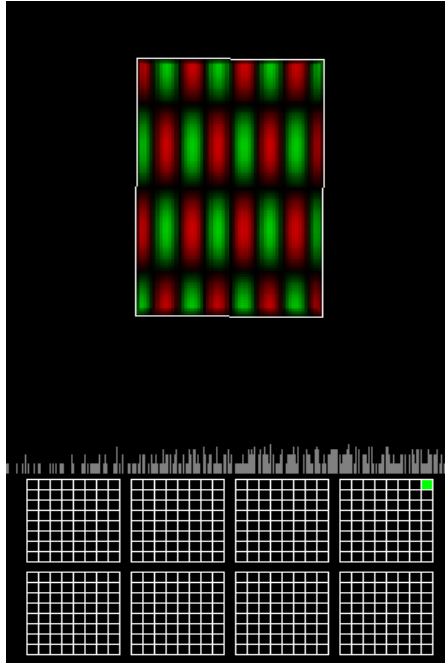
Fig. 3.7. Visualization of one single room mode (described as 7,0,3) in the applet-window: By rotating (with the mouse) the virtual room and changing the perspective (seen from above), it is possible to see a representation of the static wave and its polarity illustrated as red areas (acoustic pressure positive) and green areas (acoustic pressure negative).

Further visualisation options appear on the left side of the same window:
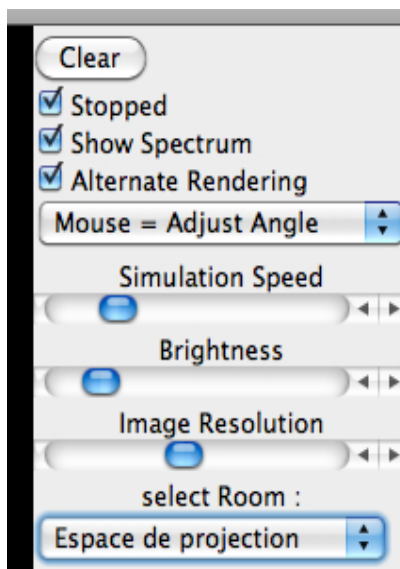
Fig. 3.8. Control panel (detail) in the applet-window with some visualization options (Simulation Speed, Brightness, Image Resolution).

These options can be used to improve graphic quality (e.g.: increasing *Image Resolution*, *Brightness*) or to save processor power (e.g.: activating *Alternate Rendering*, decreasing *Simulation Speed*, or by selecting the *Stopped* option that stops the simulation). As we have

already said, the core of this tool is represented by the Max-object called *modebox*, initially written in the C programming language, that has been used in the Java version called *mxj modebox2*. It is in the java version that the software has been further developed:
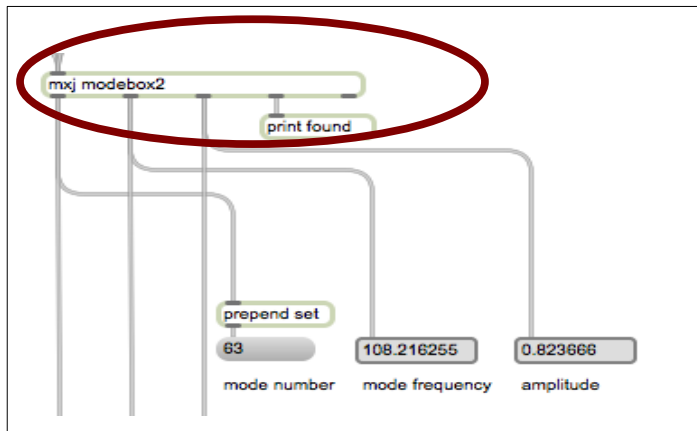
Fig. 3.9. Detail of the Max/MSP patch for room-mode analysis: Max-object *modebox.*

The first three outlets refer respectively to the number of mode, to the mode frequency (in Hertz) and to its amplitude (in a scale from -1 to 1). They output these values in lists of three float numbers. This object understands the following messages:

RoomSize (followed by three float numbers representing a measurement in meters) describes the dimensions (x,y,z) of a virtual room used for room-mode analysis;

select (followed by three integers[9] from 0 to 7) – selects one resonance mode (described by three integer numbers corresponding to the mode);

getAmp (followed by three integers from 0 to 7) – prints on the Max-message-window the amplitude corresponding to the resonance mode (described by three integers from 0 to 7);

findMode (followed by a float number representing a frequency in Hertz) – prints on the Max-message-window the mode (described by three integers from 0 to 7) and the frequency (float, in Hertz) that are the closest to the frequency given as input. The found mode is shown on the applet-window;

findModes (followed by two float numbers representing a frequency range in Hertz) – prints on the Max-message-window a list of modes (described each by three integers from 0 to 7 and frequency) found in the frequency range given as input. Found modes are shown in the applet-window;

clear (as message) initialises the *modebox* object by erasing all selected modes (frequencies);

getGridSize prints on the Max-message-window the grid[10] size (spatial resolution) of the virtual room represented by the object *modebox,* the room is divided into 100 parts, e.g. if the room is 100 meters, each interval (point that can be analysed) will be one meter long.

---

9. Three integers from 0 to 7 describe each mode in the Applet grid (see Fig. 3.7), representing the number of natural oscillations on the x, y and z-axis.

10. This value is similar to a parameter for the visualization (and simulation) in the applet window (the slider *Image Resolution*). It refers to the spatial resolution, meaning how finely the (virtual) space has been sampled to allow a discrete analysis.

The *modebox* object, illustrated in this research in the form of a demo-patch, is conceived to provide some examples of utilisation. As usual, this demo-patch works with a library that needs to be stated in the *file preferences* dialog window of Max5. After opening the patch, the applet-window will appear on the upper left-hand side of the screen. This will be used only for an immediate visual representation of the actions made inside the actual Max5 patch. The steps to initialise the patch and start the analysis will be:

1) Enter the size (in meters) of a virtual room (float numbers, x-size, y-size and z-size). The virtual room is drawn in the tridimensional graphic on the left; a zoom-tool permits a rescaling of the tridimensional model for a better view.
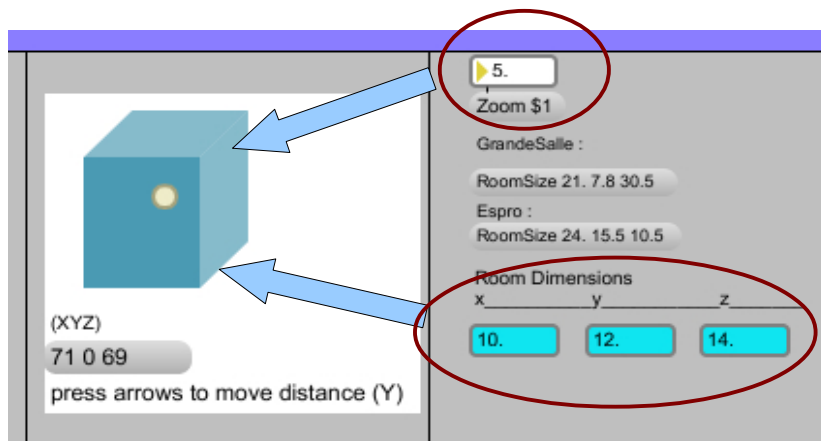
Fig. 3.10. Detail of the Max/MSP patch for room-mode analysis: tridimensional control panel with Room Dimensions and visualization zoom (marked by ovals). With this tool it is possible to manually explore the resonance mode status of each point in the virtual room model.

2) Enter a list or a range of frequencies (float numbers in Hertz) or modes (three integers from 0 to 7); frequencies (up to a number of 64) can be chosen randomly (by pressing the button *select modes randomly*) or can be found according to the closest frequency to the one desired (message *findMode* followed by a float number i.e. a frequency in Hertz):
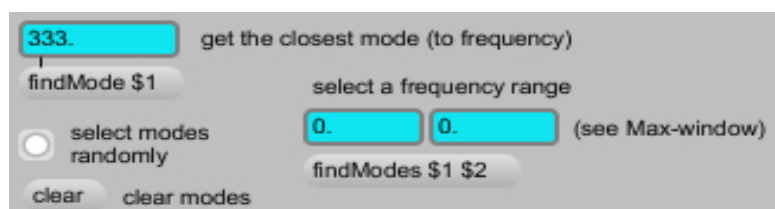
Fig. 3.11. Detail of the Max/MSP patch for room-mode analysis: the output of a desired frequency-range (all modes present within an interval) can be visualized in the Max-message-window.

By entering a precise frequency value, the program will output (on the Max-message-window) a mode with the closest frequency to the one of the input, according to the resonance-mode structure of the room with the desired size.

3) For a better understanding of the process and the analysis operated by this program, a visualisation window has been created, on the surface of which 64 tables show the evolution of each of the 64 selected modes (with a float number box indicating the corresponding frequency in Hertz). This window can be opened by pressing the button *visualize modes*:

Under each frequency value, a *Multislider* represents a wave that moves according to its intensity at various points of the virtual room:
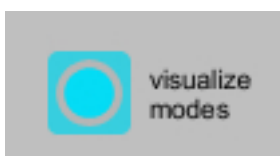
Fig. 3.12. Detail of the Max/MSP patch for room-mode analysis: button to visualize the room-mode evolution along the desired trajectory.

[visualize-modes]

| 112.540268 mode 4 | 94.766533 mode 5 | 117.91993 mode 6 | 133.317902 mode 7 |

| 53.244823 mode 14 | 139.530075 mode 15 | 17.324486 mode 16 | 134.569977 mode 17 |

| 50.799541 mode 24 | 54.849129 mode 25 | 158.200012 mode 26 | 117.212006 mode 27 |
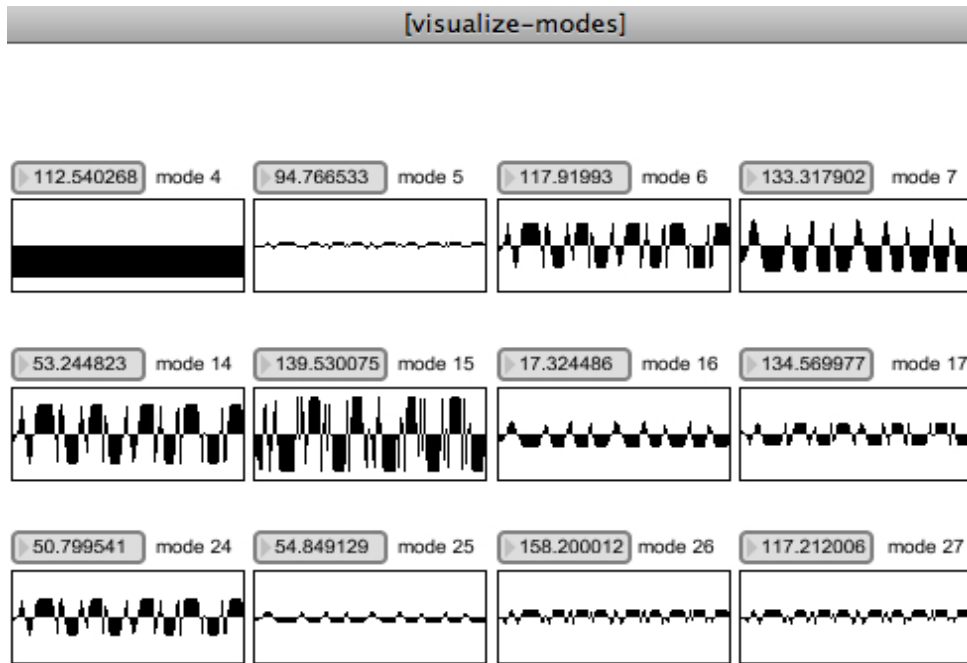
Fig. 3.13. Detail of the Max/MSP patch for room-mode analysis: this sub-patch provides a graphic representation of all found room-modes (intensity evolution along the desired trajectory).

Once the procedure of entering modal data (room mode frequencies) is finished, it is possible to visualize the behaviour of such room modes in the space. For study purposes, within this virtual model the process can take place with both active and stopped simulation (applet window with *Stopped* option):

Clear
☑ Stopped
☐ Show Spectrum
☐ Alternate Rendering
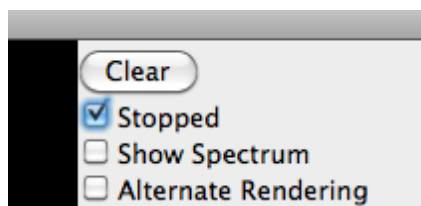
Fig. 3.14. Control panel (detail) in the applet-window with stopped visualization option.

When stopped, simulation will freeze room modes at a certain state according to the physical model implemented; of course the result of the analysis will vary depending on whether or not the simulation is active (see Fig. 3.15):

| 112.540268 mode 4 | 94.766533 mode 5 |

active applet-simulation

| 112.540268 mode 4 | 94.766533 mode 5 |

stopped applet-simulation
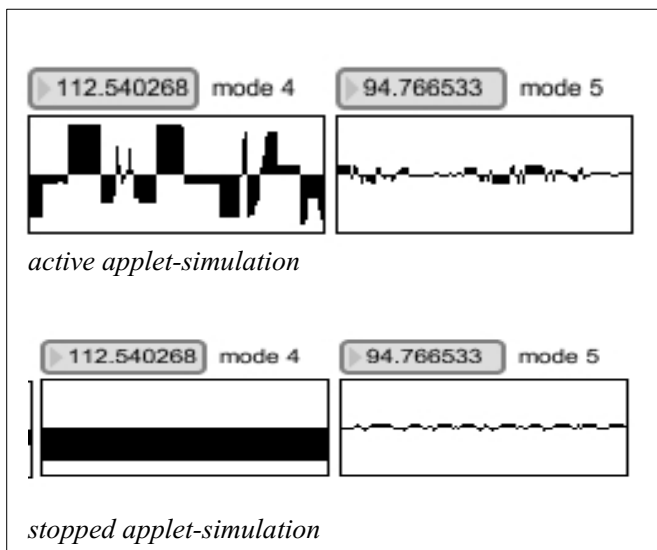
Fig. 3.15. Examples of two room modes (from left to right 112.54 Hertz and 94.76 Hertz) and their amplitudes found in a certain portion of space/time: data above (taken with active applet-simulation) differ between those below (taken with stopped applet-simulation).

The solution of working with the model with stopped applet-simulation has been preferred thus far, it can be compared to the method of analyzing a sound spectrum (introduced by the spectral composition technique): A spectrum is represented as a picture of a sound taken at a certain time, as if it were frozen.

To further explain the analogy between the two methods (sound-spectrum-analysis and room-modes-analysis) it is useful to mention that, in a program like *Audio Sculpt*[11], a spectrum can be inspected manually through a Diapason-tool that allows one to hear each partial frequency, which are displayed as grey surfaces (degrees of darkness symbolise higher or lower amplitude):
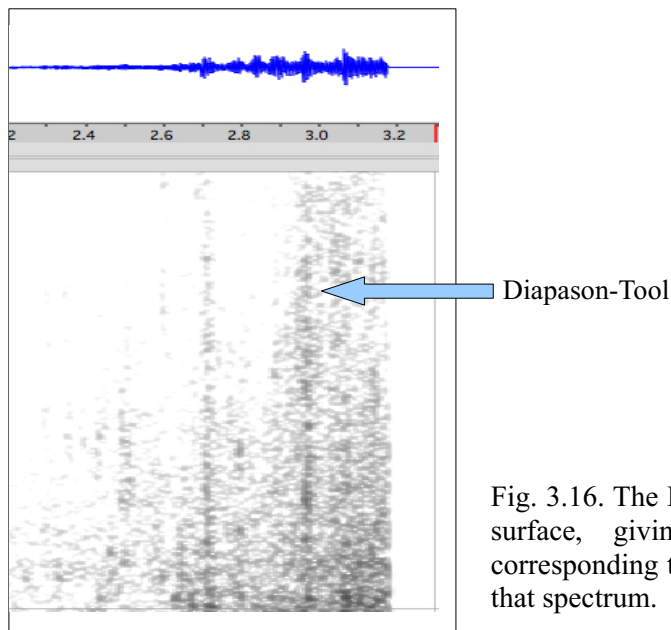
Diapason-Tool

Fig. 3.16. The Diapason-Tool can be moved on the surface, giving an audio output (sinusoid) corresponding to the partial frequency contained in that spectrum.

This method is comparable with the room-mode analysis since, instead of changing this inspection point in the frequency/time domain (the partial frequency can be chosen moving the inspection-point vertically → frequency domain, and horizontally → time domain), it is possible to move it according to a space/time domain, which means a movement (the room-mode can be chosen moving the inspection-point according three coordinates x,y,z → space domain, doing this sequentially according to a trajectory of points → time domain), as shown in Fig. 3.17:

---

11. In this example (Fig. 3.16) the graphic shows how to move a time-frequency window in the spectrogram of an audio signal (AudioSculpt version: 2.9.4b1).
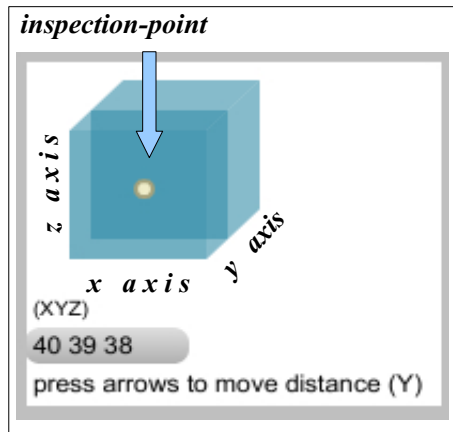
Fig. 3.17. Compared to the Diapason-Tool featured in *Audio Sculpt*, the white circle represents the inspection point that moves within the virtual room. At each position in the tridimensional model the program will calculate the state (intensity) of the chosen room modes at a certain moment t0.

The inspection-point can be compared to a microphone, moving ideally inside a room whose resonance modes have been previously excited. With the Max5 interface, this tool can be manually activated for study purposes, by moving the cursor with the mouse (trajectories on the x and z axis), and the arrow-keys (trajectories on the y axis).
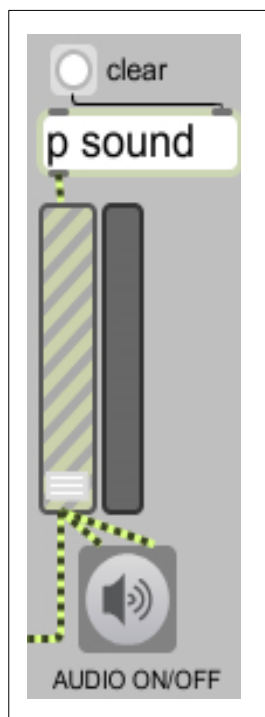
Fig. 3.18. The patcher *sound* and the audio output, clicking on the audio object the sound feedback can be switched on and off.

In addition to the visual feedback (window called *visualize-modes*), a sound output is provided: this audio feedback can be very useful in understanding the aforementioned processes hearing the evolution of room-mode amplitudes, for example according to their position in the (virtual) space. The sound-feedback interface is placed inside a patcher called *sound*, connected to an audio output (which can be switched on and off) and to a *gain~* object (picture above).

This audio rendering (inside the the *sound*-patcher) is produced by an ensemble of sinusoids having the frequencies and amplitudes of the corresponding room modes, which are produced automatically by a patcher called "*synth_*" and transformed into sinusoids by a *poly~* object called *oscV~* (with argument 64, i.e. the maximum number of instanced oscillators) that is placed inside the *synth_* patcher.
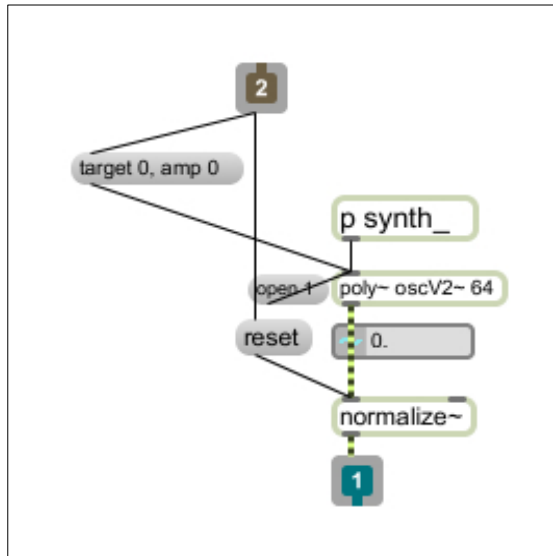
Fig. 3.19. Detail of the Max/MSP patch for room-mode analysis: patch for sound rendering.

The *synth_* patcher is built as follows:
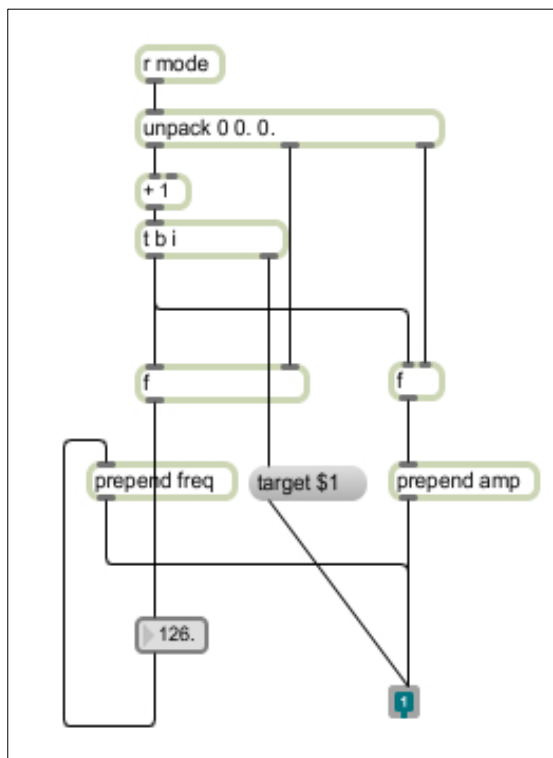
Fig. 3.20. Detail of the Max/MSP patch for room-mode analysis: This sub-patch provides a sound feedback (room-modes are transformed into a cluster of sinusoids generated by an oscillator bank).

Since for normal sized rooms resonance modes can only be distinguished at very low frequencies, the audio rendering can give a better sound result result when transposed up arbitrarily (with the slider) or better, by transposing by one or more octaves, i.e. by multiplying all frequencies[12] by 2 or multiples of 2. This *Frequency Multiplier* is placed near the sound output (Fig. 3.21):
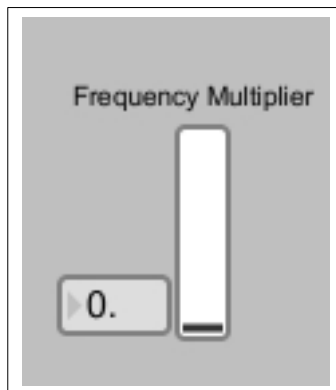
Fig. 3.21. Detail of the Max/MSP patch for room-mode analysis: This frequency multiplier transposes the sound rendering of one or several octaves.

3.2.2 From trajectories toward music material

After having illustrated the main components of the demo software, the next step would be to explain the working method that this tool is associated with in greater detail. As has already been explained, the aim of this research is to find a way in which it would be possible to use some aspects of spatiality not as a musical dimension connected merely to performance (spatialization) but more pertinently as a compositional parameter; a question that implies the possibility of its measurement (as is the case for frequency, rhythm, timbre). Moreover, wishing to insure a stricter connection between the phenomenological use of space (spatialisation) and the further music parameters, it is imperative to look for a procedure that, similarly to Stockhausen's *Kontakte*, the operational boundaries between pitch, rhythm and timbre, would at least partially disappear or become more flexible.

As a a musical consequence of this research, through the actual compositional work, the two aspects of physical space and spatialisation are restored as unity. This attitude aims to bring together the hearing experience of Lucier's I *am Sitting in a Room*, with the exactitude of musical notation of Varèse while at the same time musically conciliating the powerful impact of sound movements in Nunes' masterwork *Lichtung 1*. If we look back to the scheme (Fig. 2.7) in 2.4. these three approaches, if aesthetically inconceivable, are at least methodological possible to reconcile insofar as we want to:

- Create a working environment as close as possible to the acoustic properties of a physical space (physical representation of space);

---

12. Actually, multiplying frequencies means making the original room smaller, this process is intended only for a clearer audio feedback (for demonstrative purposes) and does not have any implication in the compositional concept that is strictly connected with a specific room (real or virtual).

- Make sure that the musical (raw) material is the expression of an intuitive, space-oriented compositional element and vice-versa (phenomenological representation of space);
- Traduce all music material into a precise notation (metaphoric representation of space).

If we look at the usual way of conceiving of and integrating spatiality into music composition, we notice that this approach would invert the generally accepted opinions regarding spatialisation (the art of moving sound in space) as the final part of the compositional process. From organisation of musical material (according to a harmonic or generally speaking a composition structure) into notation (that defines various relationships between instruments or sound sources and time of course), up to the distribution and movements of those sounds in space (trajectories):

Music material (tones, chords, etc.)	→	Music notation (score)	→	Spatialisation (trajectories)
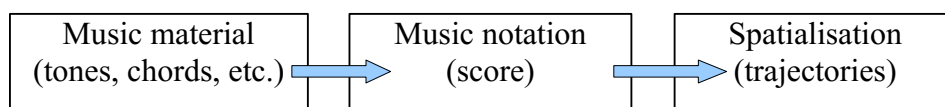
Instead, this approach will turn the whole process around, postulating an inverted order of priorities. This will start with the definition of a movement in space, which will lead to musical material, and finally to notation:

Trajectories (Spatialisation)	→	Music material (tones, chords, rhythms, etc.)	→	Music notation (score)
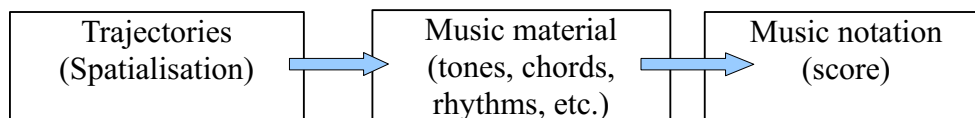
Therefore, as point of departure for such a working method, the main element triggering the whole process will be a trajectory, a succession of points in the space (expressed in x,y,z coordinates) representing (this is possible but not compulsory) a sound movement in the concert hall. The choice of such trajectories could perhaps follow the criteria of a perception strategy (for instance, the most effective sound displacement to be perceived), but mainly it will be kept open, the fruit of an artistic decision in the same way that a melody can be.

Inside the virtual space produced by the Max5 platform, it will thus produce a series of data (frequencies, amplitudes) capable of being filtered and transformed into raw musical material by another program: Open Music. Only at the end of this step will it be possible to transform such raw data into a music score. To this end, the patcher called *toOpenMusic* will be described:
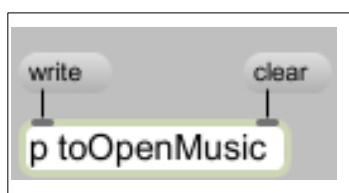
Fig. 3.22. Detail of the Max/MSP patch for room-mode analysis: the sub-patch called *toOpenMusic* produces a text-file with the analyzed data ready to be exported to the Open Music transcription software.

It contains a small patch allowing the transcription of modal data (triggered by a trajectory) using a *Text*-object.
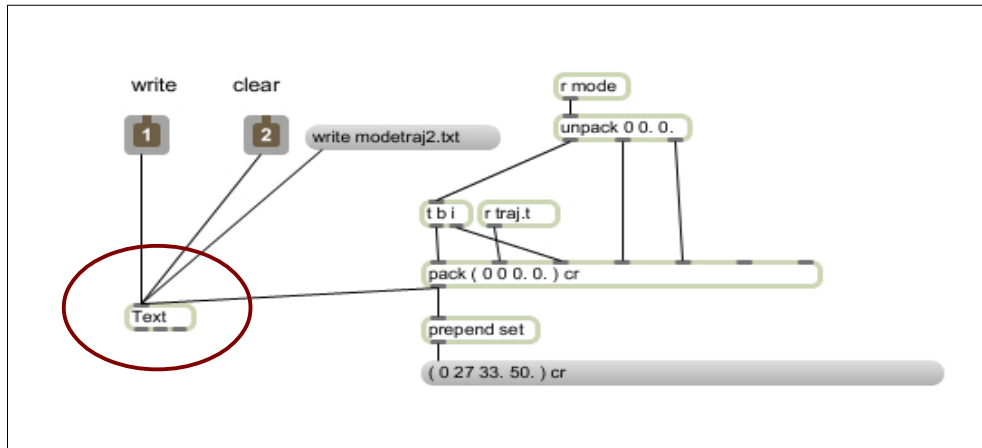
Fig. 3.23. Detail of the Max/MSP patch for room-mode analysis: In this portion of the analysis, tool patch *Text* data is transformed into a format that will be used in the Open Music transcription tool.

To produce a data format that would be suitable for the Open Music software, it is necessary to write all modal data (changing according the positions in the virtual space traced by the chosen trajectory) into a text file (file name extension: *.txt*) featuring a list of numerically ordered values (frequency expressed in Hertz, and amplitude from -1 to +1, both in float numbers).
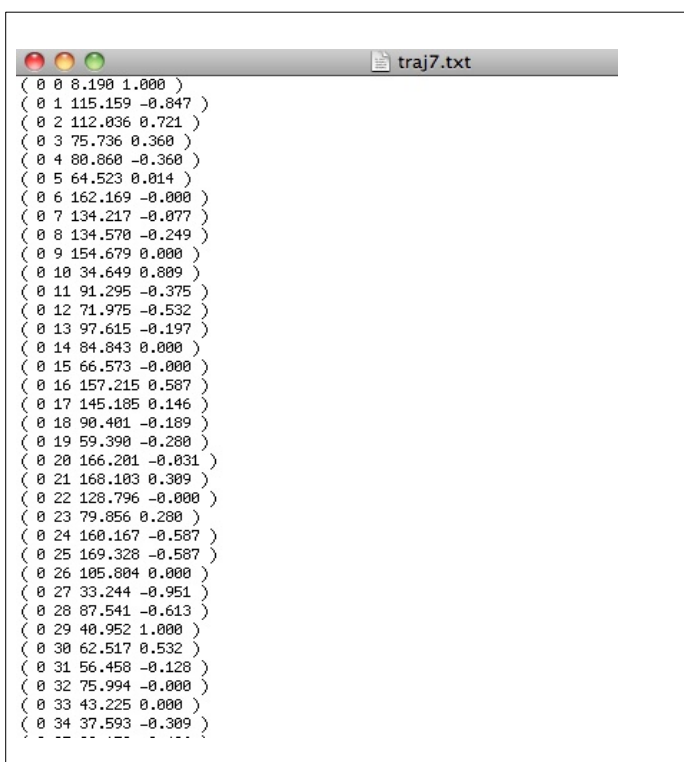
Fig. 3.24. Example of data format suitable for Open Music transcription tool. From left to right, each line indicates the number of trajectory (zero is the default value), the number of the frequency detected (list), and Hertz values of this frequency and its amplitude value.

By clicking on the *Text* object inside the patcher *toOpenMusic,* it is possible to see the result of an arbitrary trajectory (picture above). It should be mentioned that each point contains a list of 64 frequencies describing the state of each of the 64 possible frequencies (resonance modes) that the program can calculate. Each line on the list shows (from left to right):

- A number (number of trajectory if indexed, 0 is the default value);
- The number of the frequency (this is a mere order corresponding to the sequence in which it has been generated);
- The frequency associated with the resonance mode (in Hertz with three floats);
- An amplitude value (from -1. to +1.).

Once the content has been produced the program should store this information into a text file.
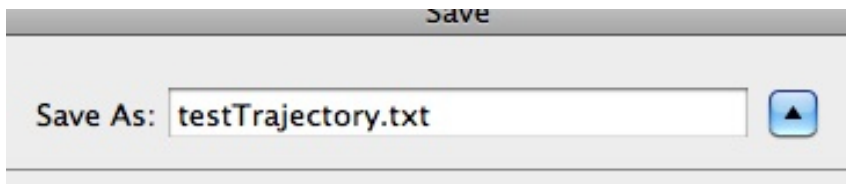
Fig. 3.25. Image of dialogue-window to store the text-file containing room-mode data.

Such a file can be produced following these steps:

- Pushing the *write* button (*clear* can be used to re-initialise the procedure, it erases all previously written data on the text file);
- A dialogue window opens in order to input a text file name;
- By moving (manually) the point in the 3D model according a desired trajectory, corresponding modal data will be stored in the text file.

At this level, the work with Max5 software is finished and the process can be continued with the appositely designed Open Music patches[13].

3.2.3 From analysis data to music text

The work with Open Music software is the last step that leads to the generation of raw musical material (sequences transcribed into a musical system) suitable for a process of musical composition. Resulting musical materials represent a music-notation translation (with some degrees of approximation, in pitch and duration) coming from modal data, generated in the Max5 virtual room model. From this data and the analysis of room-mode states at different points in the space (along a trajectory), several further types of musical data can be

---

13. Open Music (OM) is an IRCAM software that works with graphic representations of Lisp functions. The patches used for this project are essentially tools to translate into music text the raw data produced by the Max/MSP analysis. Coralie Diatkine and Jean Bresson, "OpenMusic 6 User Manual. Document Version # 1," *Ircam / Centre Georges Pompidou.* (n.d.), 12.

obtained, prefiguring a method able to convert a spatial figure into pitch, rhythm and/or dynamic. This reflects the oblique method of crossing over parameter boundaries from a musical dimension into another (see 2.3.2). It also reflects a strong methodological connection point between a musical utilisation of physical room data and the use of spatialisation, as the following graphic suggests:
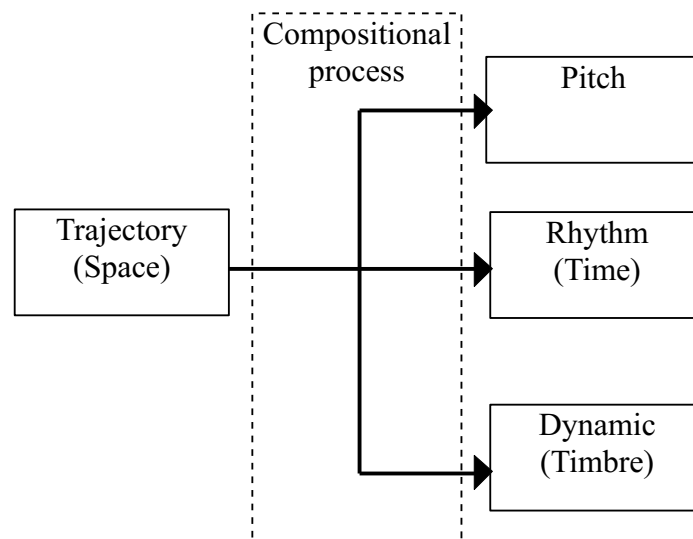
As a matter of fact, with this compositional method, the starting point of the musical construction after the chosen room dimensions (virtual tridimensional model) would actually be a movement in the given space, that is a trajectory. Seen from a music historical perspective, we could consider such trajectory akin to a cantus firmus or, with another metaphor, the theme of the music work.

It could be suggested, for instance, that the same trajectory could be translated into other states, using all those compositional artifices that are well known in the canon technique of Franco-Flemish School[14], but also some specific geometrical transformations like translations or other complex projections (Fig. 3.26).

---

14. Also called the Netherlandish School, this term indicates generally the polyphonic style of vocal music composition developed in Europe during the 15th and 16th centuries.
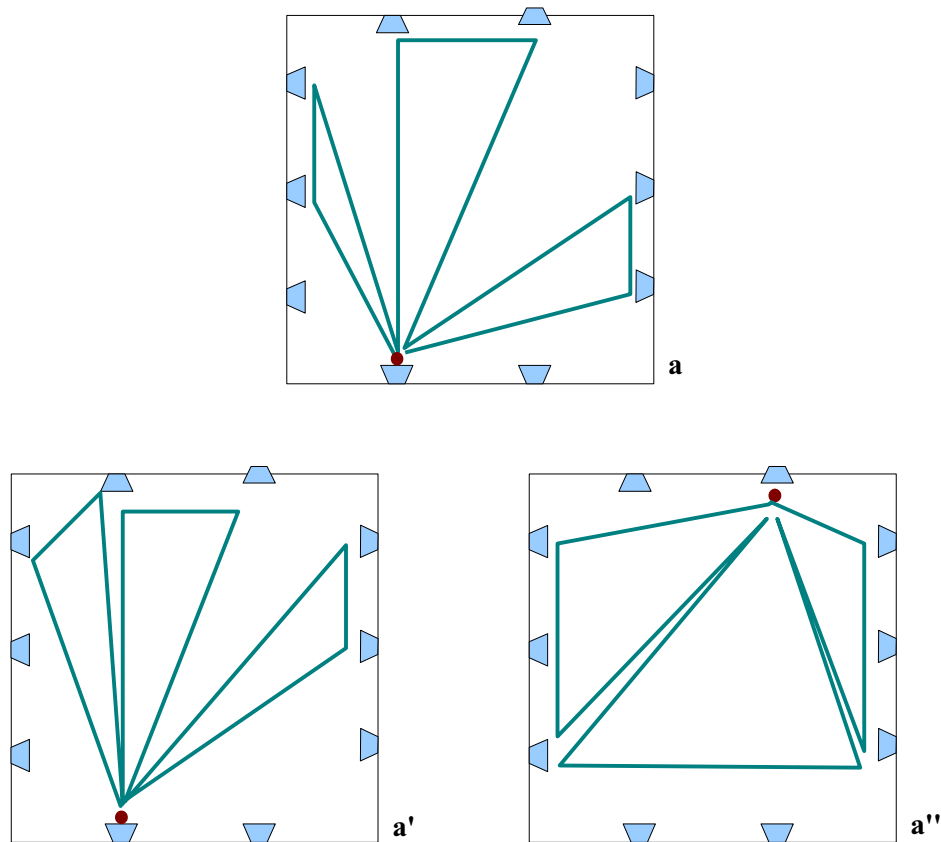
Fig. 3.26. Examples of a trajectory *a* (bi-dimensional representation in the hypothesis that trajectories are used to spatialize sounds inside a performance space with eight diffusion points) and some possible translations and transformations *a'* and *a''*. Trajectories here are transformed symmetrically, compressed and expanded.

The tools (programs) designed to transform modal data (a text file with a list of frequencies and amplitudes) into raw musical text are conceived to analyse them according certain criteria as shown in the table above (scheme of oblique compositional process). These can be described as follows:

- A tool allowing conversion of the list of frequencies (room modes) into a chord structure up to a single melodic line; since every position along the trajectory has many frequencies (a cluster) this piece of information can be filtered allowing only most present modes (stronger ones with the higher amplitude values) to be reported into the output;
- A tool allowing conversion of the list of amplitudes into a rhythmic structure; this will analyse all data and filter the 0-points of each mode (nodes), as well as inflection points (change of polarity) creating as output a sequence (on the same pitch) of different lengths;
- A tool allowing analysis of the dynamic evolution of each mode (frequency) in time; this will give as output a sequence (same pitch) with different durations corresponding to a crescendo (increasing amplitude along the trajectory) or diminuendo (decreasing amplitude along the trajectory).

These three outputs could potentially be combined or used separately, according musical and/or artistic needs.

Since a deeper explication of the programming language (Lisp[15]) – upon which Open Music is based – requires an apposite study that exceeds the scope of this research, the next paragraphs will only briefly describe these tools. Indeed, although the whole Open Music programming cannot be exhaustively explained, the most salient parts of these analysis programs will be explicated as far as is useful for their practical utilisation.

3.2.4 Melodic generation

The first and probably most important tool for gathering musical material is certainly the open Music patch called *melodic_generation,* which is able to analyse the text file obtained with Max software giving a melodic sequence up to a chord structure as output. The method behind this tool consists of filtering the ensemble of frequencies gathered from an initial trajectory in the virtual room according to a dynamic threshold (expressed in MIDI-values – or velocity – from 0 to 127). By keeping the dynamic threshold rather low (that means keeping almost all frequencies detected at each point of the trajectory) a chord will be produced, and a raising of the dynamic value narrows the number of frequencies that result as output. Several attempts using different velocity values shall be made in order to understand at which dynamic value a melodic sequence (one sole frequency) can be filtered.

The patch *melodic_generation* starts with a *textfile*-object on the left side at the top of the patch window where the .*txt* file produced by the Max software shall be imported:
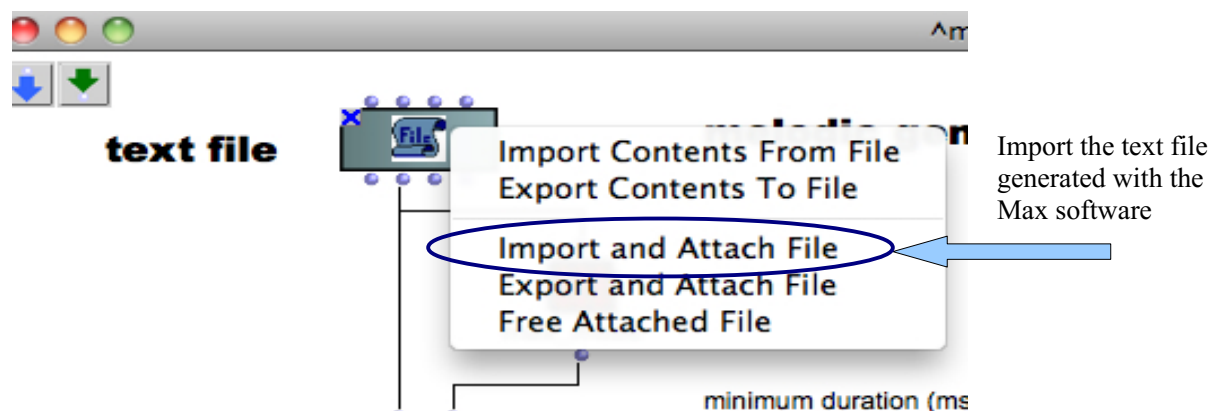
Fig. 3.27. Open Music software: Image of dialogue-window to import the text-file generated with the Max/MSP software. With the action CTRL+click, a menu-window displaying different options opens, and with the mouse the option *Import and Attach File* shall be chosen (by placing the cursor on it)

---

15. The term Lisp is an abbreviation for LISt Processing, this programming language is based on data and functions expressed by list structures. Diatkine, Bresson, n.d., 12.

Before starting the analysis, it is possible to check the contents of this *textfile*-object[16]: by double clicking on it, a window appears showing the list of data. Such lists (see Fig. 3.24) consist of four elements from left to right:

- Number of trajectory (default number is 0);
- Number of mode (at each point of the trajectory a series of 64 modes are analysed, these are numbered from 0 to 64);
- Frequency (in Hertz);
- Amplitude (from -1 to +1).

In this patch there are two main parameters that can be changed in the apposite number-windows:

- A velocity threshold from 0 to 127 corresponding to the minimum dynamic (or mode amplitude) to be detected (as explained above);
- A minimum duration (in milliseconds) for the musical transcription of the resulting chords or melodic structure. Each point of the trajectory will be thus transformed into a chord lasting a certain duration in the score produced by the Open Music program. The main level of this patch is shown in the following picture. It presents: A first part, on the left side of the window (PART 1 marked by dashed square), where the time-scaling value (minimum duration in milliseconds) can be entered by double clicking in the number box below the comment *minimum duration (ms),* and a second part (PART 2 – continuous line square), the core of the program where the analysis is made. In the latter, in the number box below the comment *minimum dynamic (velocity between 0 and 127),* a dynamic value can be entered, again by double clicking. Such number boxes are marked with a red circle.

---

16. Prior to working with the patch (in the way that will be shown later), the *textfile*-object shall also be locked by selecting it and pressing the key B on the keyboard; a small blue cross appears at the top (left side) of that object. This procedure, peculiar to the Open Music software, allows the object to keep its content when the patch is evaluated. If a different text file needs to be loaded, the procedure would then be: de-locking (select the object, press B key) – loading (select the object, CTRL+click on the object) – and finally locking it again before starting the analysis (select the object, press B key).
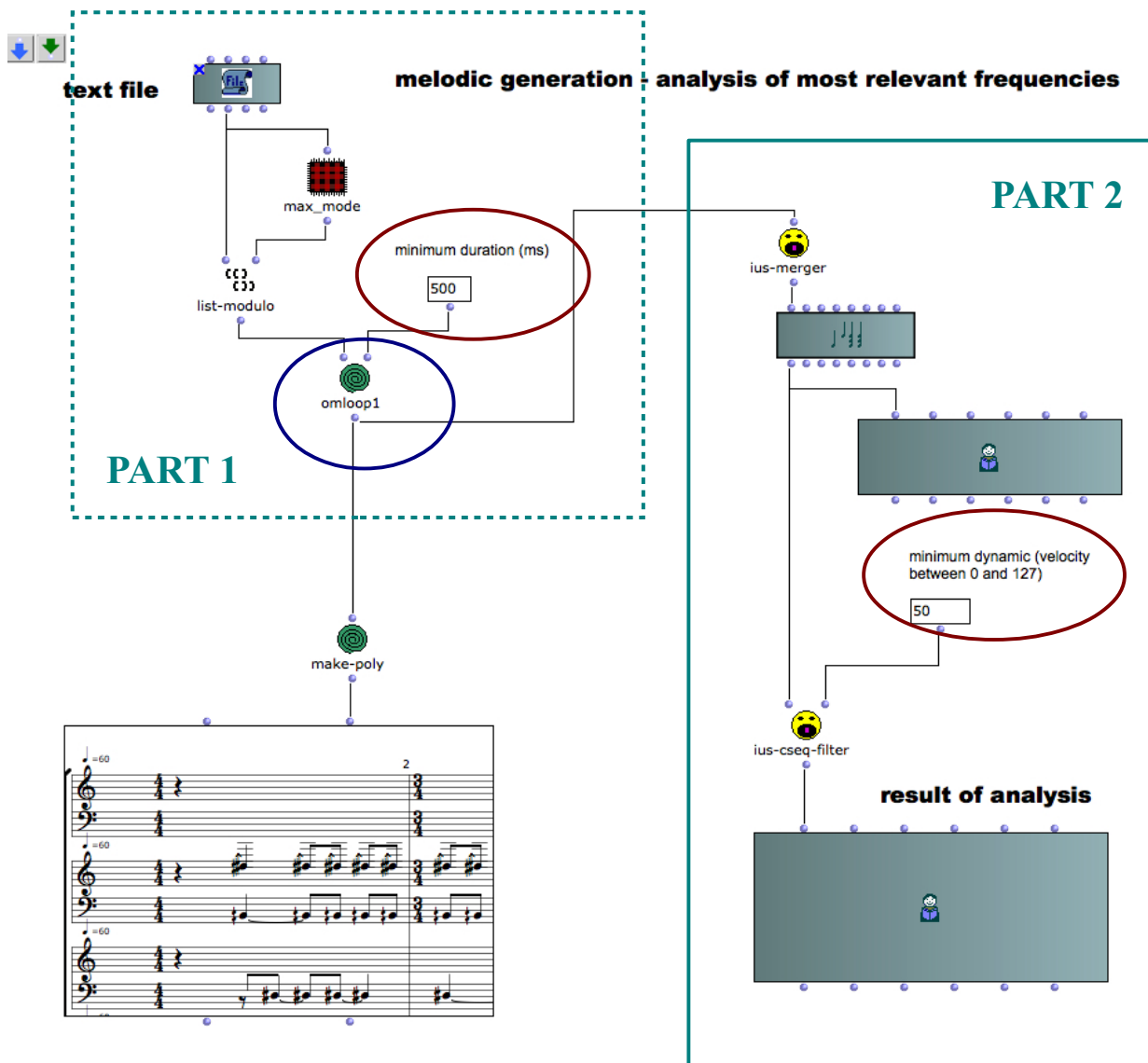
Fig. 3.29. Detail of Open Music patch for room-mode analysis: tool for melodic generation.

PART 1 is the section of the program where *Textfile*-data are prepared and ordered to be analysed in the second one (PART 2 on the right side of the window). The OM-Loop object *omloop1* (marked by a blue circle) combines such data in the form of lists, which are then forwarded in the second part. They can be visualized on the left side of the patch as well (bottom), where the *poly*-object gives a general view of all frequencies that have been detected and reported in the text file. Each system (here using a double bass-clef because frequencies are quite low) corresponds to a frequency, this is a mere global overview of the frequencies contained in the text files. The actual analysis starts in the next portion of the patch.
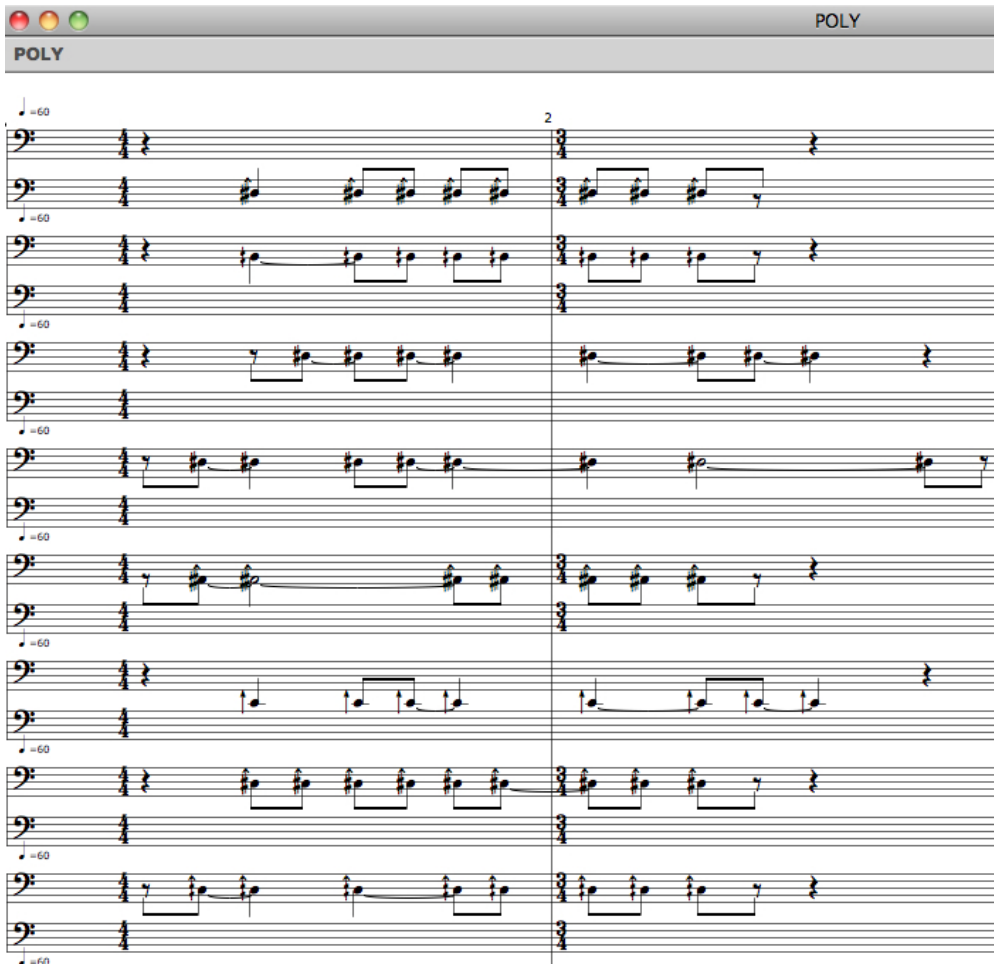
Fig. 3.30. This poly-object at the end of PART 1 offers an overall view of all frequencies detected.

Continuing the description of PART 1, the *omloop1* patch is a recursive sub-program that builds lists to create a series of chord sequences (*chord-seq* objects). Thereafter, these are routed toward the second part of the patch for melodic generation.

To this end, an Internal Patch Box (an abstraction called *inflex*) computes such lists into *chord-seq* objects. It has three inputs, one each for frequency, amplitude and minimum duration values. This data needs to be extracted from the input lists before going to *inflex:* Lists are taken from *input0* and, as is the case for classic Open Music loop programs, they are iterated (object *listloop*) in order to get the third and fourth element of each list, corresponding respectively to frequency and amplitude values.
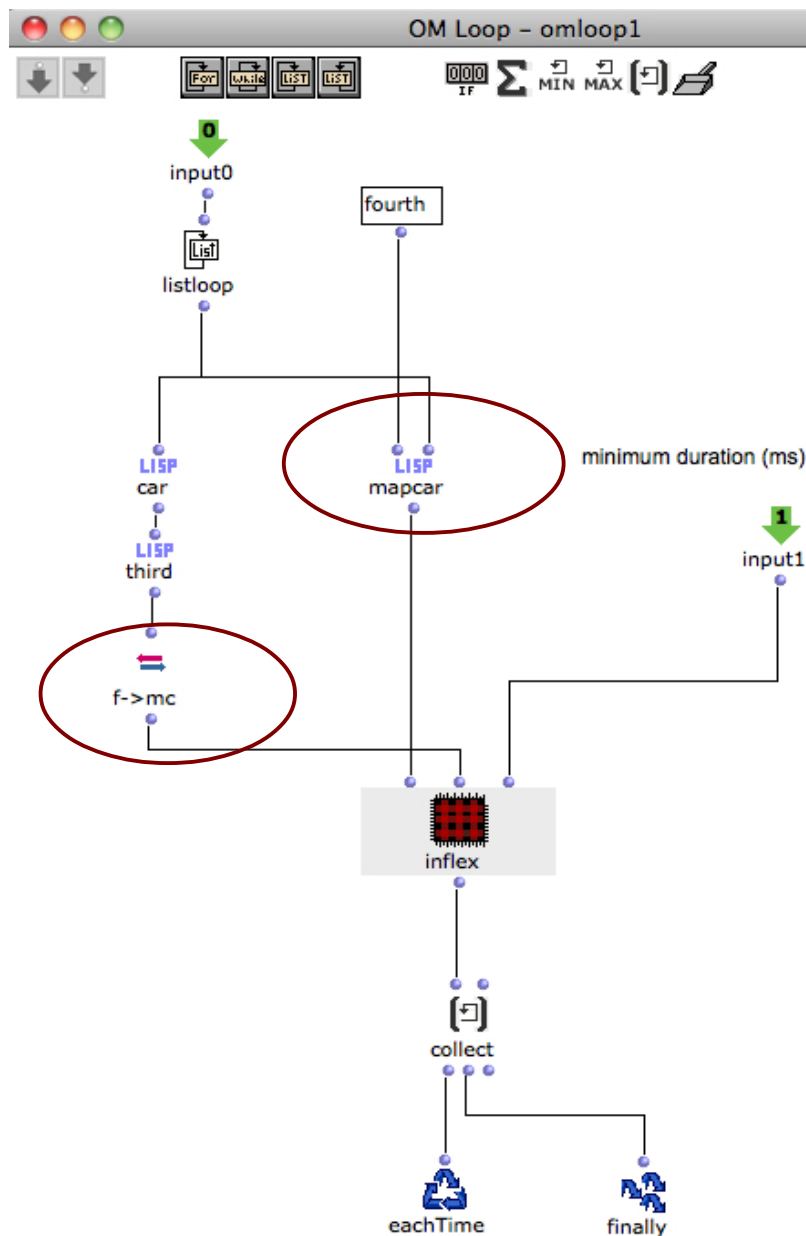
Fig. 3.31. After the object *listloop* iterates all lists coming from the *textfile* object, frequencies are transformed into *midicent*-values (object *f->mc*) and all the fourth values in the lists (amplitudes, float numbers from -1 to 1) are routed into the *inflex* Internal Patch Box.

The minimum duration (*input1*) is given manually (main level of patch *melodic_generation*). All three series of data are routed into the *inflex* sub-patch as follows:

     input0 → amplitudes (list)

     input1 → frequencies (list)

     input2 → minimum duration (a single value).

If input inlets 1 and 2 (frequencies and minimum duration) are used to build respectively the number of chords or notes (the object length returns the number of elements i.e. how many frequencies are contained in the input list) and their temporal succession (the object *x->dx* computes a list of intervals from a list of points and creates notes of equal lengths since the

minimum duration is one value for all of them), the work on data coming through input 2 seems more complex.
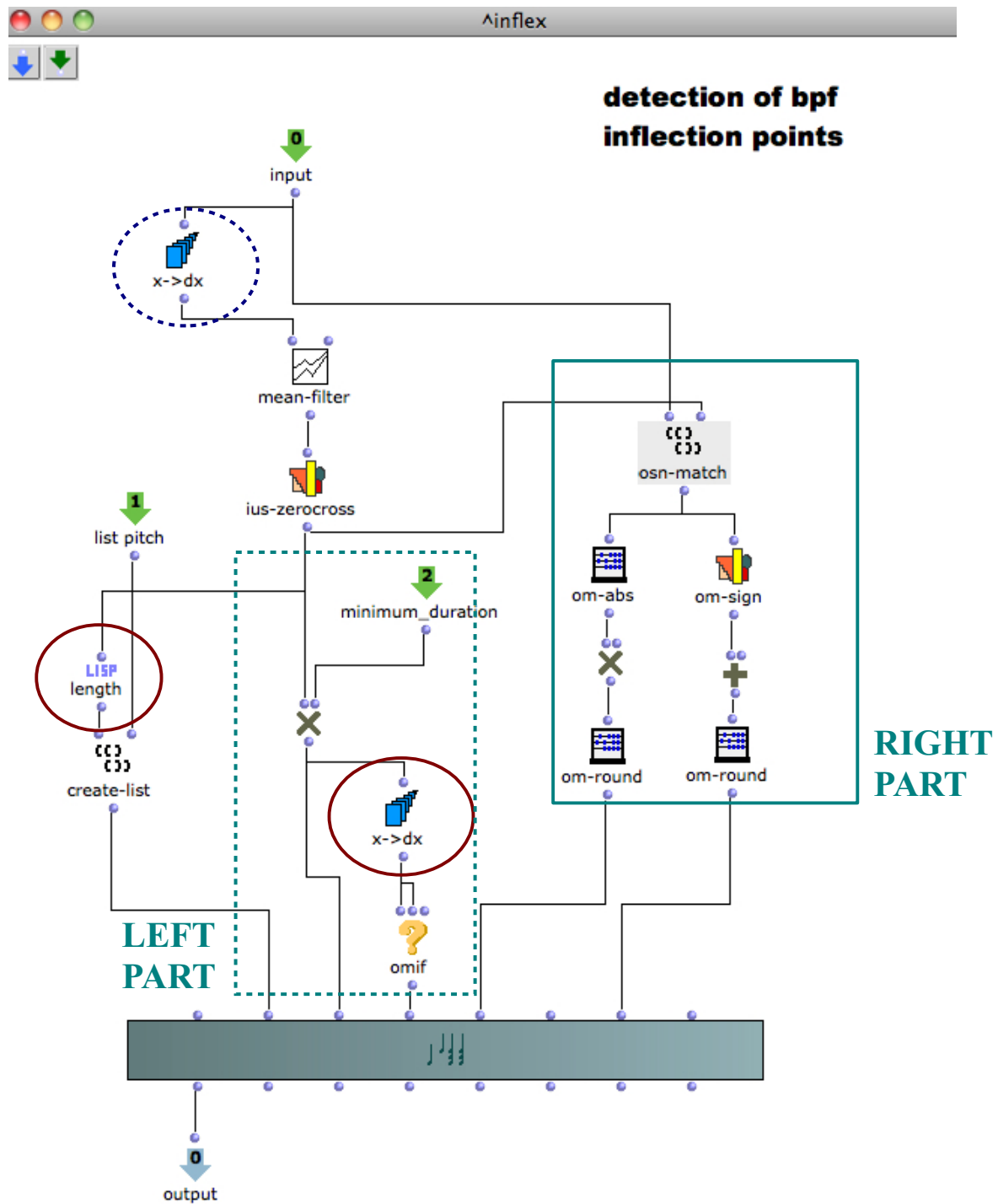
Fig. 3.32. The *length*-object on the left side determines how many notes the *chord-seq* will contain (it counts the frequencies and forms a list with that number of elements), whereas the *x->dx* object (marked by a red circle) gives the desired duration (minimum duration value).

Coming from *input0*, the list of amplitudes are used by the first object *x->dx* to form a bpf (Break Point Function, marked by a dashed circle). Afterwards, the objects *mean-filter* and *ius-zerocross* respectively filter and operate a segmentation of this Break Point Function and the result of this computation is routed to two further parts:

In the LEFT PART (marked by a dotted-line square) this list (coming from the object *ius-zerocross*) is multiplied by the minimum duration value (main level of the patch *melodic_generation*). The results are:

- A list of so called *onsets* (points where the notes – or chords – shall start inside the *chord-seq* object) that is routed directly in the third inlet of the final *chord-seq;*
- A list of durations (*ldur*) made by a new *x->dx* object routed in the fourth inlet of the final *chord-seq.*

In the RIGHT PART (marked by a continuous-line square) the object *osn-match* builds a new list by picking the amplitudes coming through the left inlet (list of amplitudes from *input0*) at positions defined by the list outputted by *ius-zerocross,* coming through the right inlet. The result is:

- A list of MIDI-velocity values (absolute amplitude values multiplied by 120 and finally rounded to avoid float numbers) routed in the fifth inlet of the final *chord-seq* object through the object *om-sign* into the seventh *chord-seq* inlet (*lchan*).

Going back to the main level of the patcher *melodic_generation*, PART 2 is the program portion where the actual musical material (melodic sequences or chords) is generated.

Chord-seq (1) result of *ius-merger* computation.

Input the threshold level (velocity, from0 to 127) inside the number box

minimum dynamic (velocity between 0 and 127)

50

result of analysis

The result of the analysis, visualized in a *voice*-object
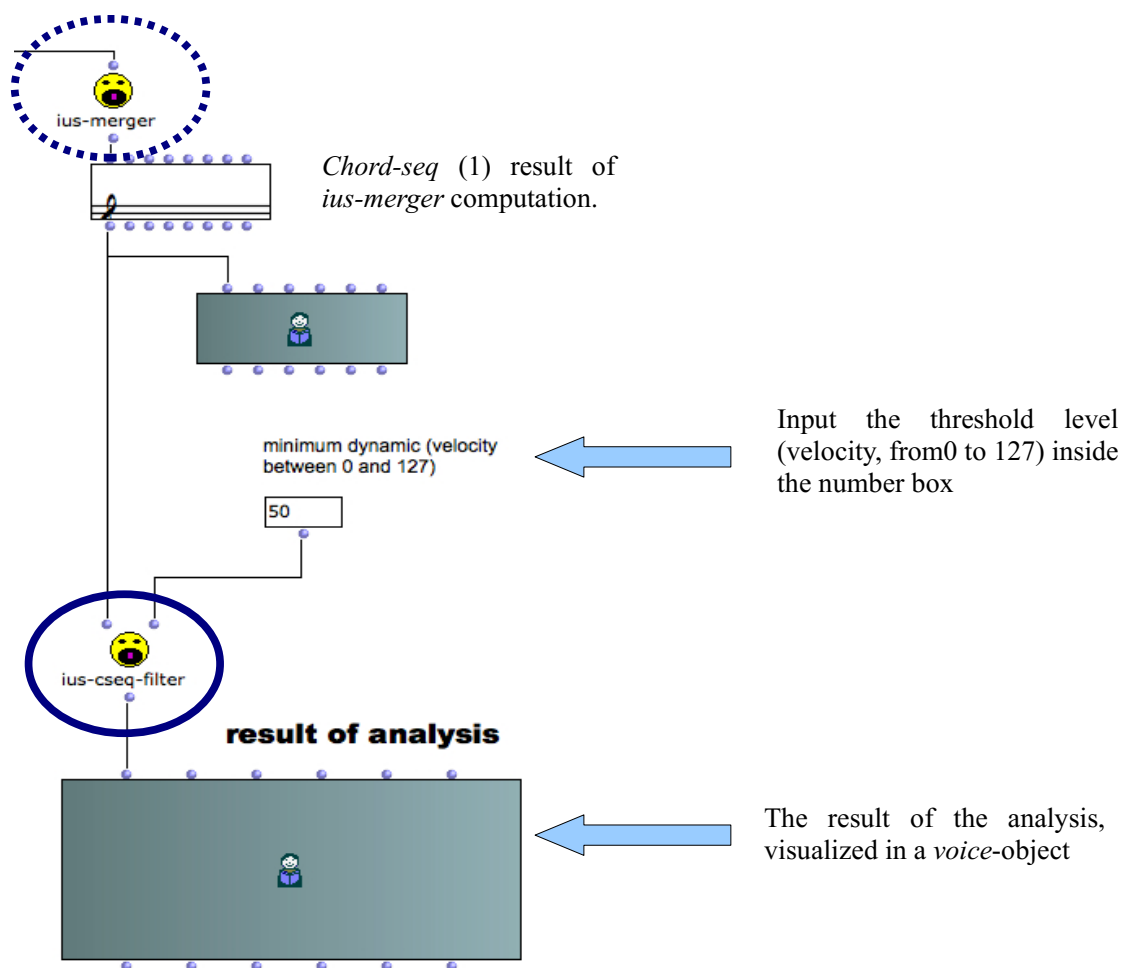
Fig. 3.33. Final part of the patch *melodic_generation:* important input is the threshold value (dynamic) to filter the results of the analysis.

From the *omloop1*, all *chord-seq* objects are merged into a single one, thanks to the Generic Function *ius-merger* (marked by a dashed circle). The result can be seen in the *chord-seq* object below:
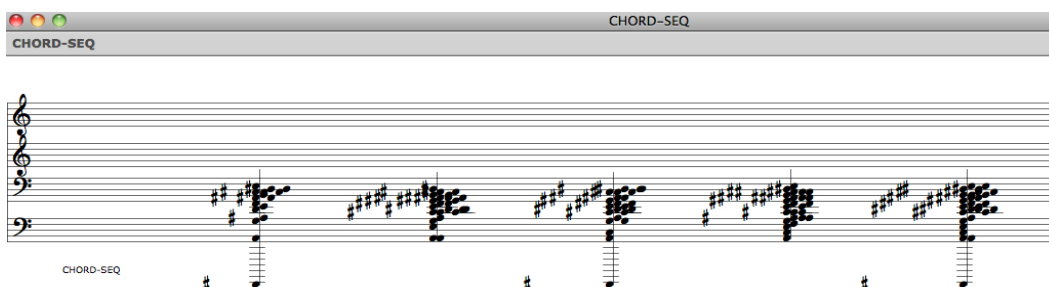
Fig. 3.34. *Chord-seq* (1) result of *ius-merger* computation, all *chord-seq* are merged together.

At this point the most important Generic Function called *ius-cseq-filter* will allow a melodic or chord extraction (and transcription) from the room mode data. It filters the content of a *chord-seq* according to the dynamics (velocity) of notes. Those notes with a velocity below the threshold are erased.

As we see in the final part of the patch, the threshold (given arbitrarily, depending on the musical needs) will filter a certain number of notes building a chord structure, displayed in the *voice*-object at the very bottom of the patch, and representing the final result of the calculation. As an example, three different results are shown here, from a complex chord to a simpler one (threshold 50 and 100) and finally a melodic line (threshold 119):
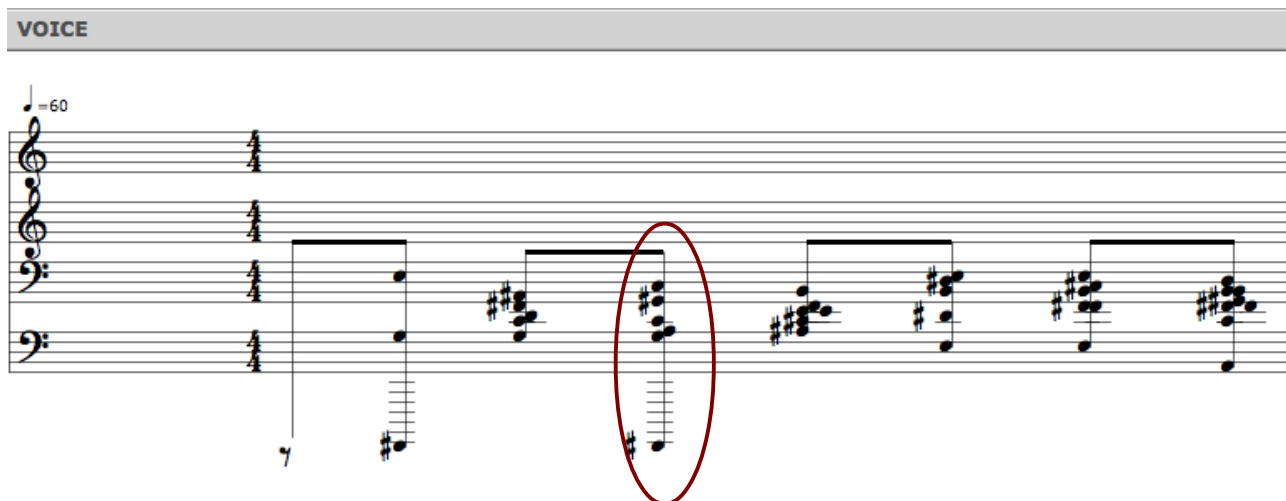
Fig. 3.35. Output calculated with threshold=50; the chord marked with a red oval shall be taken to compare the different results.

Comparing the content (chords) of the *chord-seq* above with those of the one below it is visible how the number of notes per chord decreases. The chords marked with a red oval are the same but the first contains six pitches (frequencies) and the second only three. In the following example (with higher threshold) one chord is missing (the one on the second quaver from the beginning) because the amplitude was lower than velocity 100:
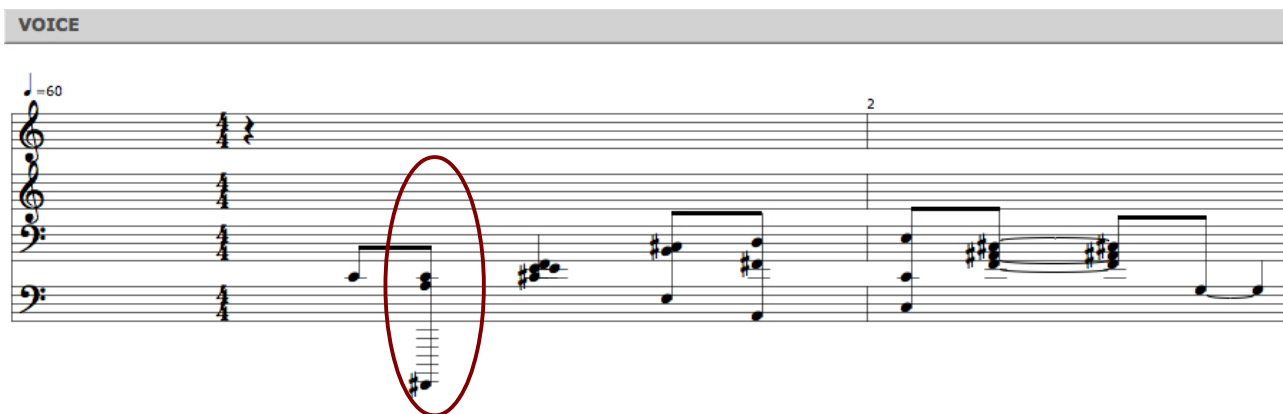
Fig. 3.36. Result with threshold=100; the chord marked with a red oval contains less notes then the one in the preceding example.

In the last example (with a very high threshold, velocity=119) it is possible to filter out a melodic line: The velocity value was found manually after several attempts as it dependants on the amplitudes detected (Fig. 3.37):
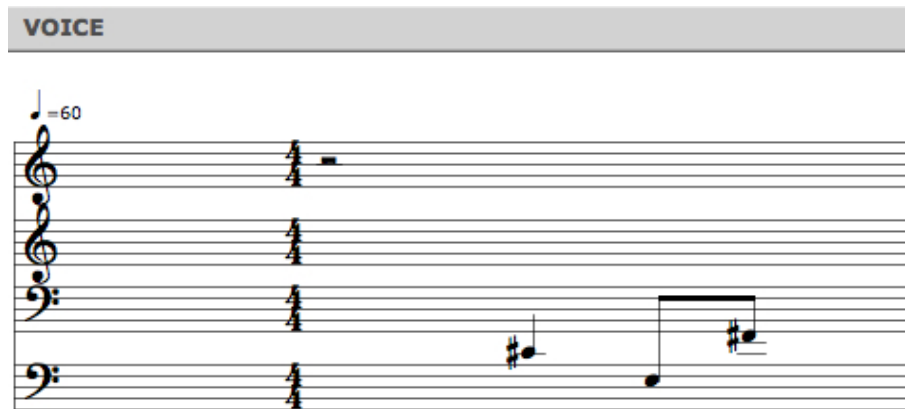
Fig. 3.37. Final result of the *melodic_generation* patch with a melodic line filtered from the cluster-like agglomerates of frequencies

3.2.5 Generation of rhythmic and dynamic structures

The second tool programmed with Open Music is designed to provide (through an analysis of room modes) a rhythmic sequence as output and, within the same tool (or patch), a description (in music text i.e. with notes and dynamic signs like *pp*, *mf* or *ff*) of a dynamic development. These two kinds of output are provided simultaneously (inside the same *poly*-object that represents the end of the analysis) but of course they can be used separately, if so desired.

If going from room modes to frequency domain is self-evident because of the nature of such resonant modes, the connection of this acoustic phenomenon with rhythm may appear quite hidden and artificial. But, as a matter of fact, standing waves present points where they combine, producing a loud spot (called antinode) and where partial or complete cancellations (node) occur. If these zero-points together with the inflection points (where a polarity change occurs) could be detected inside the virtual space and along the chosen trajectory, it would be possible to infer a rhythmic structure. This would be comparable with a sequence made by notes that stop and restart many times: Different note lengths describe a rhythm (regular or irregular). To this end, the Open Music patch called *rhythmic-dynamic-analysis* will be explained (see Fig. 3.38) with a brief description of its main components.
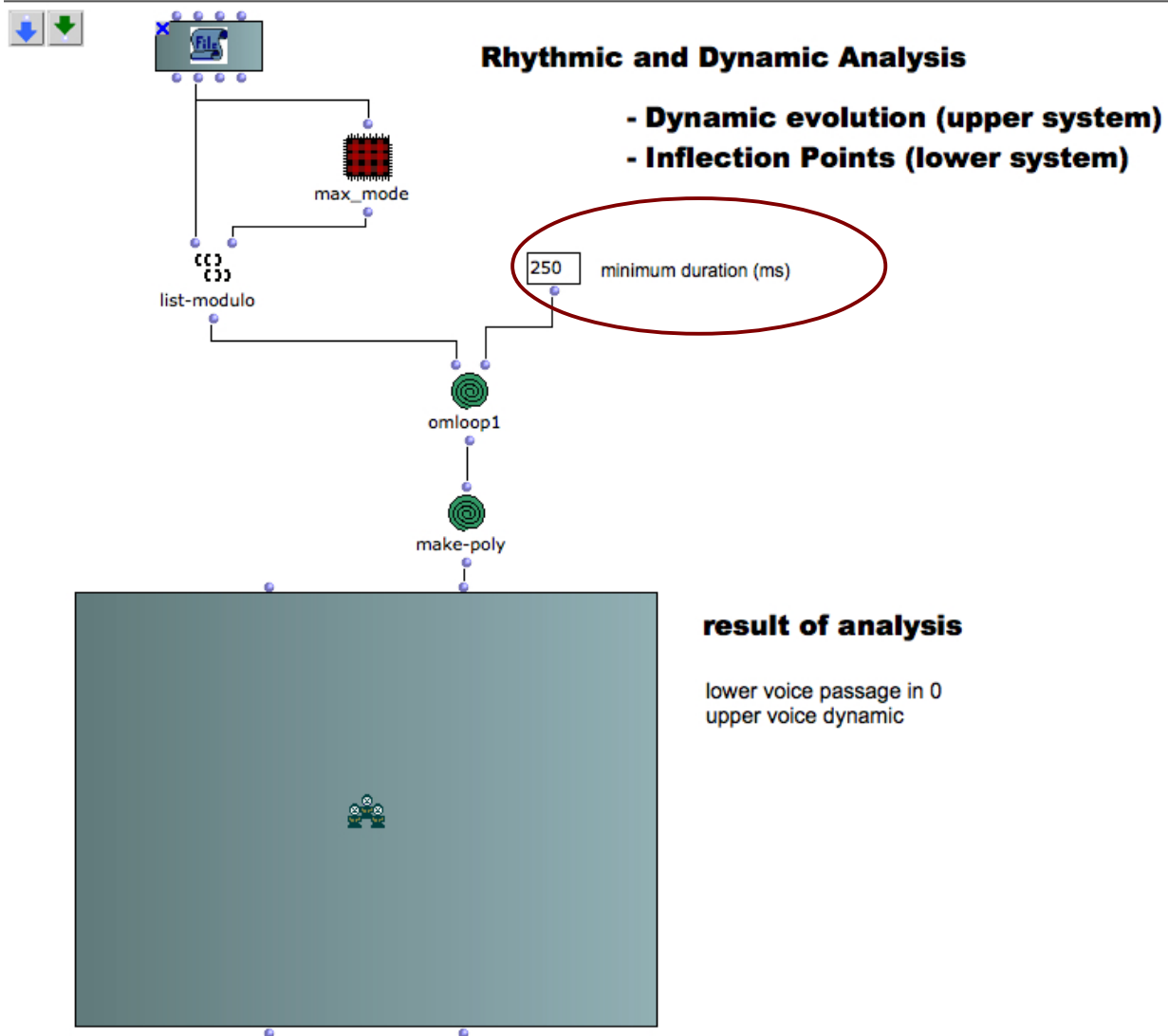
Fig. 3.38. Final part of the patch *rhythmic-dynamic-analysis:* important input is the minimum duration value to filter the results of the analysis.

This patch outputs (in the *Poly*-object at the bottom) an analysis of resonance modes according rhythmic and dynamic development. Output format is a *Poly* with all detected frequencies (corresponding to all analysed room modes) written on two systems (or *chord-seq*) for each frequency (mode):

- On the lower system[17] the rhythmic sequence (coming from the analysis of the amplitude inflection points of the corresponding frequency);
- On the higher system a transcription of its dynamic evolution (including the 0-points, marked with a dynamic *ppp* in green).

Before going deeper into the constituent part of this patch, it is useful to look the kind of data format provided in the output and how to visualize it correctly. When working with this tool,

17. It is useful to remark that in the *Poly*-window, in order to visualize better the very low frequency, each system consists of a double bass-clef-system (notes written on the bottom one are two octaves lower than notated, this is an Open Music default setting).

after evaluating the final *Poly*-object, one must open the *Poly*-window and visualize the dynamic information in the window by clicking on the small scroll menu on the bottom on the left, marked by a red circle. Additionally, when working with very low frequencies, it is advisable to select the double bass-clef option in the scroll menu at the bottom marked with a blue circle (*Staff*). Concerning the visualization of single pitches (frequency corresponding to one room mode), we see in this example two (double) bass-clef systems (marked by a thick square). The upper one (marked by a red square) refers to the dynamic evolution – in space – of that single mode (including zero-points: Nodes, marked in green), the lower one (green square) to the polarity inflection points of the same mode:

Fig. 3.39. The main analysis result of this patch is outputted in the last *Poly*-object, displayed on two musical staves, one for the dynamic evolution (including points where amplitude reaches zero, marked in green), the other for the temporal succession of polarity change (inflection points).

Unlike the previous Open Music Tool (*melodic_generation*, as seen in 3.2.4), where two input values were needed to launch (and to work with) the room mode analysis, in this patch only one parameter can be changed in the apposite number-window (marked with a red circle). This is a minimum duration (in milliseconds) for the musical transcription of the resulting pitches representing the minimum duration of each note in the resulting output.

In order to better understand the meaning of this parameter inside the patch, it is useful to remember that when the trajectory is traced (in the tridimensional model inside the Max patch), each fragment is made at basically the same speed, so that each point in the virtual tridimensional space is reached within the same time interval. The graphic below provides a bi-dimensional example:
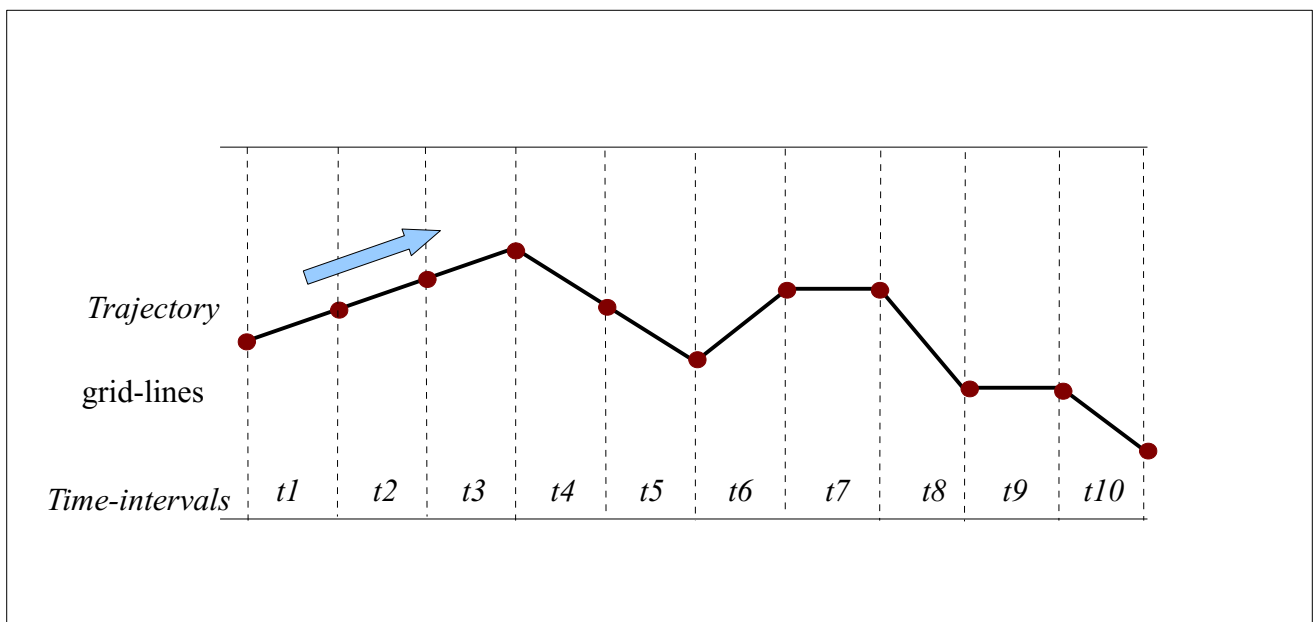
Fig. 3.40. Bi-dimensional simplification of the way in which a trajectory is traced inside the virtual room model: Its subdivision is organized with regular time intervals inside a discrete (sampled) space, defined by a spatial grid with adjustable resolution.

The chosen trajectory is traced inside a regular grid (whose resolution can change). In this simplification, it is supposed to move with the same speed and within the same time-intervals because each trajectory-segment is of equal length (in the tridimensional model there is no information about speed and time, the model does not report the time that the user needs to go from one point to the other).

The value called *minimum duration* will be useful to supply a duration magnitude in the temporal quantification inside a musical text (output). Analysing the same modal data (without changing *Textfile*-object content) with a minimum duration of 125 and then 400 milliseconds for instance, would give different degrees of temporal resolution

Fig. 3.41. Example of output (*Poly*-object) with a value of 125 ms.

Fig. 3.42. Example of output (*Poly*-object) with a value of 400 ms.

As a consequence of this, depending on the (musical) utilisation of the raw data output, it could be possible to compare two (or more) outputs to determine a way to transcribe such data into a final musical score. At this point, a general description of the components of the rhythmic-dynamic analysis is provided.

The work with this patch starts, as was the case with the previous one (*melodic_generation*), by loading a text-file produced by the Max software inside the *Texfile*-object placed on the top of the patch on the left side:
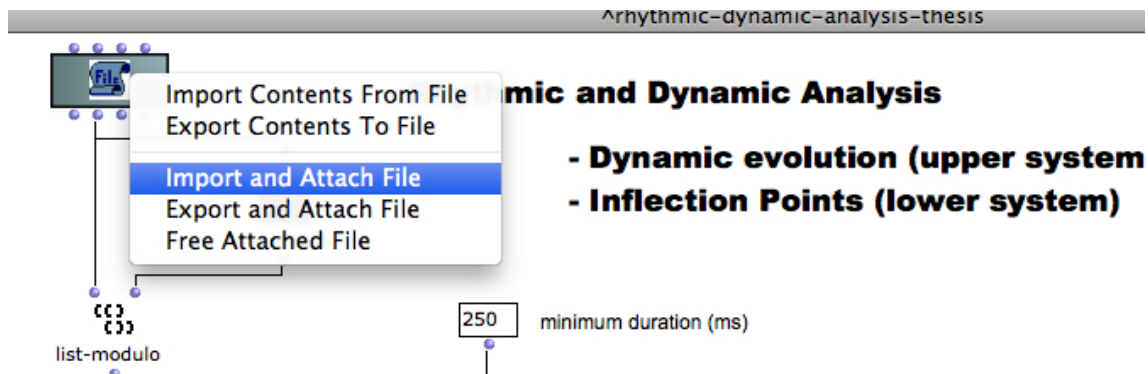
Fig. 3.43. Detail of the Open Music software: dialogue-window to load an analysis text-file.

When the menu appears, by selecting *Import and Attach File* it is possible to load a text file (with *.txt* file name extension). As has been already shown, before loading, the *Textfile*-object is unlocked (select it and press the "B" key) and then locked once the text file is attached (performing the same action).
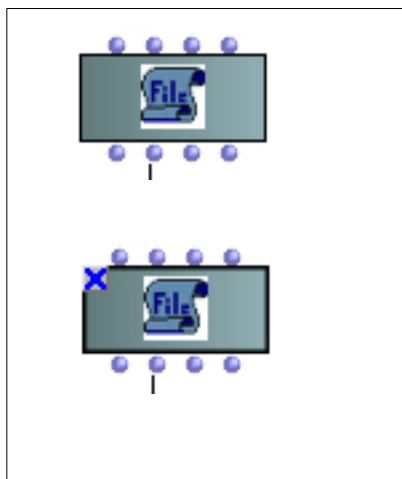
Fig. 3.43. *Textfile*-object unlocked (top image) and locked (bottom image).

Scrolling down to the main level of the patch, the *omloop1* patch is a recursive sub-program that builds lists to create a series of chord sequences (*chord-seq* objects). These are routed afterward toward the final part of the patch to build a *Poly*-object together.

The sub-patch *omloop1* has two main inputs (Fig. 3.44):

- *input0* is the value given arbitrarily (minimum duration) that will quantify the temporal
  transcription inside the final Poly-object
- *input1* comes from the objects *list-modulo* (it groups the element of the lists coming from
  the *Textfile*-object distant of a regular interval given by the patch *max_mode*)

Inside *omloop1* two inputs are routed:

- The list provided by *list-modulo* (it is a list of lists) through *input0;*
- The value of minimum duration through *input1*.
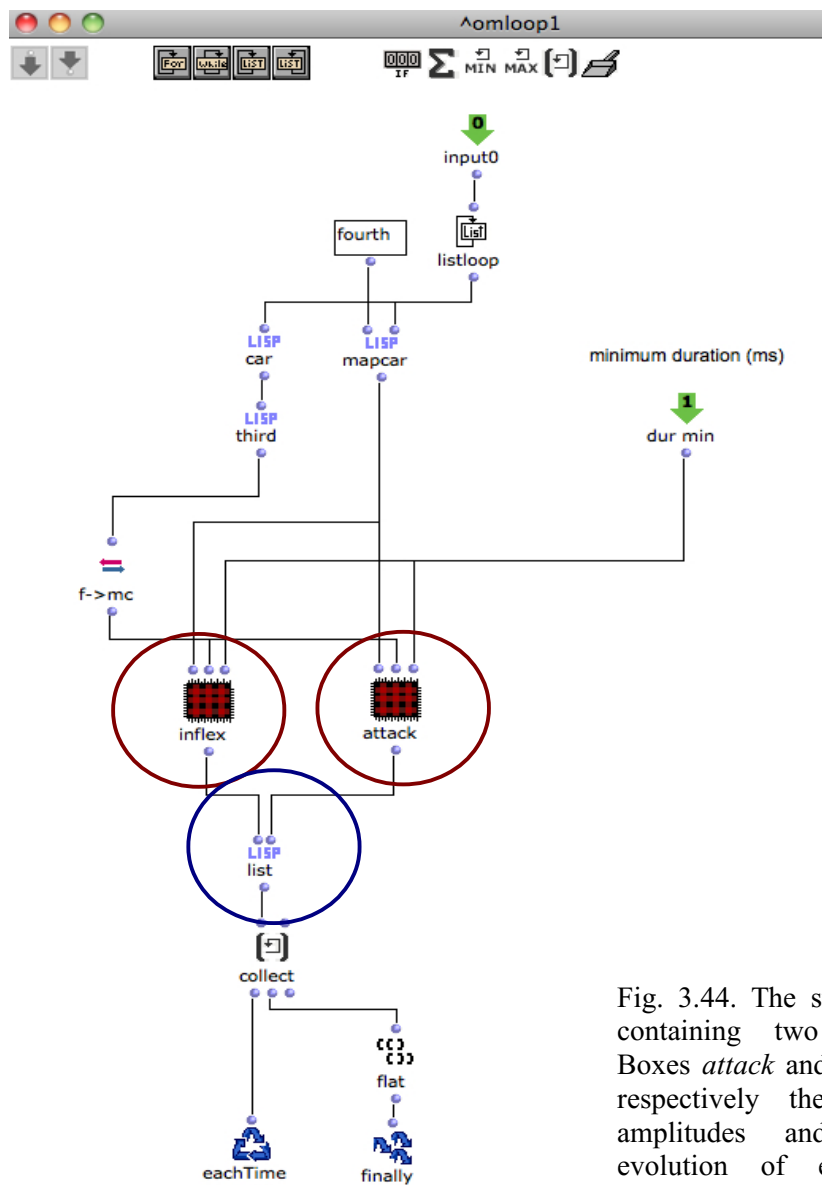
Fig. 3.44. The sub-patch *omloop1* containing two Internal Patch Boxes *attack* and *inflex* computing respectively the zero-points of amplitudes and the dynamic evolution of each room-mode frequency.

Two main Internal Patch Boxes called *attack* and *inflex* (marked by a red circle) operate an analysis to detect the inflection points of each resonance mode (points where polarity changes) and the dynamic evolution of each mode (dynamic change). Both sub-patches take the same kind of data from their three inputs, input0 = amplitudes, input1= pitches (midicent), input2 = minimum duration (also called *quantum*). Data contained in the list of lists are split and transformed into the format suitable to build *chord-seq* in the *Poly*-object. The object *listloop* iterates the elements within the list, (coming from the *input0* of the sub-patch *omloop1*) as follows:

- The fourth element of each list (amplitude) is extracted from each list with the object *mapcar* (associated to the function *fourth*), it is routed in the *input0* of each Internal Patch Box;
- The third element of each list is extracted with the object *third* (frequency, expressed in Hertz) is forwarded through *f->mc* (to be transformed in midicent values) and routed in the *input1* of each Internal Patch Box;
- The minimum duration is routed directly inside the *input2* from the main level of the patch *rhythmic-dynamic-analysis*.

The Internal Patch Box *inflex* has been explained in the previous paragraph (see 3.2.4), and the patch *attack* will be explained below. Each time a recursion (loop) is computed inside the *omloop1* sub-patch, *attack* creates a list that is converted into a *chord-seq*. In the final output (inside the *Poly*-object at the bottom of the main level of the patch) this will be the lower system, on which the attacks (inflection points referring to positive or negative amplitude values) are notated in the form of a rhythmic sequence (Fig. 3.46).
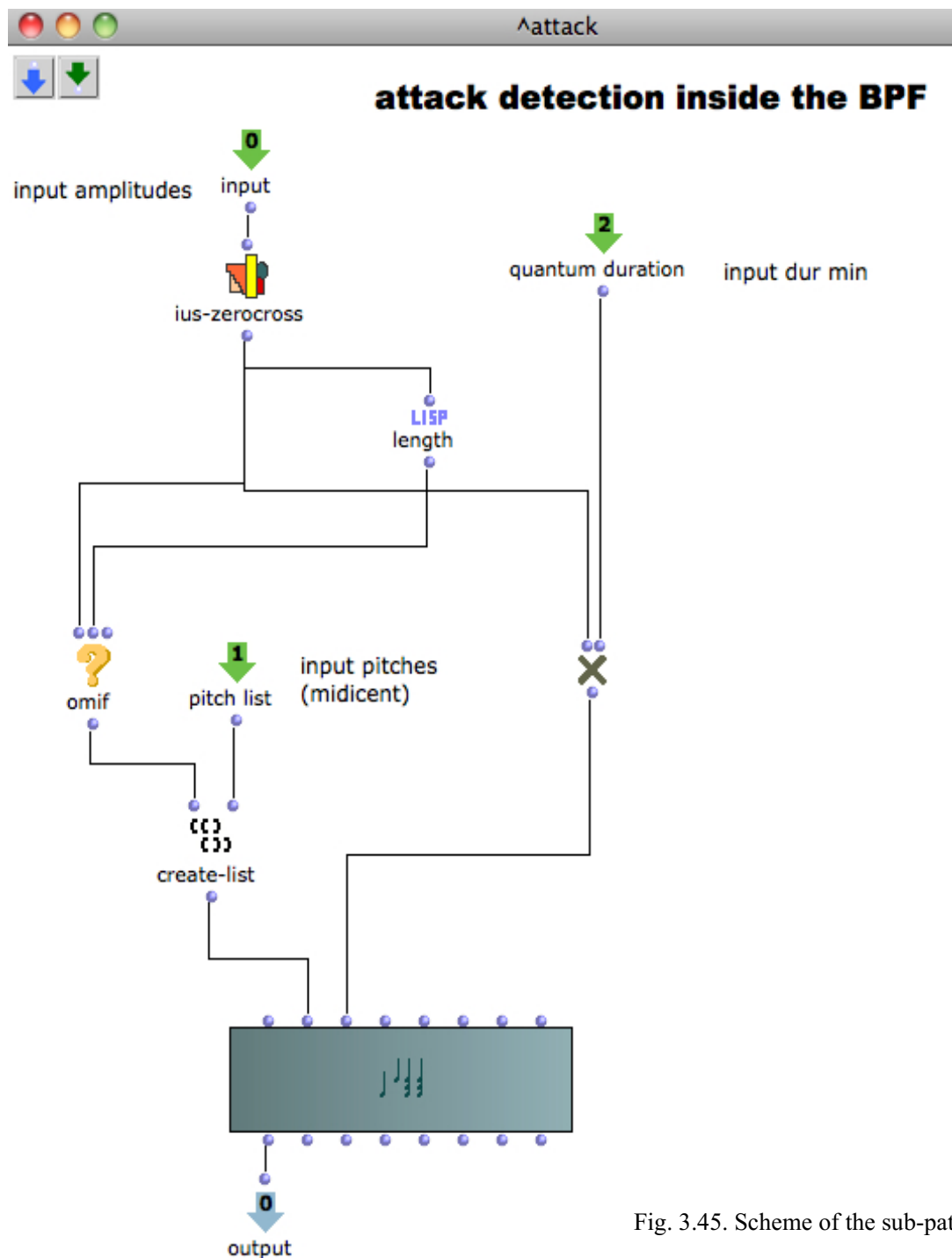
Fig. 3.45. Scheme of the sub-patch *attack*.

The list containing amplitude values coming through *input0* is segmented by the Generic Function *ius-zerocross*, whose result is routed inside a *length*-object (returning the number of elements in the input sequence) as well as inside the Generic Function *omif*. The latter assembles the segmentation data (coming directly from *ius-zerocross*) and the number of elements (coming from *length*) to feed the Function *create-list*, which will build a sequence on notes inside the *chord-seq*. This object (*create-list*) takes the left input (from *omif*) as a list length and the right input (a list of pitches coming from the patch omloop1) as a list of elements. The last parameter needed to build this *chord-seq*, the durations, are given directly

from the entered value of minimum duration (main level of patch *rhythmic-dynamic-analysis*).

Both sub-patches *inflex* and *attack* serve the object *list* (marked with a red circle) to build a series of *chord-seq* that are collected and stored inside the final Poly-object. The ones built inside *attack* will be displayed on the lower system, those built inside *inflex* on the upper system (or *chord-seq*), referring to the same pitch (room-mode).
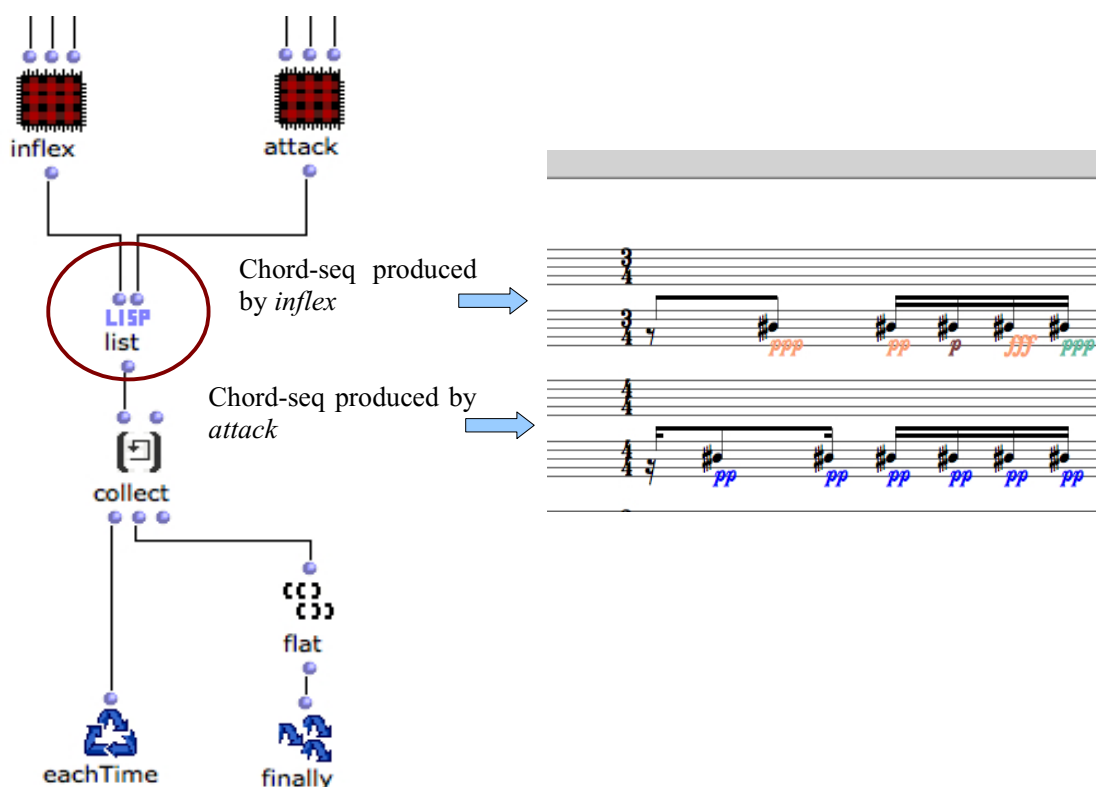
Fig. 3.46. Example of data output, attack and dynamic quantification expressed in a musical format. In the upper system polarity changes in dynamics are marked with different colors: orange (negative), dark red (positive), whereas the ppp (green) refers to zero-points.

In the transcription of such data, due to a list-syntax procedure, some external notes pitched as Middle-C (C_4) might appear at the end of the *chord-seq* (on all systems).

This can happen when list data are truncated and the program fills out the empty elements with default pitches (and default dynamics that are *ff*). In the example below such notes are marked with a red circle (Fig. 3.47):
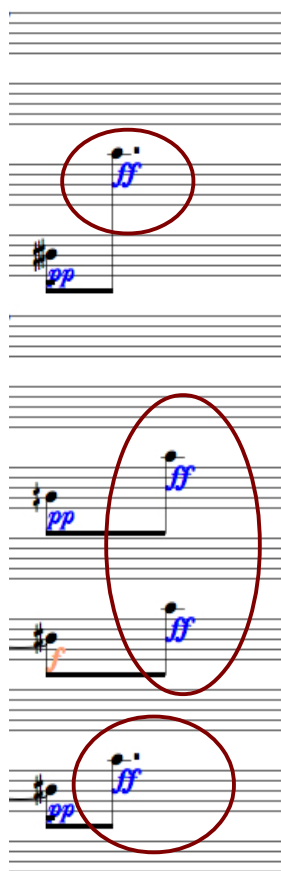
Fig. 3.47. Example of some external notes (pitched as Middle-C) at the end of a chord-seq; these notes don't belong to the analysis and shall be ignored.

3.2.6 A further possible working method

Since the result of a trajectory in the 3D virtual space can be heard thanks to the audio rendering patcher, as shown in 3.2.1 (Fig. 3.18), it would also be possible to work in a different manner, using the already existing spectral analysis tools in the application *Audio Sculpt.* In this case the audio result of a spatialisation trajectory (sinusoids, potentially transposed for better listening quality) would be recorded as an audio file and used to feed an *Audio Sculpt* analysis. Before describing a trajectory using the Max software, produce a memory allocation for an audio file by clicking on the "open" button (connected to a *sfrecord~* object), a dialog window opens asking for the name of such file.
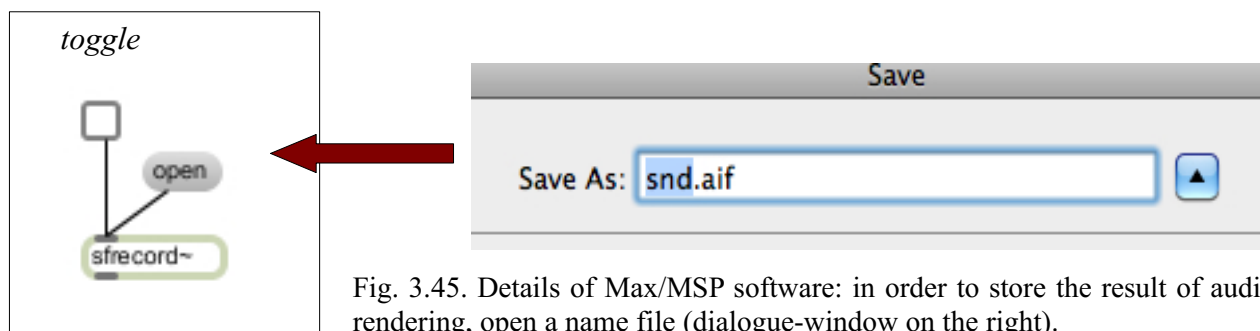
Fig. 3.45. Details of Max/MSP software: in order to store the result of audio rendering, open a name file (dialogue-window on the right).

Once the audio file (mono) is ready to be recorded, the toggle can be switched on and the trajectory can be launched. At the end of the trajectory, the toggle is switched off and the audio file is ready for use. The output audio file would be now visualized (and analysed) with the program *Audio Sculpt* (Fig. 3.46).
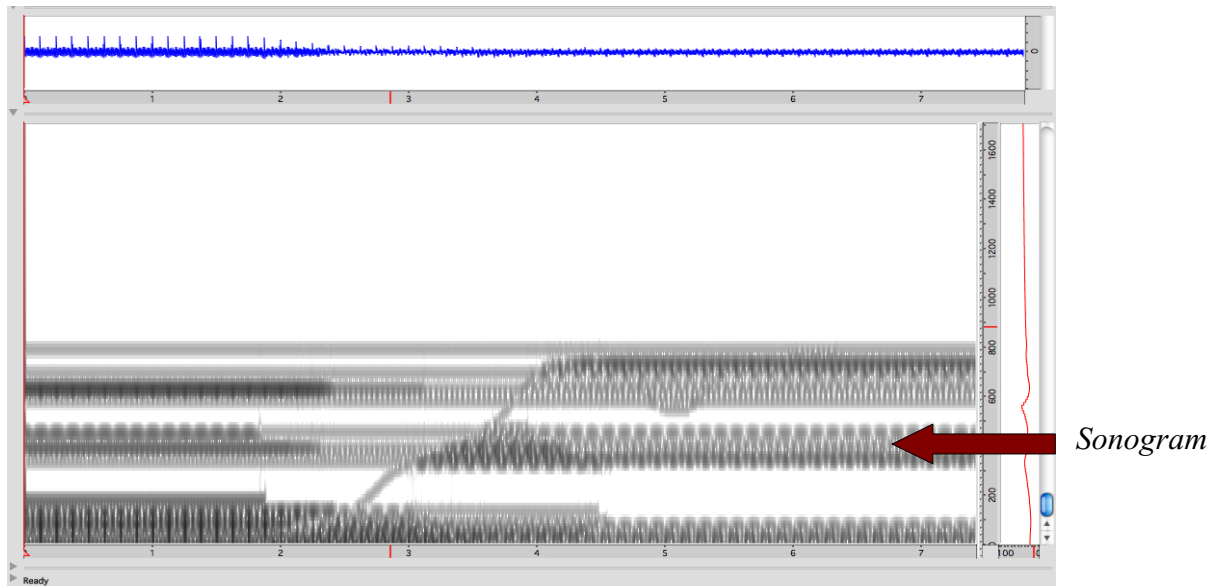
Fig. 3.46. Example of sonogram in the *Audio Sculpt* spectral analysis.

After calculating the sonogram, the usual series of analysis tools can be used, for instance:

Fundamental Tracking Analysis:
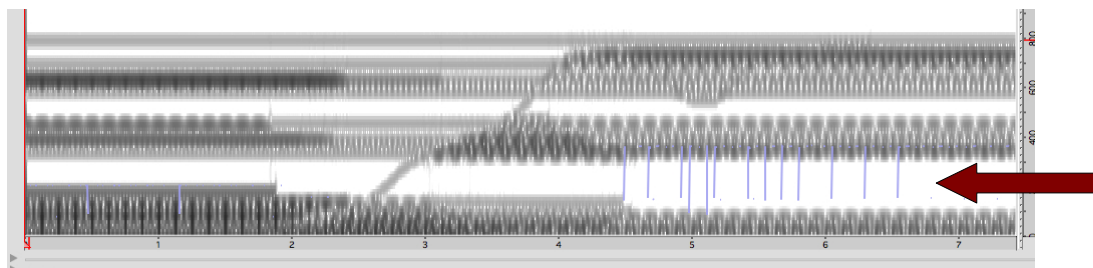
Fig. 3.47. Example of sonogram in the *Audio Sculpt* spectral analysis (Fundamental Tracking). Arrow shows the visualization of fundamental frequencies (vertical lines).

Partial Tracking Analysis:
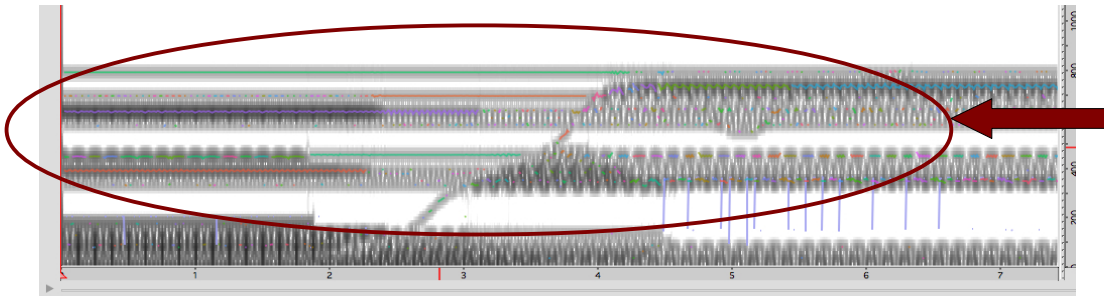
Fig. 3.48. Example of sonogram in the *Audio Sculpt* spectral analysis (Partial Tracking), partial frequencies are marked by different colors.

Chord Sequence Analysis:
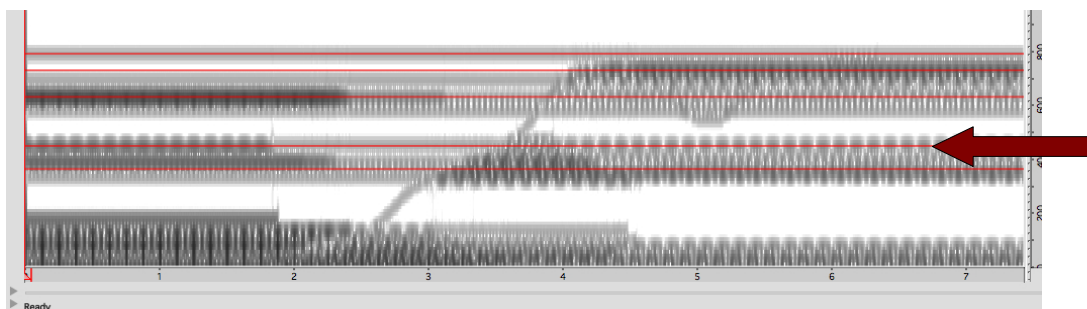
Fig. 3.49. Example of sonogram in the *Audio Sculpt* spectral analysis (Chord Sequence), partial frequencies are visualized and selected to build (in Open Music) a series of chords.

Markers:
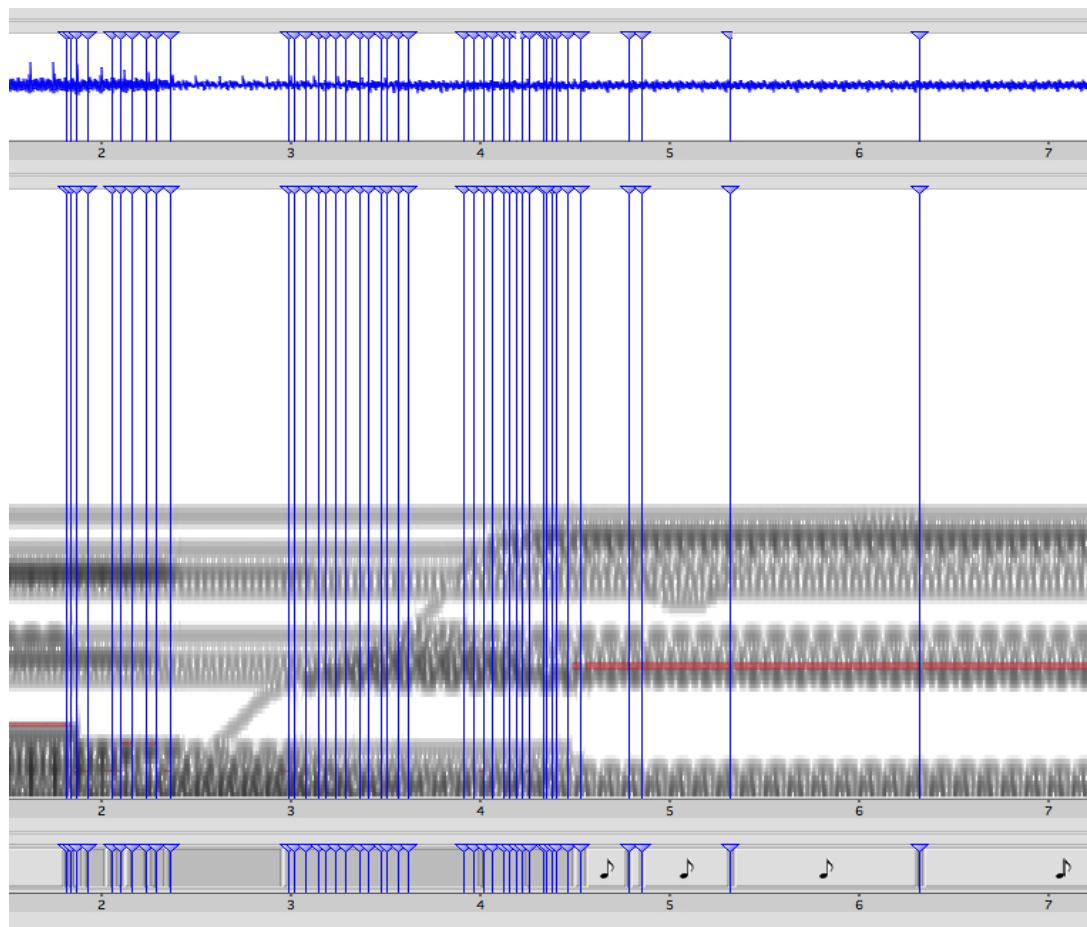
Fig. 3.49. Example of markers in the *Audio Sculpt* spectral analysis.

Partial Tracking Analysis will later be saved on *sdif* files (on the *Audio Sculpt* menu) and used to generate a musical transcription (on five-line music systems), i.e. from frequency values into notes with another Open Music Patch:
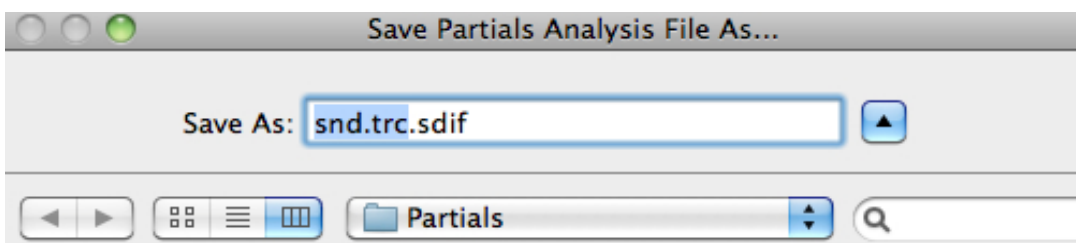
Fig. 3.50. Detail of Audio Sculpt software: dialogue-window to save the analysis result into a file.

Using such *sdif* files for the music transposition within Open Music, means to input them into patches (other than the ones described before and designed expressly for the room-mode analysis transcription) that allow musical transcription.

To this aim, the following Open Music Patch using the *repmus* Open Music Library can be used (Fig. 3.51, *repmus*-example):
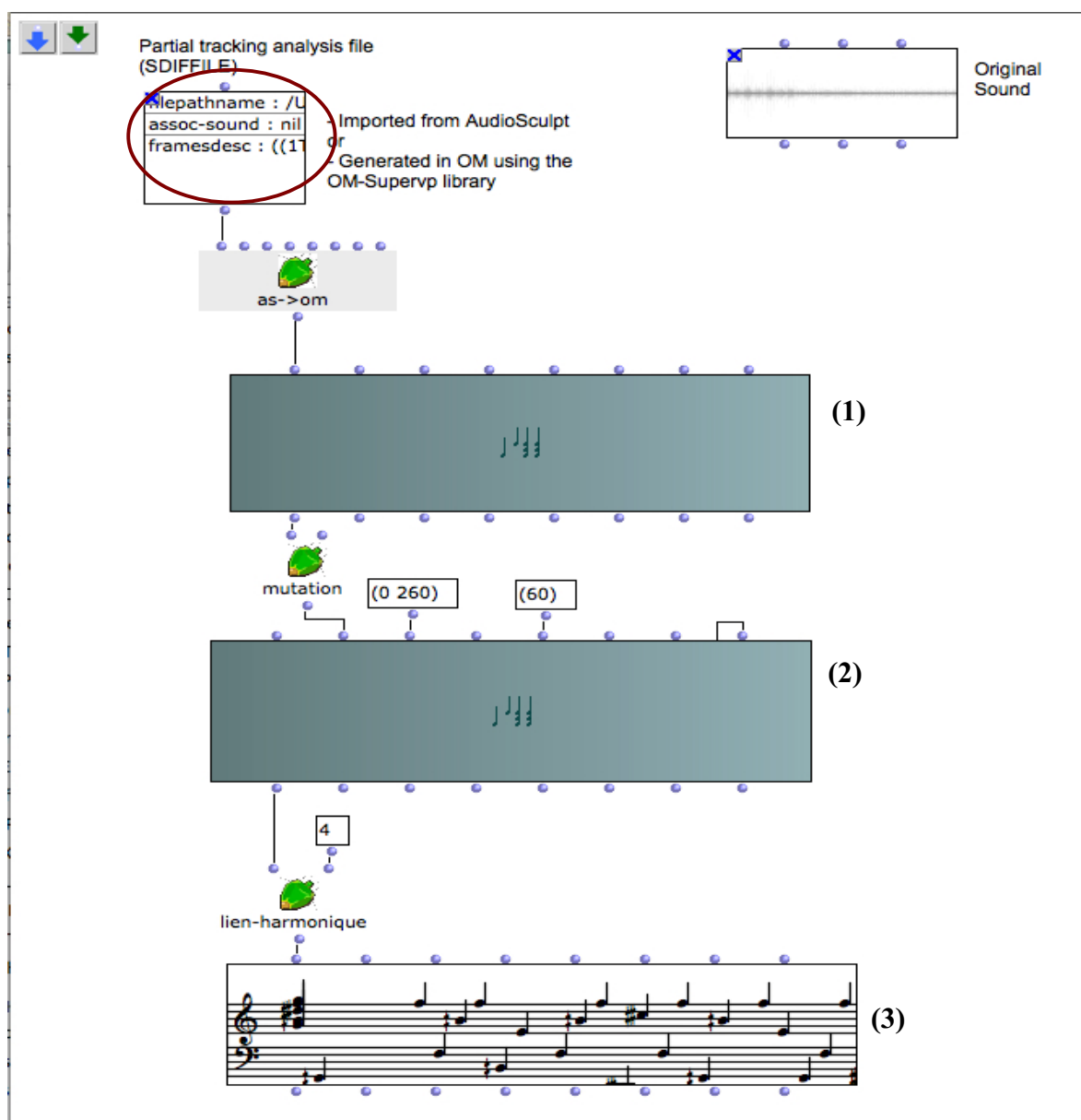
Fig. 3.51. Detail of Open Music software: with the *repmus* library, the result of an Audio Sculpt analysis can be transcribed into music text.

This patch needs the analysis file (*.sdif* format) generated with *Audio Sculpt* Partial Tracking Analysis that should be loaded in the object *SDIFFILE* (marked by a red circle). To load the analysis file, the object shall be evaluated (by select it and pressing the V key), after which a dialogue window asks one to choose a *.sdif* file.

Once this action has been performed, the *SDIFFILE* object can be locked (by selecting it and pressing the B key). The main object in this patch, *as->om* automatically performs (with

default settings) a musical transcription of the whole frequency content of the sdif-file, reported in the *chord-seq* marked with (1):
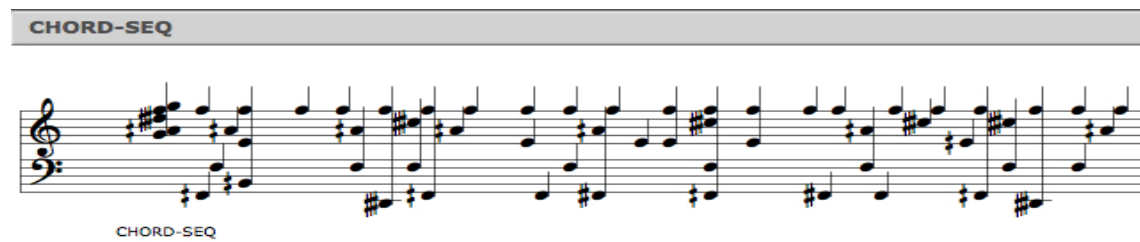
Fig. 3.52. Example of *Chord-seq* (1), outputted from a *repmus* Open Music patch, here all frequencies are transcribed.

Since the result reports the content of the initial sound with extreme fidelity (i.e. the analysis file in *sdif*-format contains a very big number of frequency information), it is useful to filter it to avoid redundancy (the same frequency is detected many times) and transform it into more musical output. Consequently the resulting *chord-seq* is routed into the *mutation*-object, which computes a transition sequence between chords – *chord-seq* marked with (2) – that is finally used to create a sort of polyphony through the Generic Function *lien-harmonique* (from the French: harmonic link) that joins the notes in common between chords. The result of this calculation is shown in the *chord-seq* marked with (3).

Fig. 3.53. *Chord-seq* (3), final result of the analysis with the *as->om* patch, here the musical transcription has been formatted with the Open Music object *lien-harmonique*.

CHAPTER 4

ANALYSIS: *IUS LUCIS*

4.1 An example of practical application, *Ius Lucis* (2006/2007)

In order to describe a practical application of the aforementioned software and some of the operational aspects of a compositional method using the informatics tools described in the previous chapter, this section of our enquiry will provide a detailed analysis of some sections of the musical composition *Ius Lucis* (composed from 2006 until 2007). Because this is the first musical work that has been realized using – in some of its parts – the softwares developed for a room-mode analysis and for a musical transcription (programmed in Max/MSP and Open Music), it will be useful to examine the working process and its artistic output. Before entering the analysis of those sections of the music directly concerned, it will be helpful to have a general overview of the whole work and provide some information that will allow a better understanding of the subject of this analysis. Because all aspects of the work are deeply interconnected, this description will simultaneously summarize both musical and technological matters, practical and substantial issues, hoping to explain how and why the score and live-electronic design are profoundly integrated.

4.1.1 Instrumentation

Ius Lucis is a mixed work (instrumental and electronics) written for two instrumental ensembles (called Ensemble 1 and Ensemble 2), placed in two separate concert halls:

Ensemble 1

oboe 1*, clarinet 1 in Bb*, one percussion player (gongs, *Plattenglocken*, wood-blocks)
flute 1 (doubling bass flute), horn 1 in F, violin 1 – placed on the left
viola 1, cello 1, contrabass clarinet in Bb – placed in the middle
flute 2 (also bass flute), horn 2 in F, violin 2 – placed on the right
synthesizer (only for live-electronic control), principal conductor.

Ensemble 2

oboe 2* (doubling english horn), clarinet 2 in Bb* (doubling bass clarinet in Bb), trombone 1* and trombone 2* (each playing a medium-sized tam-tam with a vibraphone mallet), viola 2, cello 2, assistant conductor (in some sections synchronizes Ensemble 2 following the main conductor on a video screen).

* instruments *playing in standing position*

4.1.2 Spatial set-up and implications on compositional decisions

The principle characteristic of the work *Ius Lucis*[1] is certainly its spatial organization, since the two instrumental ensembles are placed in two separate concert rooms, which are connected using different technologies.[2]

First of all, it is crucial to say that the audience is placed in both concert rooms: the idea of having two different (but with strong structural and musical relations) musical developments is a central point of the whole project. Each audience listens successively to the first and the second ensembles (or vice-versa: the decision can be made spontaneously, nevertheless starting with one or the other gives a different perception of the work as a whole) and then changes place after the intermission. When listening to the second part (Ensemble 1 or 2) the music presents new materials as well as already heard elements, which are more or less difficult to recognize. Surely the experience of having a listening process dealing with memory (each listener memorizes a certain amount of music elements during the first part

---

1. The complete title of the work is *Ius Lucis for two Ensembles in two theaters* (2006/2007).
2. The first performance of this work took place on June, 6th 2007 in Paris at *Grande Salle* (Centre Georges Pompidou) and *Espace de Projection* (I.R.C.A.M.), the two rooms were connected by optical fiber cable. In the second public performance at ZKM (Zentrum für Kunst und Medientechnologie) in Karlsruhe (Germany) it was performed inside the two concert halls of the centre, the Medientheater and the Kubus, signals were routed inside the internal server and routed to each room. The aim was to avoid too big of a delay in the transmission of signals between the two rooms.

that are immediately put in another context while listening to the second part), broadens perspective on the idea of musical performance, requiring highly developed listening skills of the audience. As a matter of fact, the dislocation of the musicians is the result of two factors, which are of both artistic and practical nature.

On one side, this decision was made in order to allow more effective electronic sound transformation: the so-called cross-synthesis (a sound transformation happening between two signals, whose timbres are mixed by using the spectral envelope of the first – called modulating signal – and the spectrum without any amplitude of the second – called carrier), which in this piece happens in real-time. By separating the two instrumental groups, there is no masking effect of the modulating signal (coming from the other room) on the transformation result. Such cross-synthesis happens in both directions as shown in the graphic below:
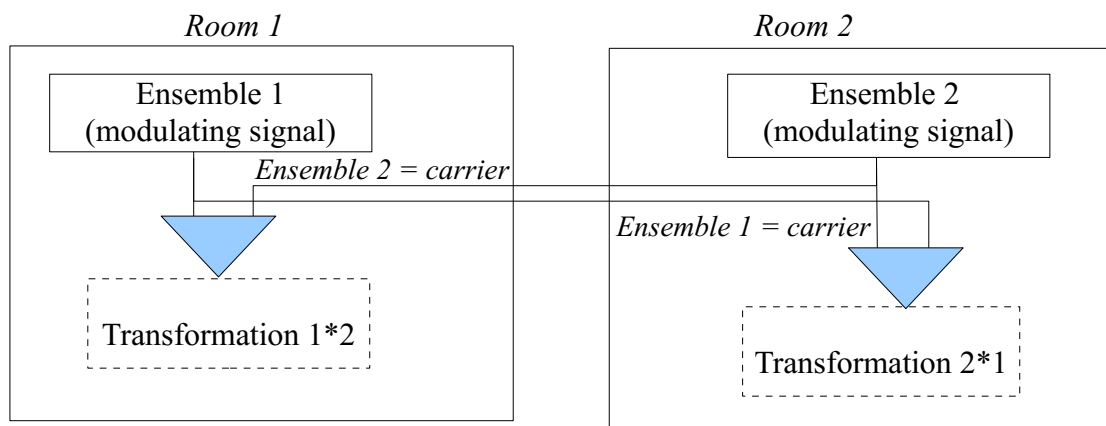
Fig. 4.1. Scheme of live-signals and live-electronic interactions and routing between the two performance rooms: Transformations can be both local (only one ore more live-signals are transformed and projected in the same room) and remote (one ore more signals are transformed with remote-signal(s).

By avoiding the acoustic presence of both signals in the room, the results of real-time transformations (Ensemble 1 modulating Ensemble 2 and vice-versa) are clearly perceivable, since each time one of them is played in a remote position (the carrier). As each of the two ensembles are playing different sounds (with some relationships that we will see later), a new layer represented by electronic sounds joins the musical development in each concert situation. On the other side, it is easy to understand that such a configuration develops an aspect of musical composition that can be seen throughout history in similar works[3] (for

3. At least two representative examples of overlapped works can be cited: Darius Milhaud's (1892 – 1974) 14th and 15th string quartets composed between 1948 and 1949 that can be played also together as string octet; *Hoch-Zeiten* by Karlheinz Stockhausen for choir and orchestra in two rooms (composed 2000– 2001 as the 5th scene of his opera *Sonntag aus Licht*). Where in the first example the two parts are added, in the second the composer structures the work in order to superpose some sections between choir and orchestra, this is accomplished by projecting remote musicians' sound into the second room and vice-versa using the cable connection. Karlheinz Stockhausen presents the work as follows in the program presentation of the first performance: *[...] „Siebenmal während der Dauer von circa 32 Minuten werden Momente der Orchestermusik in den Saal der Choraufführung eingeblendet, und siebenmal Momente der Chormusik in den Saal der Orchesteraufführung. In der Pause wechseln Chor und Orchester die Säle, so daß jeder Hörer zwei sehr verschiedene und doch verwandte Teile erlebt. Der Titel HOCH-ZEITEN meint musikalische Ergänzungen und Vereinigungen der fünf Sprachen und*

multiple orchestras or instrumental groups) reaching a triple level of musical counterpoint in *Ius Lucis*:

- Counterpoint within each ensemble (traditional counterpoint as in polyphonic works);
- Counterpoint between the two ensembles (all those relationships that are taken into account to assure an effective live-electronic real-time transformation[4]);
- A global counterpoint that can be defined as structural, as the two parts at some points cross and intersect.

This being the case, an apparent limitation such as splitting the instrumental ensemble into two parts gives an array of musical and technical possibilities, and it is important to remark that these are linked to the concerns of real-time interactions in music performance. This is to observe the palette of different ways to use instrumental sounds vis-à-vis live-electronics in such a configuration. An instrumental sound knows a vast degree of possibilities, from not transformed to fully transformed, when put in the context of a parallel musical action in which it can take part according to various compositional rules. For example, an instrument 1 from Ensemble 1 (first concert room) could be used (and therefore routed) to interact with another (remote) instrument 2 (placed in the second concert room, belonging to Ensemble 2) as shown in the next graphic (Fig. 4.2).
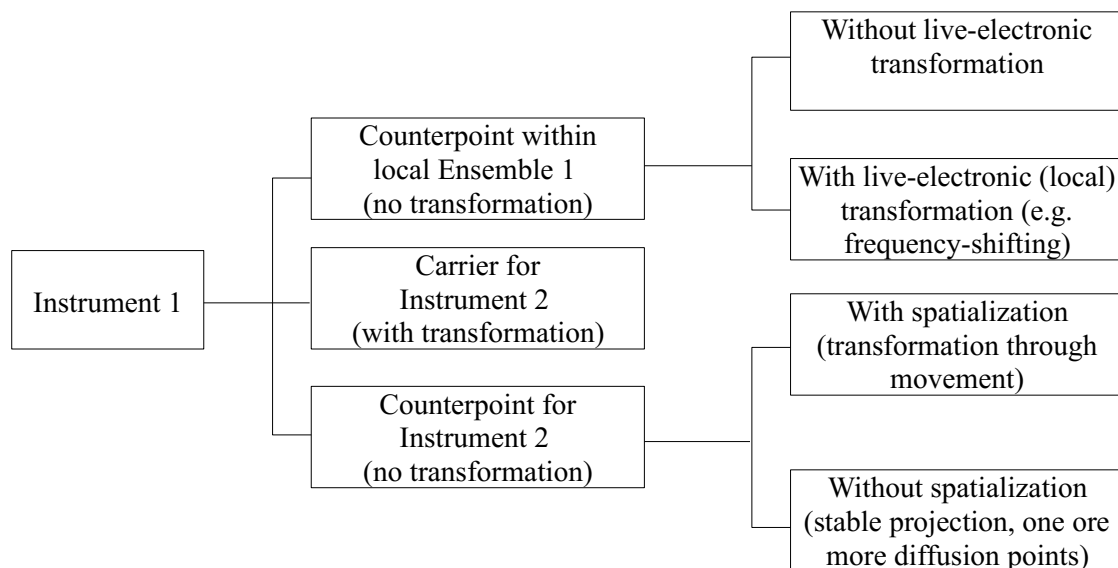
Fig. 4.2. Diagram of the possible utilizations that a generic instrument can have inside the score or within the live-electronic transformation (and spatialization) techniques.

Of course, an instrument can have more than one of the above-mentioned functions, as it can behave for instance as both local counterpoint and carrier for the remote ensemble at the same time (since instrumental mapping between Ensemble 1 and Ensemble 2 is not parallel).

---

fünf instrumentalen Charaktere. Die fünf Chorgruppen und fünf Orchestergruppen werden mit Taktspuren synchronisiert, die ich gesprochen habe und die zu den lenkenden Musikerinnen bzw. Musikern der zweimal fünf Gruppen über Kopfhörer übertragen werden." [...] Karlheinz Stockhausen, "Hoch-Zeiten Programme," *Stockhausen-Verlag,* 2002, http://www.stockhausen.org/hoch_zeiten_programme.pdf.
4. When using cross-synthesis it is imperative to have two signals that are very different in timbre (spectrum). For this reasons not only single instruments are coupled but also groups of more instruments on each side (ensemble) are routed together to create a complex sound.

Different routing decisions have been made to assure a variety of musical discourse. The following graphic example shows a possible relationship between Ensemble 1 and 2 for each perspective (concert room):
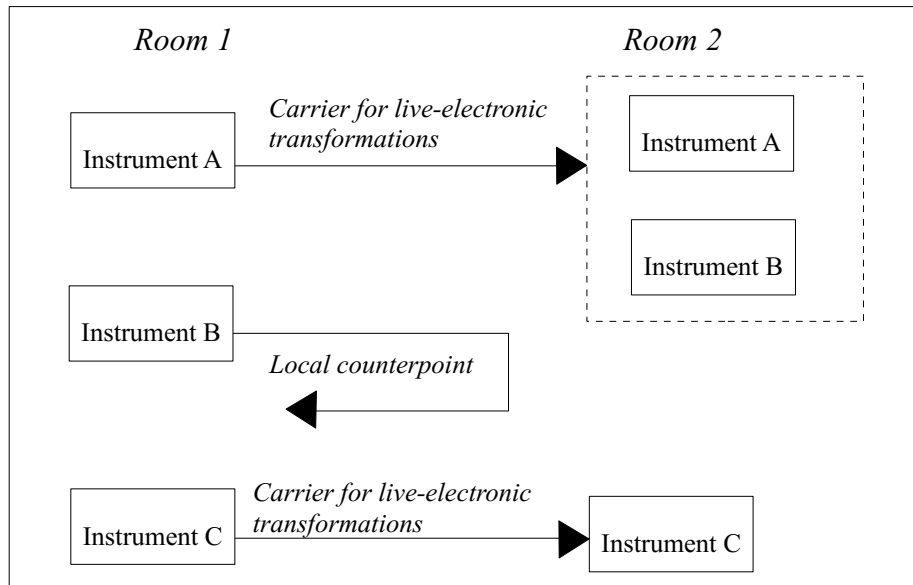
Fig. 4.3. Example of the multiple utilizations of some instruments according their local or remote functions.

And from the opposite perspective, from Room 2 to Room 1 (picture below):
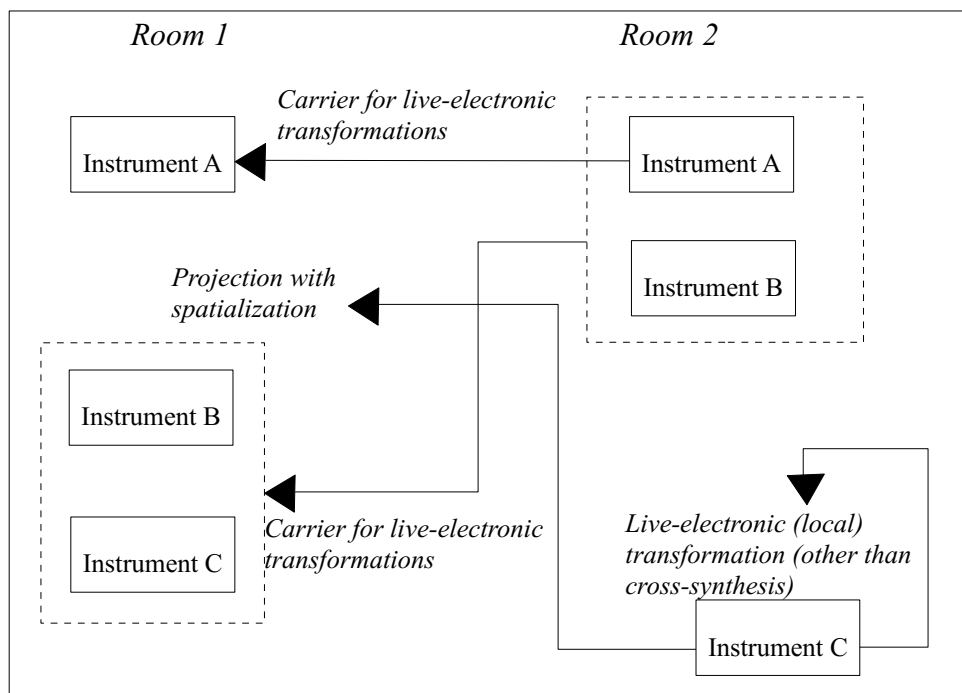
Fig. 4.4. Example of the multiple utilizations of some instruments according to their local or remote functions. Such mapping is not symmetrical. Different combinations and solutions have been found for each Ensemble depending on musical needs.

The spatial set up of *Ius Lucis* is indeed designed to allow a large range of choices in combining instruments (and groups of them) between local and remote ensembles in the compositional process, as seen in the examples above. Furthermore, another spatial feature has been introduced: Instruments are placed in two different ways inside the two concert rooms, in order to create two fully different acoustic situations for the listeners, a traditional frontal arrangement on the stage (Ensemble 1, though placed stereophonically) and an immersive one (Ensemble 2, musicians are playing around the audience). These arrangements on stage and inside the concert room are designed to allow a differentiation between the two parts of the musical work, but also to reach a certain degree of spatiality in the instrumental writing itself, given that, as is well known, a dislocation of sound sources (also within the frontal grouping) activates a perception of space. The next graphics (Fig. 4.5 and 4.6) show the arrangements of Ensembles 1 and 2:
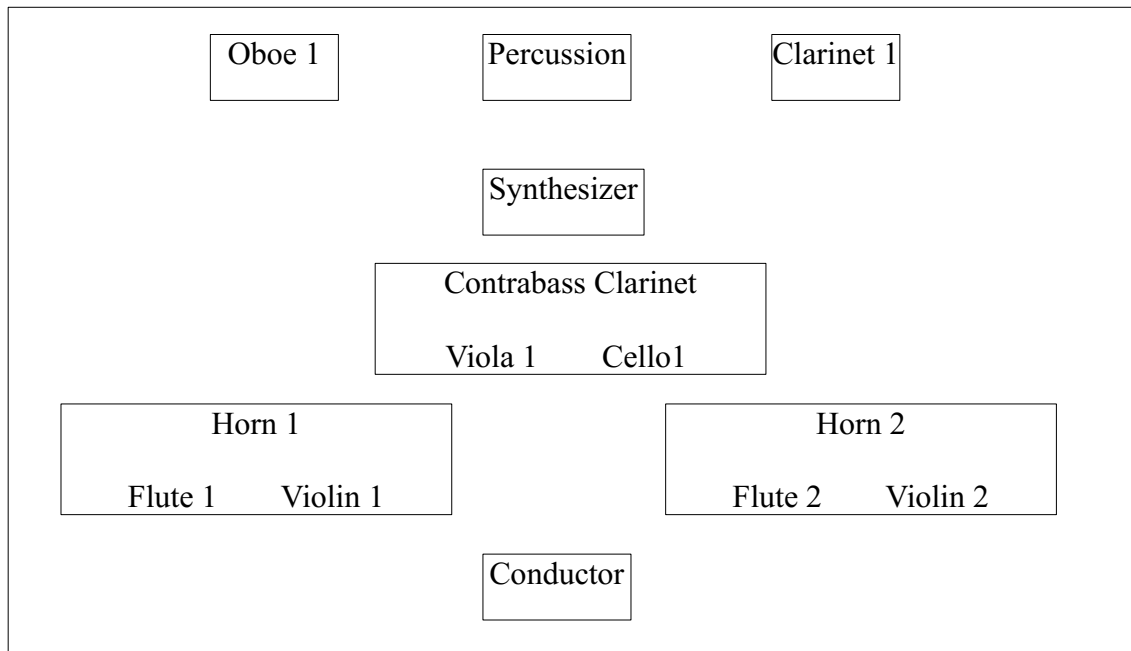
Fig. 4.5. Placement of Ensemble 1 on stage (Room 1).
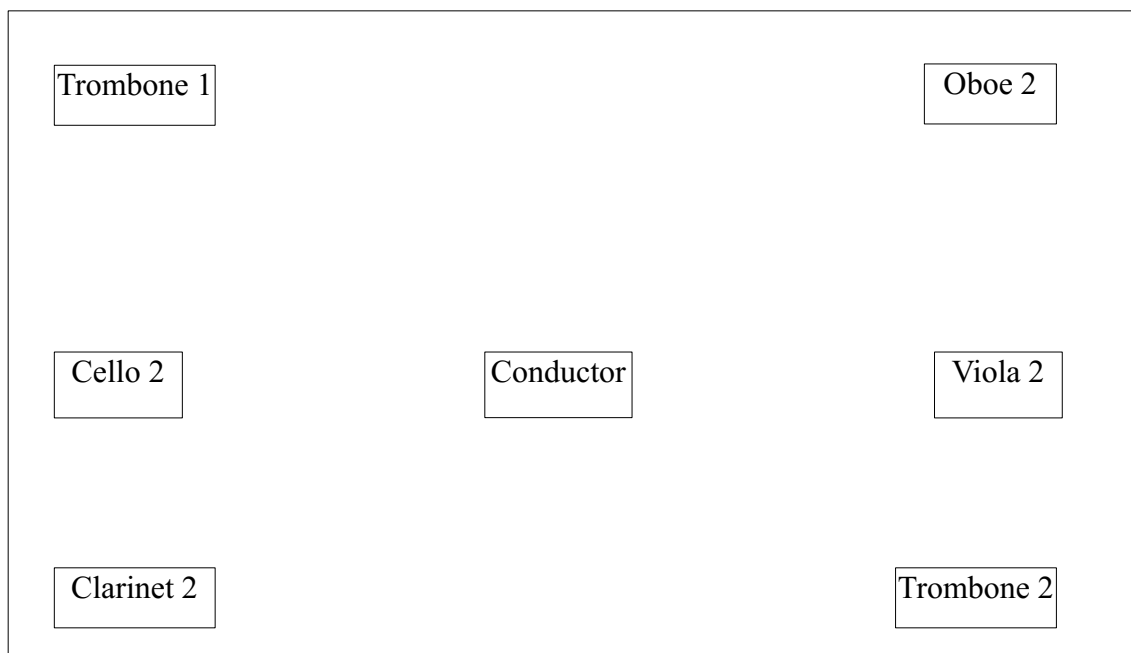
Fig. 4.6. Placement of Ensemble 2 (Room 2): here instruments are placed around the audience.

After having seen the placement of acoustic sound sources (instruments), the following two graphics will show the positioning of loudspeakers, organized as a twelve-point diffusion system (concert room 1) and an eight-point system (concert room 2), both surrounding the audience:
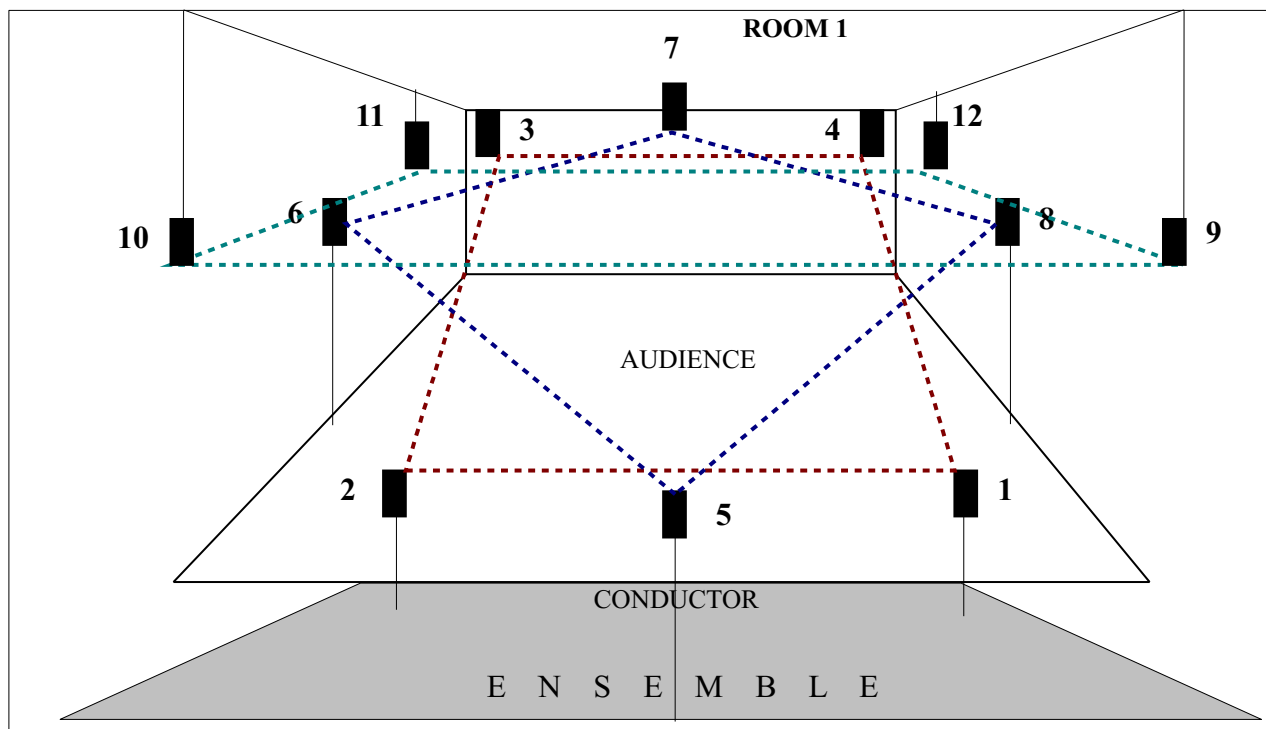
Fig. 4.7. Scheme of Room 1: audience, ensemble and loudspeaker placement.

In the first room (above graphic: perspective seen from the stage), three groups of four loudspeakers each are placed at different heights around the audience, extending the acoustic space created by the ensemble into the audience. In the second room (below graphic), two four-speaker groups are also placed at two different heights and close to the six musicians who are placed around the audience. This loudspeaker positioning basically doubles the circular arrangement of the six musicians.
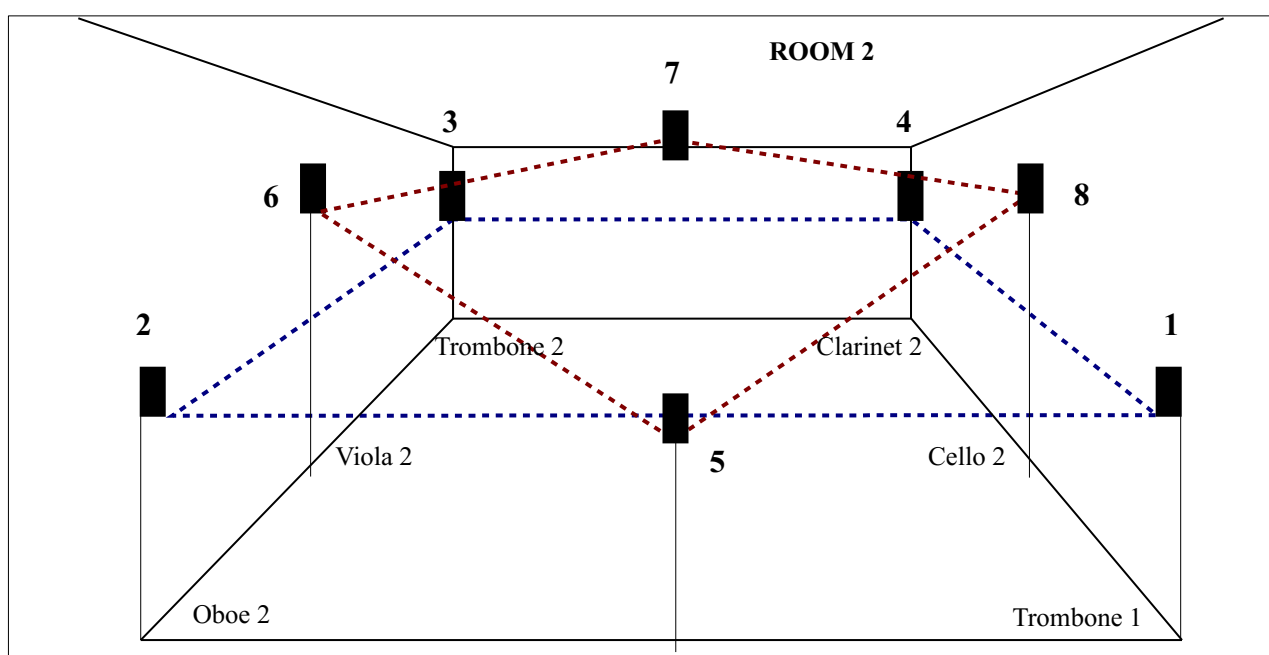
Fig. 4.8. Scheme of Room 2: audience, ensemble and loudspeaker placement.

4.1.3 General overview of the score and live-electronic platform (patch)

On each page of the full-score of the work, both ensembles (playing synchronously) are divided according to instruments' placement on the stage (Ensemble 1) and according to the usual orchestral score-order hierarchy (woodwinds – brass – strings) for Ensemble 2. The larger ensemble is separated into four main groups: A group at the very back of the stage (oboe 1, clarinet 1 and percussion), a central one (viola 1, cello 1 and contrabass clarinet) and two identical trios (flute, horn and violin) placed on the left and on the right are graphically separated, as each one is meant to constitute a unit. At the bottom of the upper page half, the keyboard music line (this midi instrument is used only to trigger live-electronic programs so it is basically playing chromatic scales as each midi note sends a new program – or new parameters – to the computers) and the live-electronic systems complete the Ensemble 1 score. The same positioning of live-electronic staves is chosen for Ensemble 2. This reflects the choice to use a concert-patch (a single interface programmed in Max/MSP) running on both computers (in room 1 and room 2) but with only one half active:
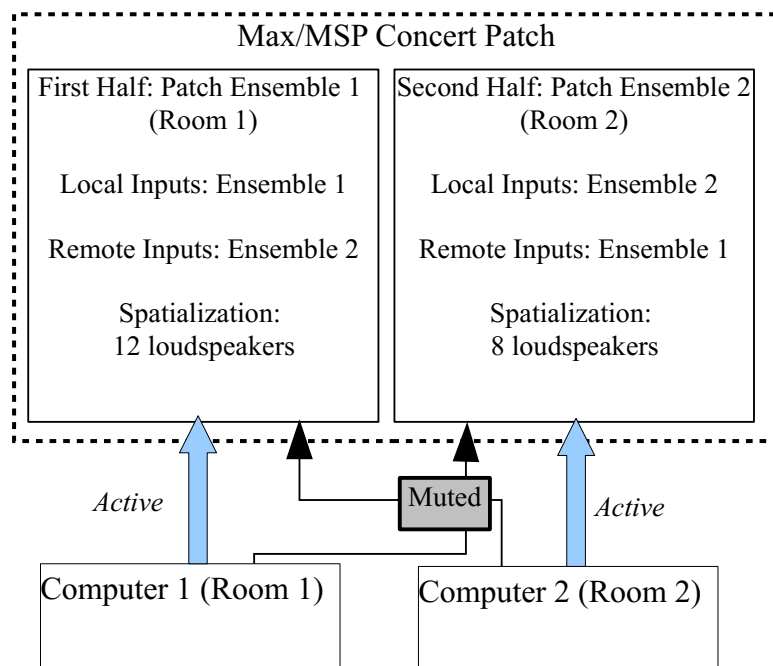
Fig. 4.9. Scheme of the overall architecture and correspondence between concert rooms and Max/MSP (and sound) control.

Following pictures show the main level of the Max/MSP interface with the part for Ensemble 1 and 2 activated (and muted):
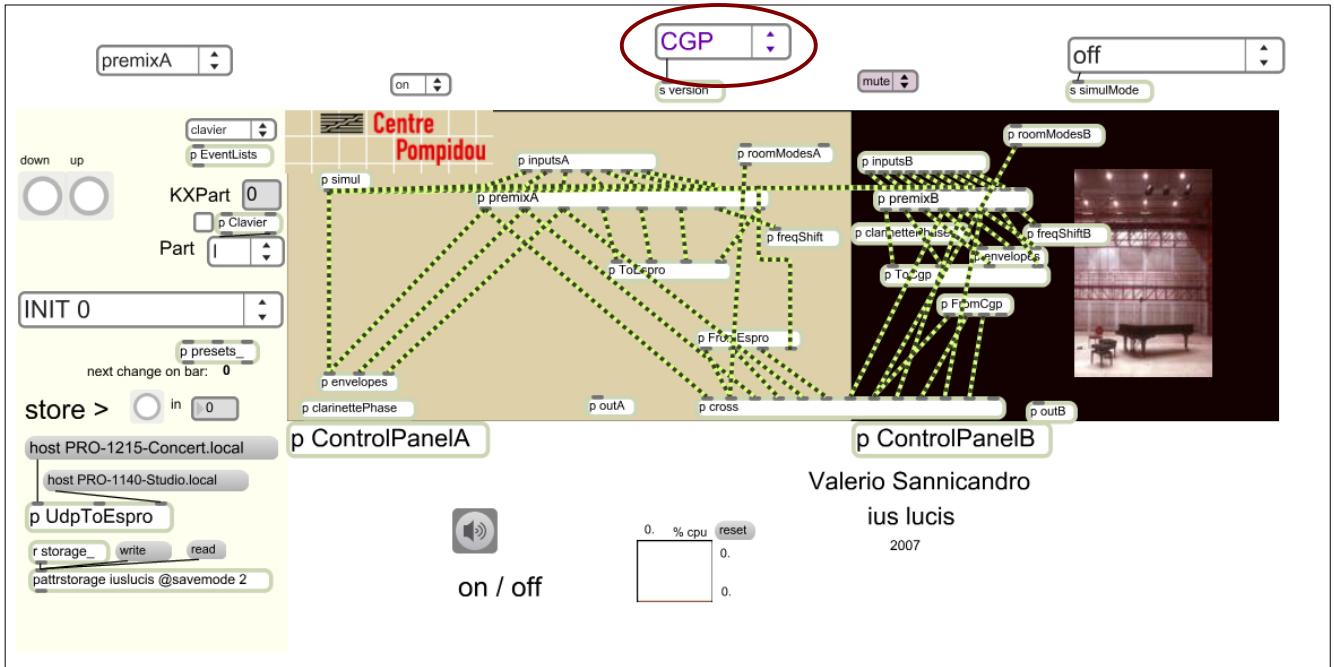
Fig. 4.10. Max/MSP Interface activated for Room 1: *CGP* (Centre Georges Pompidou, Room 1 for the first performance of the work), the second half is muted (black area).
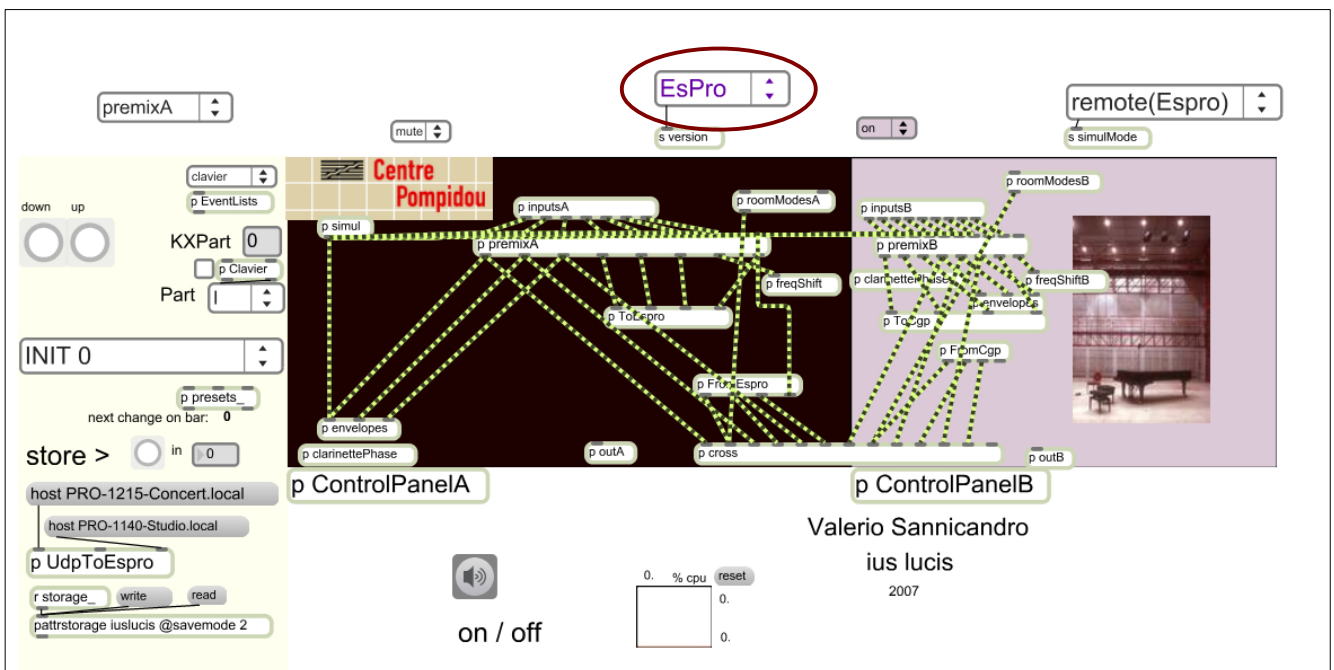
Fig. 4.11. Max/MSP Interface activated for Room 2: *EsPro* (Espace de Projection, Room 2 for the first performance of the work), the first half is muted (black area).

To underline the cyclical idea of two twin-pieces (Ensemble 1 and 2, which are both complementary and autonomous), another feature has been introduced to metric structure: The two parts running synchronously are thought as metric palindromes. Excluding the central part of the work (which is written rhythmically in space-notation), the measure order is perfectly symmetrical:
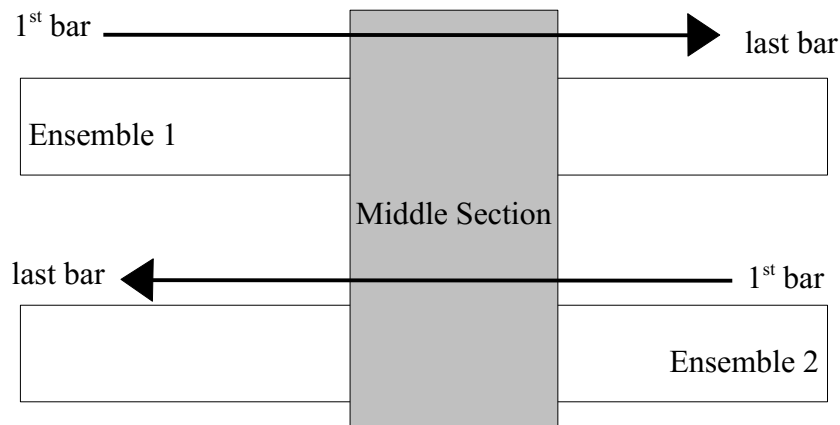
The following example shows the way in which the metric structure of the work has been built

Bars:	5	6	7	8	9	10	11	....	643	644	645	646	647	648	649
Metric:	$\frac{4}{8}$	$\frac{3}{16}$	$\frac{6}{8}$	$\frac{3}{16}$	$\frac{2+3}{32}$	$\frac{2}{8}$	$\frac{4+3}{32}$	....	$\frac{3+4}{32}$	$\frac{2}{8}$	$\frac{3+2}{32}$	$\frac{3}{16}$	$\frac{6}{8}$	$\frac{3}{16}$	$\frac{4}{8}$

The same symmetry has been used to compose the harmonic structure of the work. Two palindromic, harmonic paths are superposed, as shown in the graphic below:
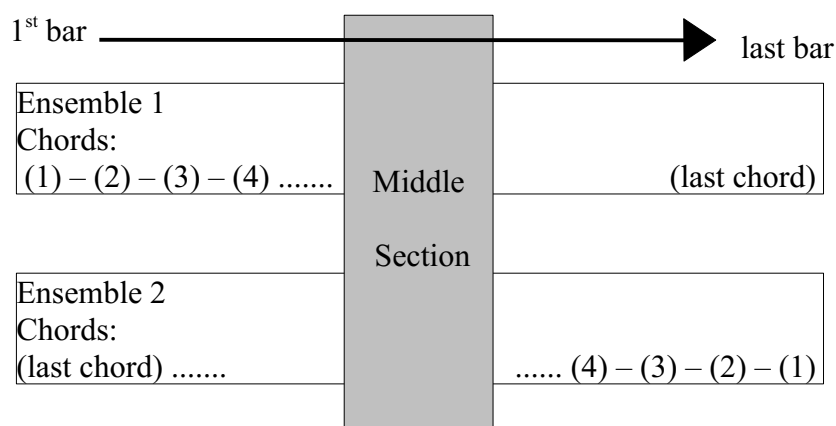
In this case, such superposition is not as strict (completely symmetrical) as in the metric structure, since the harmonic path has a musical direction. In order to preserve the inner musical coherence of the harmonic sequences, chords have not been inverted with a mere

geometrical retrogradation. Instead, each section is described by a harmonic succession and keeps the same chord repertoire but the evolution and permutation order are different (chords are mixed, split and combined differently when used to compose polyphonic structures within an ensemble).

To explicate some sections of the work and show this procedure in greater detail (which also contains many moments where this principle is not rigorously followed, especially in the permutation and dislocations of chord pitches in time), on the following pages, two parts of the score are compared and explained: The beginning section (from bar 1 to 63) of Ensemble 1 and the ending section of Ensemble 2 (from bar 591 until the end). The harmonic sequence on which this section has been composed consists of four main chords which are almost used in their original version in Ensemble 1:

Chord (1)   Chord (2)   Chord (3)   Chord (4)
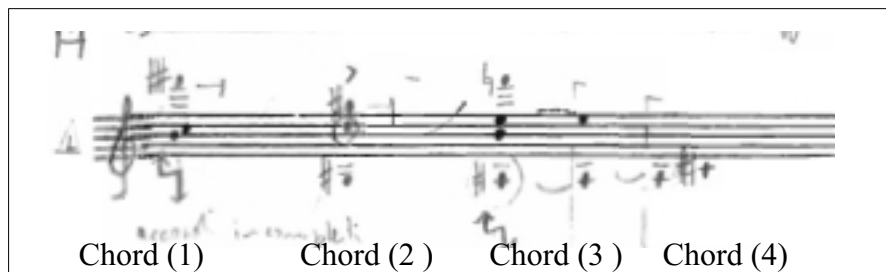
Fig. 4.12. *Ius Lucis* - manuscript with the harmonic structures (detail), the first four chords used for the beginning of Ensemble 1 part.

These are taken from a chord-repertoire that is used as a basis for the whole work (see next picture). Although it is not directly connected to the use of resonance modes, this table can be useful for the explanation of some parts of the score. It is conceived as a network of chords (using quarter-tones as the thinnest pitch definition) where harmonic sequences are built following different paths (horizontal, diagonal or a combination of both, from left to right and vice-versa).

Fig. 4.13. *Ius Lucis* – hand-written scheme of the global chord repertoire.

The first chord (1) is clearly visible in the first bar of the piece and lasts several bars (Ensemble 1). It is used to generate a continuum of changing timbres between different groups (the opposite trios, left and right), it appears complete (three pitches: B, C and F-three-quarter-tone-sharp) in measure 2. The highest note comes for short moments and disappears again, it is kept steady inside the chord later in measures 4 and 14. From bar 6 (trio right) a slight variation of this chord appears (A-three-quarter-tone-sharp instead of B-natural) in violin 2 (double stopping):

Fig. 4.14. *Ius Lucis* – excerpt from the score: bars 1–4 (Ensemble 1).

The next chord (2) appears in bar 15, resulting from a crescendo of both trios, where, again, a tight and delicate change of timbres is created, almost completely parallel except for some *sforzandi* distributed successively (later in bar 19) to horns 1 and 2 (Fig. 4.15).

Fig. 4.15. *Ius Lucis* – excerpt from the score: bars 12–17 (Ensemble 1).

The third chord (3) enters slightly modified (in its three-note form, B, D-sharp – instead of E-natural – and high F) in bar 30, but it is prepared (only the D-sharp) beginning in bar 23 when the middle trio enters, (its first entrance in the piece). After a short moment when it is heard complete (one bar), the two trios (left and right) start a dialogue-like section again, focussing on only one pitch: the high F, using many timbres, dynamics and articulations until bar 38 (where all three notes are heard) and bar 41, where the trio in the middle enters again (B- and E-natural), showing the chord (3) in its original form (see Fig. 4.16).

Fig. 4.16. *Ius Lucis* – excerpt from the score: bars 25– 33 (Ensemble 1).

The last chord (4) in the example shown below (the third, A-sharp, C-three-quarter-tone-sharp) starts to appear at bar 52 (in its complete form in bar 63). Again, in this case a new chord is used to underline the entry of a new instrument, the contrabass clarinet, which until this moment was tacet (it enters with a very characteristic percussive sound on a new pitch, G-sharp).

Fig. 4.17. *Ius Lucis* – excerpt from the score: detail of Ensemble 1 (bars 52 – 54).

However the A-sharp appears before this moment, in bar 48 (viola and cello), where there is a transition chord (A-sharp, E) that is heard in bar 47 – as to prepare the new section with a defined change of timbres – played by the two trios (left and right) *unisono* but with slightly de-phased, quick *crescendi-diminuendi* (marked by two ovals). This chord lasts, with some variations, until measure 74.

Fig. 4.18. *Ius Lucis* – excerpt from the score: bars 42–51 (Ensemble 1).

The same chords can be found in Ensemble 2, albeit with some substantial changes (due to musical necessities) and mixed with other notes, at the final section of the score, from bar 579 until the end of the work[5]. In this case, as has already been explained, chords are placed in inverse position. This means that, following Ensemble 2's harmonic path chords (1), (2), (3) and (4) will appear in retrograde (from the 4th until the 1st). Chord (4), the first to appear in Ensemble 2, actually starts at bar 595 (only one pitch, A-sharp played by clarinet 2 and A-three-quarter-tone-sharp played by cello 2 with the same technique – left-hand *pizzicato* with *col legno* bowing as seen performed by cello 1 in Ensemble 1).

5. This section corresponds structurally to the starting section (Ensemble 1) from bar 1 to bar 74. As it happens in Ensemble 1, Chord (4) is mutated and transformed during the last measures of this section. Therefore it will be more useful to track the harmonic development of Ensemble 2 starting some bars later.

Even if the corresponding section begins in measure 592, the new harmonic context of Chord (4) that will be, step-by-step, A-sharp and C-sharp, is prepared through a short segment of four or five bars. This connection from the previous musical and harmonic situation is made by the two trombones, trombone 2 starts a soft G-three-quarter-tone-sharp (low register) after a dramatic, scream-like cluster crescendo (woodwinds and viola – with double-stopped natural harmonics). This note is used to trigger a new section approaching harmonically to Chord (4), since it leads to a low A-sharp (trombone 1), an A-three-quarter-tone-sharp (very high register, played by viola 2 as and artificial touch-fourth harmonic), a B-natural *sforzando* (viola 2 – pizzicato and trombone 1), which is finally a prelude to cello 2 (left-hand *pizzicato* on B-natural and *col legno* A-three-quarter-tonr-sharp). As has been seen in Ensemble 1 at measure 47, the transition chord (A-sharp, E-natural) appears as well in Ensemble 2 at bar 607 (marked by a square). This is the section corresponding to Chord (3), but in Ensemble 2 this chord appears in a manner different from the original version.

Fig. 4.19. *Ius Lucis* – excerpt from the score: bars 607–614 (Ensemble 2).

In fact, later (from bar 612) the two trombones again start a transition section polarized on A-sharp and C-sharp (fourth chord, slightly modified), which could be considered a reminiscence of the previous harmonic situation,that is to underline the birth of a high cluster chord (signalized before always with a A-sharp or A-quarter-tone-sharp, for instance in bar 585 – trombone 1 *sforzato*, bar 589 – trombone 2 *sforzato*). The new high, scream-like chord, played as a crescendo comes out this time on a high B-natural, played by both trombones in unison (measure 614). In this section, Chord (3) is atomized, and developed musically according to each of its components, overlapped with other harmonic materials.

At the beginning of this part, bar 607, the B-natural (oboe 2, bar 608) and the highest note of Chord (4), F-natural, on which the musical development seems to focus up to the unison at end of this section in bars 620–623 (see Fig. 4.20), appear successively over the transition chord (A-sharp, E-natural, G-three-quarter-tone-sharp).

Fig. 4.20. *Ius Lucis* – excerpt from the score: bars 615–623 (Ensemble 2).

The second chord in Ensemble 2 also follows a very different path, since it is mutated or used only in some parts, mixed with other tones. It formally appears (following the metric symmetry) in bar 639 (corresponding to bar 15 for Ensemble 1), marked by a rectangle in Fig. 4.21 (although it timidly appears before in bar 632 played by viola and cello).

Fig. 4.21. *Ius Lucis* – excerpt from the score: from bar 639 until bar 644 (Ensemble 2).

This chord began to be prepared in bar 627 (the new section starts actually at bar 625 but the previous sections needs still two bars to fade out), with the D-natural (played by cello – natural harmonic – and trombone 1). Later, as a melodic transformation of the chromatic *Flatterzunge* scale-fragment (clarinet 2, also playing quarter-tones) in bar 627, the high G-sharp of chord (2) appears (last beat of bar 629) as the beginning note of a new chromatic, descending scale-fragment. The following section, on account of its length, features Chord (2) passing through various states. The bars following the micro-tonal scale-fragments (bars 630–631) are defined by a cluster-like harmony (focused within a minor second): D-natural, D-sharp, D-three-quarter-tone-sharp played by the cello, and E-natural played first by trombone 1 and then by the viola. Or, for instance, in bar 633 after a short appearance (previous bar) in its original form, it is superposed to the E and high F of Chord (3).

Finally, the section corresponding to Chord (1) as seen in Ensemble 1, is found in the measures from 640 until the end. At this point the initial three-note chord is changed (A-sharp instead of B-natural) and has additional notes, for example E (played by the clarinet and cello – as flageolet) or D (played as a double-stop chord by the cello in measure 644).

Fig. 4.22. *Ius Lucis* – excerpt from the score: bars 639–644 (Ensemble 2).

Such external notes tend to disappear by the time the piece reaches its end (coherent with the idea of harmonic symmetry and therefore following the harmonic content of Ensemble 1 in the first bar), suggesting that the extra pitches have been introduced to give – by way of a relatively long section of about thirteen bars – a sensation of decreasing musical intensity (dynamics become gradually softer and the density of instruments decreases). The next example (Fig. 4.23) shows the very last bar of Ensemble 2.

Fig. 4.23. *Ius Lucis* – excerpt from the score: bars 651 until the end (Ensemble 2).

As a remark about the overall structure, it is interesting to observe that on a general level, Ensemble 1 is composed as a *crescendo* (starts with a very soft section and ends with a tutti), while Ensemble 2 is built in the opposite way (see Fig. 4.24). This morphological element is justified by the fact that the global form is also shaped as a palindrome. All of these features, metric organisation, harmonic structures and, finally gesture in general converge to shape a cyclic work. Ideally, in the first of the listening options (Ensemble 1 first, then Ensemble 2) listeners leave the first room with the memory of a long and dramatic accumulation of sounds, finding again, after the intermission the same chord and a similar rhythmic element at the beginning of the piece in the second room.
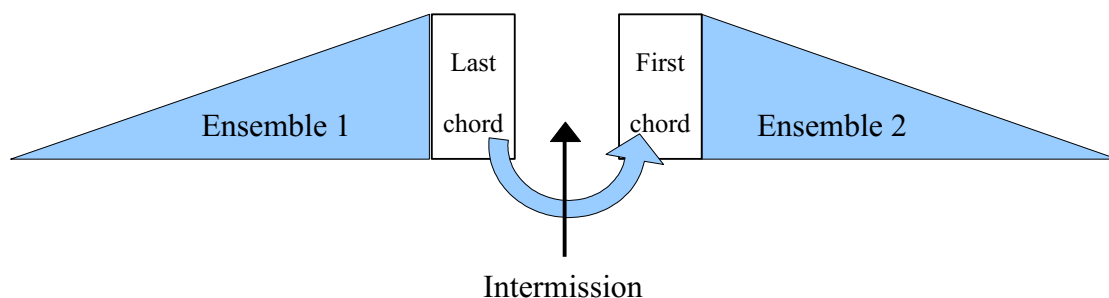
Fig. 4.24. Schematic representation of the global shape of *Ius Lucis*: The first part (Ensemble 1) moves slowly towards a musical intensification and increase of sound, while Ensemble 2 moves in a direction that can be defined as a global diminuendo. There is a direct harmonic correspondence between the last chord of Ensemble 1 and the first of Ensemble 2.

Fig. 4.25. *Ius Lucis* – excerpt from the score: bar 651 until the end (Ensemble 1).

Fig. 4.26. *Ius Lucis* – excerpt from the score: bars 1–5 (Ensemble 2).

With the second option (an audience starting with Ensemble 2), after the intermission the same level of musical activity (Ensemble 2 ends with the conclusion of a constant diminuendo) left in the second room is found in the first with the Ensemble 1's beginning (see Fig. 4.27, 4.28 and 4.29).
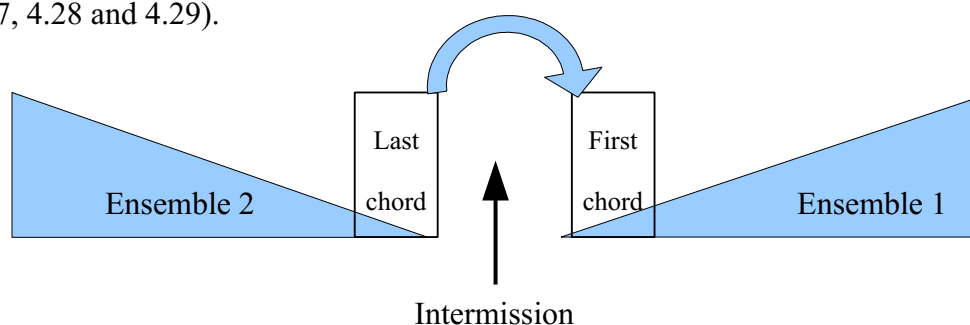
Fig. 4.27. Schematic representation of the global shape of *Ius Lucis*. Here again, in the opposite order (starting with Ensemble 2), there is a direct harmonic correspondence between the last chord of Ensemble 2 and the first of Ensemble 1.Moreover, both parts (the ending of Ensemble 2 and the beginning of Ensemble 1) have a similar musical character.

Fig. 4.28. *Ius Lucis* – excerpt from the score: from bar 651 until the end (detail of Ensemble 2).

Fig. 4.29. *Ius Luci*s – excerpt from the score: bars 1–5 (detail of Ensemble 1).

4.1.4 Live-electronics and graphic notation

In order to facilitate a reading of the electronic notation, essential to understanding the musical use of the software and its output used to compose the work, it will be indispensable to explain some of the special signs used in the electronic score and what they mean inside the Max/MSP program used for concert performances.

Two main sound transformations (real-time) have been used throughout the music work: Cross-synthesis and frequency-shifting. The second one consists of a multiple shifter used to transform the input sound to create a chord. In the following example (Fig. 4.30), it is assumed that an instrument is playing the pitch A (220 Hz):

Frequency-Shifting Module

Fig. 4.30. *Ius Luci*s – Scheme of the frequency-shifting module used to transform (locally) instrumental sounds.

This module (one for Ensemble 1 and one for Ensemble 2) is notated in the electronic score with FS and it is used only to transform instruments locally (sounds from remote ensemble are not affected).

The most important real-time transformation, generically called cross-synthesis, consists of a module that groups two different effects:

- A cross-synthesis engine (based on the same algorithm of the generalized cross-synthesis as it can be found in the program *AudioSculpt*);
- A Convolution[6] engine appositely programmed (convolving the local and the remote signal);
- A Spectral Mapping that shifts the result of the preceding two effects in order to emphasize its timbre.

This module works with two input sounds. The first (modulating sound) is local, the second (Carrier) is remote, i.e. coming from the ensemble playing in the other room. In the following example it is assumed that the live-electronic transformation happens in room 1, therefore the local signal is represented by Ensemble 1 and the remote one by Ensemble 2 (Fig. 4.31).

INPUTS

Cross-Synthesis Module
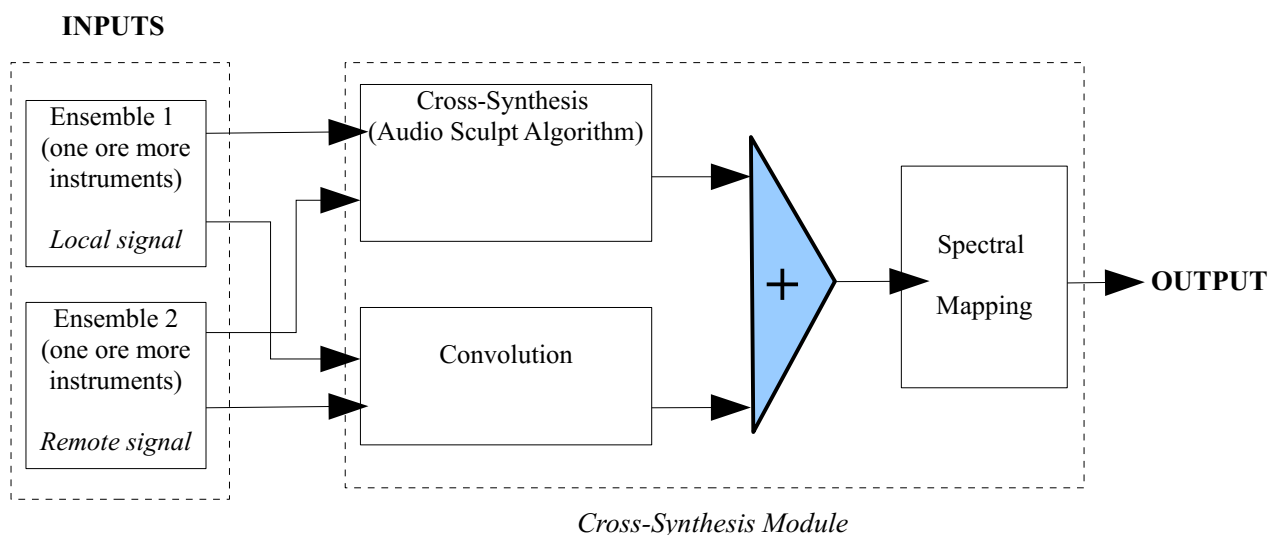
Fig. 4.31. *Ius Luci*s – Scheme of the cross-synthesis module (made by a cross-synthesis as in the Audio Sculpt algorithm) and a convolution, used to transform (remotely) instrumental sounds.

Concerning the first effect (taken from the Cross-Synthesis algorithm of Audio Sculpt), it is useful to give the transformed sound an outer shape (see Fig. 4.32), this will also be used (without any crossing) to transport the sound from one room to the other.

---

6. Convolution in digital signal processing is a well-known technique, transforming two waveforms as inputs in time and frequency domain, which means multiplying their spectra (frequency information). A multiplication of frequency means that strong frequencies will be amplified and weak ones become even softer. The reason why this kind of sound processing has been chosen is because there is a very direct connection between this sound transformation and space (in a reverberant space, convolution can easily be produced by clapping the hands: This noise is the Carrier and the resonant space can be characterized by the Impulse Response).

Convolution gives a morphing effect by crossing two different spectra and accenting the frequency content. The last effect, Spectral Mapping, is used to further transform the synthesis-sounds in order to differentiate them from the complex acoustic sound textures (Ensemble 1 and 2).
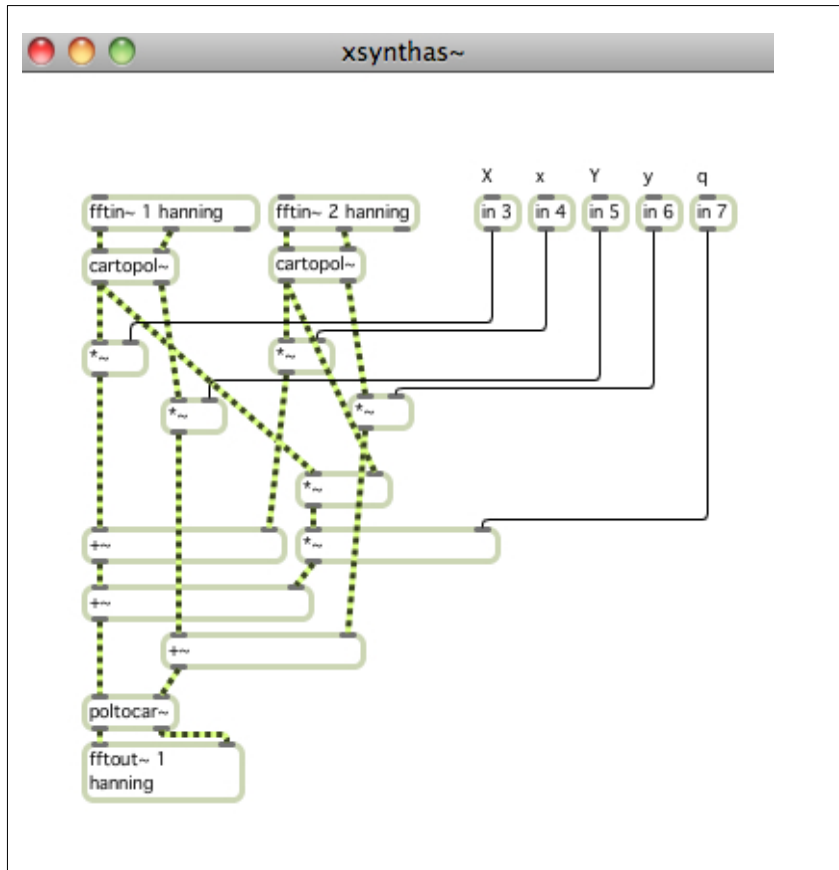
Fig. 4.32. From the Cross-Synthesis Module (Max/MSP platform): the first effect, the Audio Sculpt algorithm. The two input signals are processed according to two parameters: amplitude (marked as X for the first signal and Y for the second) and phase (marked as x for the first signal and y for the second). The last multiplicand (marked as q) enhances the frequency content of the resulting sound.

In the following picture (Fig. 4.33), there are two types of Convolution effects, programmed with two *pfft~* (Fast Fourier Transform) algorithms called *ius_convolve3* and *ius_convolve4SM2*, whereby only the first one is used (marked by a dashed oval). The *attaques-detection* sub-patch (marked by a square) is used to take a short sound-portion of remote sound as Impulse Response for the Convolution: A buffer is filled each time (variable time interval) an attack occurs, so that a rich spectrum is used to convolve the local sound.
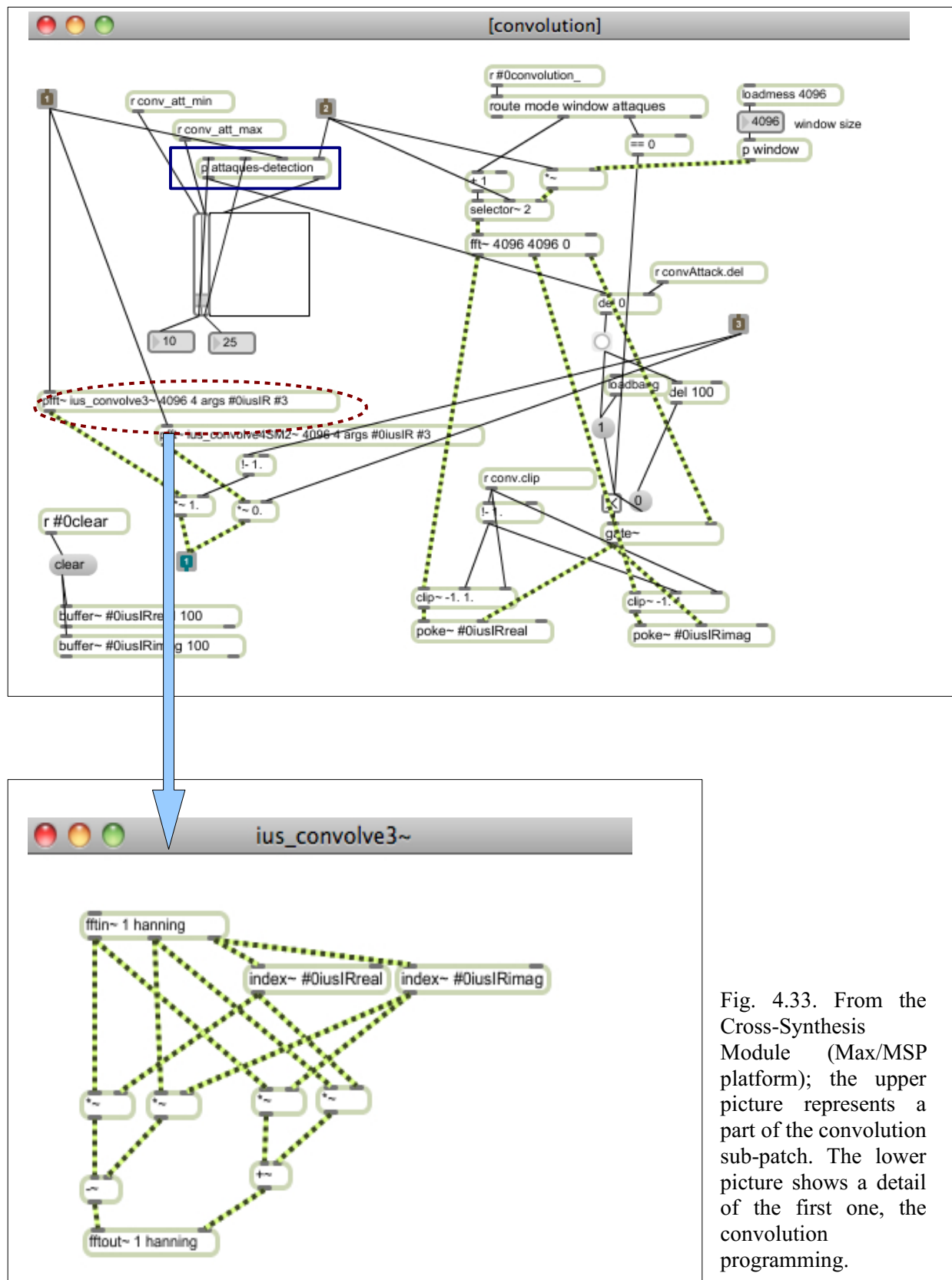
Fig. 4.33. From the Cross-Synthesis Module (Max/MSP platform); the upper picture represents a part of the convolution sub-patch. The lower picture shows a detail of the first one, the convolution programming.

The last effect, called Spectral Mapping (Fig. 4.34), has been included in the Cross-Synthesis module for reasons connected to the global perception (acoustic sounds and electronic sounds). This effect can colour the result of cross-synthesis and convolution (summed) in order to distinguish its timbre and differentiate it from the sound of the ensemble.
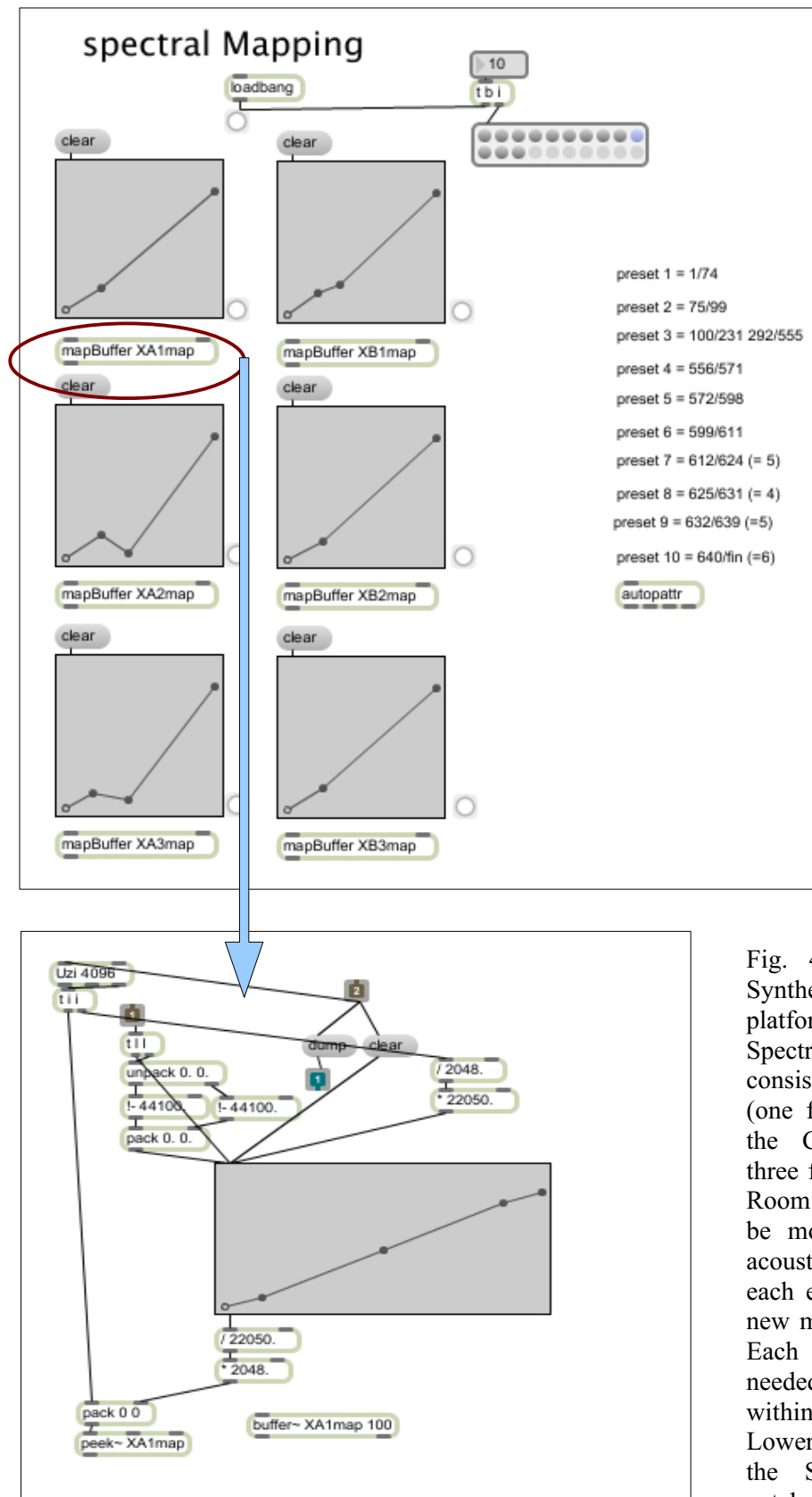
Fig. 4.34. From the Cross-Synthesis Module (Max/MSP platform). Upper picture: Spectral Mapping effect consists of six Mapping Tables (one for each output voice of the Cross-Synthesis Module, three for Room 1 and three for Room 2). Resulting spectra can be modified as much as the acoustic situation requires: At each event during the piece, a new mapping can be launched. Each voice is modified as needed. Such tables are stored within the Concert Patch.
Lower picture: an inner view of the Spectral Mapping sub-patch.

In the middle section of *Ius Lucis*, cross-synthesis is realized with only one live signal: In room 1, the contrabass clarinet is modulated by an oscillator bank whose frequencies come from room-mode analysis. In room 2, the same process is used to transform the sound of

cello2 playing a solo section. This transformation is marked on the score with ADD (which stands for additive synthesis).The live-electronic notation in the full-score is purely graphic, since the great amount of parameters, values, etc. would not have allowed exhaustive notation on the page[7]. It is solely intended for use in performance, and features four live-electronic output channels (or voices) that are called XA1, XA2, XA3, out4 (for Ensemble 1) and XB1, XB2, XB3, out4 (for Ensemble 2). These symbols refer to the three cross-synthesis modules (X = cross-synth, A, B = modules of Ensemble 1, 2, out4 is the fourth output that is used according the needs of each event). Further live-electronic transformation, a frequency-shifting module, is marked with FS (and the name of the instrument used as input).
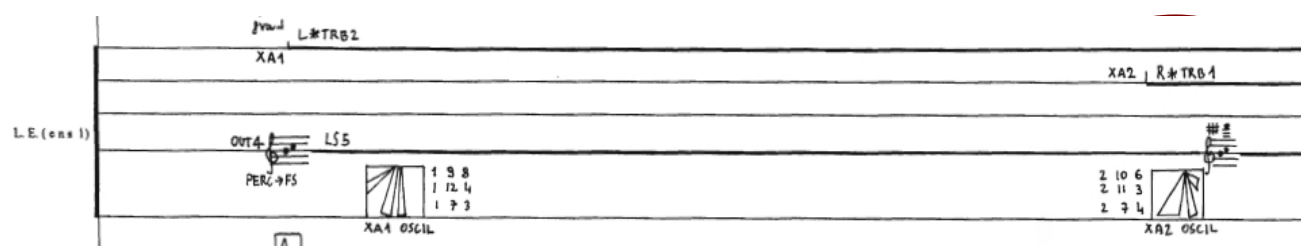
Fig. 4.35. *Ius Lucis*: live-electronic system (first page) of Ensemble 1. In the example marked by a circle, Cross-Synthesis (and Convolution) notation is expressed with R (meaning Trio Right - flute 2, horn 2 and violin 2) crossed (expressed synthetically by the sign *) with trombone 1 (TRB 1); the first is the local signal, the second is the signal coming from the other room.

On each voice-line, comparable to an instrument system, there is a short description of which instruments are crossed (in the example above: On the cross-synthesis-voice XA1 the trio-left marked with L consisting of flute 1, horn 1 and violin 1 is crossed with trombone 2 from Ensemble 2, marked with TRB2). In the case of the fourth output line (out4), in this example there is a frequency-shifting effect (percussion as input), producing two frequencies notated in treble clef (B and C), which are projected without any movement through loudspeaker number 5 (LS 5). When synthesis-sounds are spatialized (as is the case of XA1 in the example above), a graphic shows a synthetic representation of the trajectories or zones where those sounds are projected, followed by the number of loudspeakers (three groups of three loudspeakers: 1 – 9 – 8, 1 – 12 – 4 and 1 – 7 – 3) and the spatialization[8] technique) that is marked as Oscillation (OSCIL) in this example.

---

7. In order to reduce the amount of symbols on the system, a series of abbreviations have been used to mark the instruments used as input in live-electronic transformations: oboe = OB, clarinet = CL, percussion = PERC, flute 1, horn 1 and violin 1 (trio placed on the left) = L, flute 2, horn 2 and violin 2 (trio placed on the right) = R, viola 1, cello 1 and contrabass clarinet (trio placed at the middle) = M, trombone = TRB, viola = VA, cello = VC.
8. Spatialization has been realized with a program written in Max/MSP (called *spatius*) allowing the spatialization of sounds according to their amplitudes or attacks. These techniques are: Fixed Projection (FIX) stable loudspeaker(s); Oscillation (OSCIL) changing loudspeaker (or group of) at each detected attack of input (local) sound; Trajectory (TRAJ) the usual trajectory along a pre-defined array of loudspeakers (or group); Dynamic-Trajectory (TRAJDYN) a trajectory whose speed is depending on the amplitude of the input (local) sound (louder sound = faster movement); Loop (LOOP) changing loudspeakers (or group of) in a recursive way; Dynamic-Loop (LOOPDYN) a Loop whose speed is linked to the amplitude of the input (local) sound (louder sound = faster movement); Oscillating Loop (OSCILLOOP) an oscillation between two loops, the change occurs when an attack is detected on the input sound (local); Dynamic-Panorama (PANDYN) sounds are spatialized over two ore more loudspeakers (or groups of) depending on the amplitude of the input (local) sound (from less amplitude = first zone through maximum amplitude = last zone, passing by all steps).

A few more graphic elements showing a temporal development of sounds have been introduced, meaning:

a sound fading in or out   sound projection without any
                                             transformation

500 ms   1000 ms   OB1/CL1
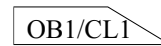
an effect lasting for the whole time of the horizontal line

L*TRB2
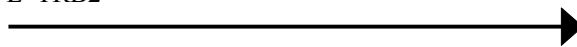
Splitting the Max/MSP interface into two halves, each for the corresponding concert room (and ensemble) was a necessary procedure in that the two instrumental groups have not only two different musical discourses (with many correlations as has been said) but also separate ways of routing, transforming and projecting sounds. The following picture (Fig. 4.36) shows the same bars, now of the live-electronic system (first page of the full-score) for Ensemble 2:
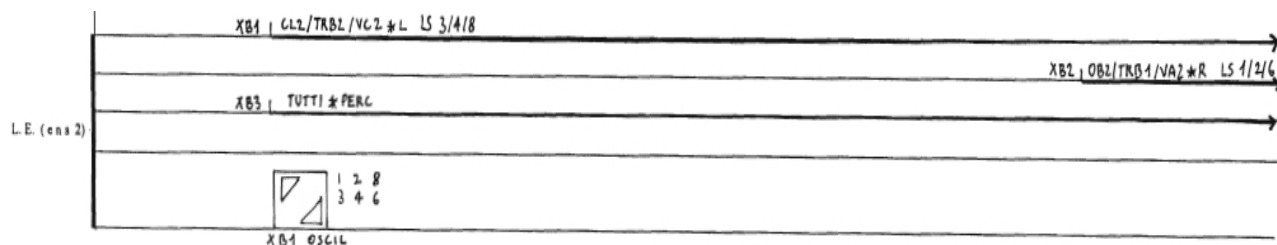
Fig. 4.36. *Ius Lucis*: live-electronic system (first page) of Ensemble 2.

Because an exhaustive description of live-electronic generated sounds is almost impossible, as is the case for foreseeing entirely the behavior of real-time sound transformation programs (depending on the actual musicians' performance), the way this electronic score has been notated is closer to the intent of the *partition virtuelle,* a virtual score as it is meant by the French composer Philippe Manoury[9]. As a matter of fact, even if previously experimented and simulated, electronic sounds and spatialization movements keep – as it is for this kind of live-

---

9. Manoury writes about the idea of *partition virtuelle,* meaning that such virtual scores of mixed music works (instrumental/vocal and real-time electronics) consist of a conspicuous hidden part coded inside the machine's memory (computer performing live-electronic programs for performance). This part, however, is strictly dependent on the musician's interpretation (and musical text), as it is the only key to fully understand the true relationships between performer and machine (formalized and coded in form of programming language):
[…] *"La partition virtuelle est donc une partition dont on connaît, a priori, la nature des éléments qui vont être traités mais dont on ignore les valeurs exactes qui vont définir ces éléments."* [...] Philippe Manoury, "La note et le son – Écrits et entretiens (1981 – 1998)," (Paris: L'Harmattan, 1998), 74.

performance interactions – a certain range of freedom, given that each time players perform music there are some differences.

4.1.5 Spatialization techniques and notation

As has been expressed in the previous chapter, research on room modes and software development assure a different vision of space and spatialisation in the context of a musical composition: Spatialisation (expressed as trajectory) is the key to generating musical material on the basis of room-mode analysis. This approach, as it will be explained later in this chapter, is the working method used to compose the middle section of *Ius Lucis.*

However, over the course of the work, other techniques for the mere movement of sounds in space(s) were used and a wide range of possibilities have been created, due to the special configuration, extending and developing the original idea of moving sound sources in several directions. Throughout the compositional process of this musical work, aside from the idea of trajectory as the primary element that would be able to form musical structures, thanks to the room-mode analysis[10] some other solutions played a central role in both instrumental and electronic composition:

- A spatialization that could be realized acoustically within the instrumental writing and therefore, dependant on orchestration (instrument positioning in concert room and within the ensemble on stage);
- A spatialization in the traditional sense of the term (electronic sounds moving throughout the loudspeaker array) with some parameters (speed, localisation, etc.) that would be dependant on instrumental performance such as dynamics, attacks or directionality;
- A global spatialization plan that would become structural and able to define or design musical actions inside a certain instrumental context, now possible thanks to the dislocation of sounds between rooms (this kind of spatialization is connected to the idea of global counterpoint, as seen in 4.1.2).

As for the first kind of spatialisation, in some sections of the score the positioning of instruments is itself a generator of spatiality: If in Ensemble 2 this happens continuously (because of the placement of instruments around the audience), in Ensemble 1 it is not less evident.
In fact, dividing the twelve instruments[11] into four groups (whereby the group at the bottom, consisting of oboe, clarinet and percussion is widely spread out and therefore can be considered as three further isolated sound-source points), already suggests a spatiality in nuce.

---

10. This is the case for some sections of the score (bars 232–422) concerning three main instruments: viola 1 and contrabass clarinet for Ensemble 1 and cello 2 for Ensemble 2. All three are used as solo instruments. The role of the rest of the ensembles as well as the live-electronic transformations, changes at each section as will be shown.
11. The musicians playing MIDI-keyboard, that would be the thirteenth player in the ensemble, has not been counted since it is a control instrument, used to synchronize live-electronic programs. If a click-track were used, this instrument would not be necessary anymore, but an agogic freedom is preferable. This solution allows musicians (conductor) to adjust the tempi according to the situation.

The beginning of Ensemble 1 can be considered the best example of a spatialization that starts from the instrumental ensemble and grows over the course of the piece until it eventually reaches both rooms.

Fig. 4.37. *Ius Lucis*: a part of the score (first page, bars 1–4) showing an acoustic spatialization within Ensemble 1. The left trio (flute 1, horn 1 and violin 1) leads a dialogue with the other groups. In measure 4, the right trio (marked by a circle) with the same instrumentation answers with the same chord.

Fig. 4.38. *Ius Lucis*: a part of the score (second page, measures 5 until 11) where the trio on the left introduces spots (same chord as at the beginning) at the verge of a crescendo played by the trio on the right (marked by a circle). A further effect of spatiality is reached few bars later (bar 9) where the trio on the left again leads the musical discourse. This alternation also continues later (measure 23), when the middle trio (contrabass clarinet, viola, cello) interrupts this sequence, presenting a new chord.

In Ensemble 2 this sound alternation between two extreme points in the concert room, further accentuated by the immersive spatial configuration, is particularly manifest in the ending, the section that corresponds structurally to the example shown before (Ensemble 1, measures 5–11). In this situation, Ensemble 2 is playing the same chord (B, C, high F-three-quarter-tone-sharp) as Ensemble 1 (because of the harmonic symmetry), but orchestrated differently. A first spatial dialogue of two sound impulses is given by the two trombone players playing a tam-tam; a comparable motion to that of Ensemble 1 is reproduced between viola 2 and cello 2 (marked by a circle in the next graphic example), as well as between the two woodwinds in bars 5–11. Spatialization notation is in this case equivalent to the score notation, as it is the position of the players that determines the impression of sound dislocation in the placement of musicians, both frontal and surrounding.

Fig. 4.39. *Ius Lucis*: score detail of Ensemble 2 (bars 645– 650) showing instruments placed at the opposite corners of the concert room, involved in a sort of dialogue with similar musical figures (marked by ovals).

Concerning the second technique (spatialization as movement of sounds throughout a loudspeaker array), it needs to be said that this operation is strictly dependent on real-time performance, i.e. from musician's playing. Several forms and methods of moving sounds around the concert room have been developed, which are rigorously dependant on acoustic and dynamic elements. This comes from the idea that each spatial phenomenon occurs as a reaction to something (sound, noise) produced, therefore its parameter (such as movement speed, frequency of change between loudspeakers, etc.) shall be connected to the manner in which sounds are produced. The Max-object programmed to control spatialization is called *spatius~* (arguments being the number of projection points, i.e. loudspeakers), which is connected to an interface (Fig. 4.40) where messages can be launched.
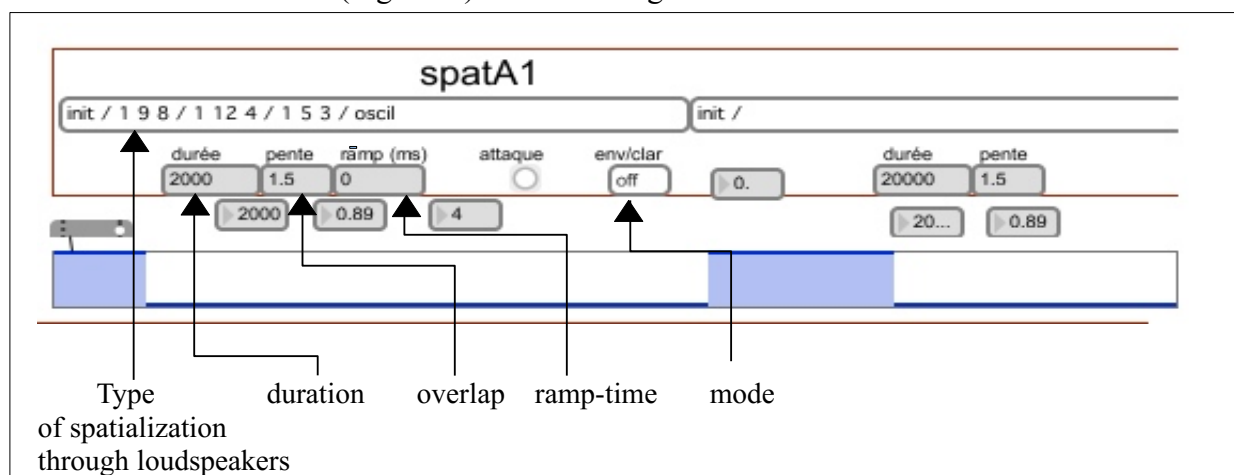
Fig. 4.40. Detail of *Ius Lucis* concert patch on Max/MSP platform: spat control window referring to one of the four spatialization channels (A1). The last parameter – mode – is used to activate different kinds of envelope followers.

Spatialization is notated using the name of the technique used, followed by loudspeaker number(s) – if there is no movement (e.g.: LS 1 or LS 1 / 3 / 5) or by a square representing approximately trajectories, regions and groups of loudspeakers inside the concert hall:
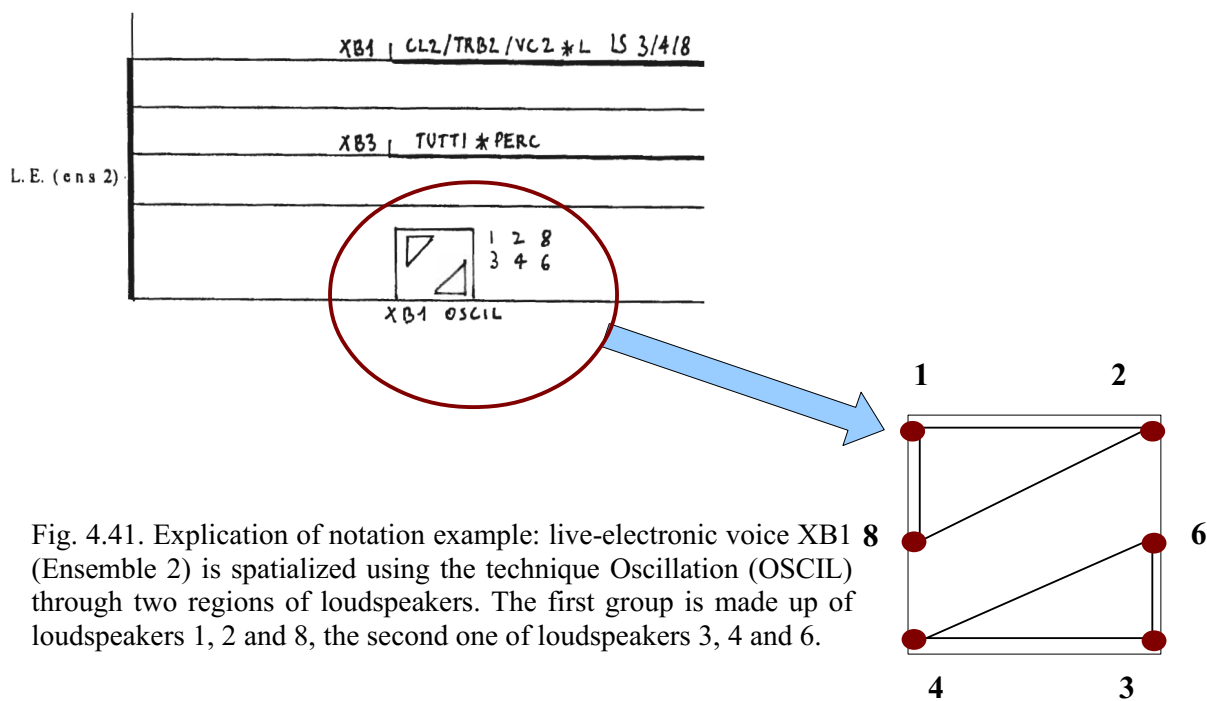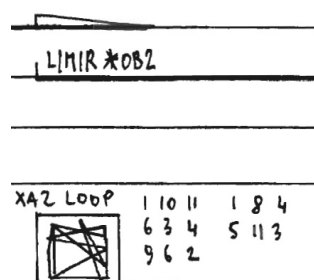

Fig. 4.41. Explication of notation example: live-electronic voice XB1 (Ensemble 2) is spatialized using the technique Oscillation (OSCIL) through two regions of loudspeakers. The first group is made up of loudspeakers 1, 2 and 8, the second one of loudspeakers 3, 4 and 6.

Spatialization is realized with a series of tools allowing a strict connection between live-playing and sound projection. The next list contains all spatialization techniques used in *Ius Lucis* (each with an example of its application taken from the score) :

Spatialization linked to dynamic change – amplitude

Dynamic Panorama (PANDYN)

Dynamic Loop (LOOPDYN)

Spatialization linked to dynamic change – attacks

Oscillation (OSCIL)

Oscillating Loop (OSCILLOOP)

Autonomous Spatialization

Fixed Projection (FIX)

Trajectory (TRAJ)

Loop (LOOP)

Dynamic Panorama is a technique used to spatialize a sound along a trajectory or, more frequently, regions of loudspeakers (groups of multiple loudspeakers), where the position within the trajectory (or group of loudspeakers) depends on the amplitude of the sound itself (louder sound = further position):
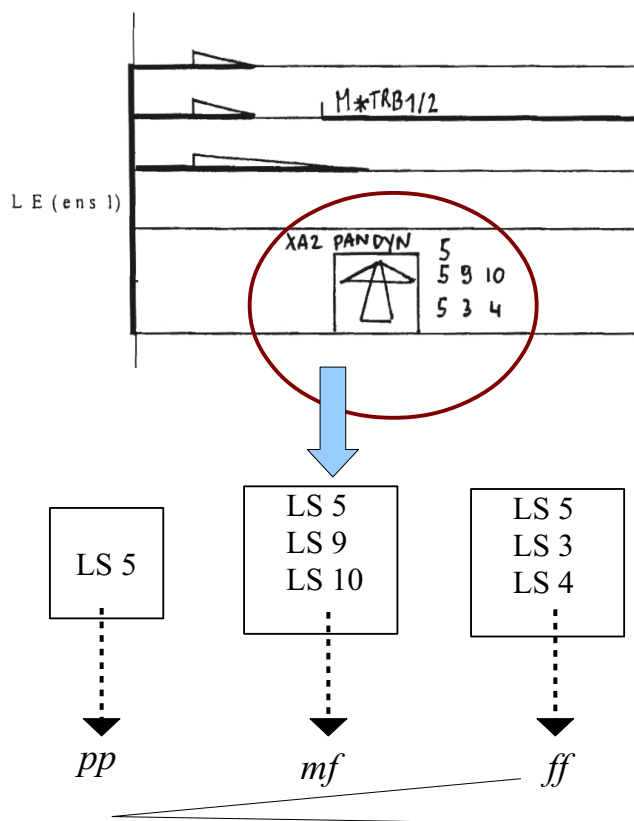
Fig. 4.42. Explication of notation example: live-electronic voice XA2 (Ensemble 1) is spatialized using the technique Dynamic Panorama (PANDYN) through three regions of loudspeakers. The first is loudspeaker 5; the second one consists of loudspeakers 5, 9 and 10; the third of loudspeakers 5, 3 and 4. Dynamic values (*pp* = pianissimo, *mf* = mezzoforte, *ff* = fortissimo) are relative values, based on an initial convention.

A very effective spatialization method, Dynamic Loop has been used extensively throughout the piece, because input sound amplitude (instrument or group of instruments) controls the speed of a recursive trajectory (Loop) on which a synthesis-sound is moved with high fidelity.
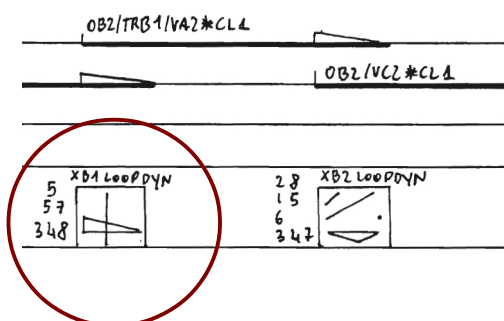
Fig. 4.43. Explication of notation example: live-electronic voice XB1 (Ensemble 2) is spatialized using the technique Dynamic Loop (LOOPDYN) through one single diffusion point and two regions of loudspeakers. The first is loudspeakers 5, the second one consists of loudspeakers 5 and 7, the third one of loudspeakers 3, 4 and 8. Sound is spatialized over these three groups recursively, but initial speed is multiplied proportionally to the input amplitude (local instruments).

Oscillation is a spatialization technique that has also been widely used, because it is strictly connected with attacks (instrumental parts) and therefore very efficacious for making sound movements in space perceivable. Instrumental attacks are thus detected and used to trigger a change in the loudspeaker configuration. While the loop-technique, even with dynamic control, performs a continuous recursive trajectory, OSCIL (Oscillation) does not change until the next attack has been detected. It is very useful not only for spatializing quick, sharp or percussive repeating sounds (therefore having a high degree of spatialization movement), but also long sustained notes (starting perhaps with a *sforzando* or accent) when they have to be projected in a static manner.
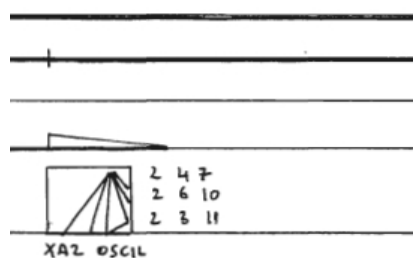
Fig. 4.44. Explication of notation example: The live-electronic voice XA2 (Ensemble 1) is spatialized using the technique Oscillation (OSCIL). This happens through three regions of loudspeakers. The first is made of loudspeakers 2, 4 and 7, the second one of loudspeakers 2, 6 and 10, the third of loudspeakers 2, 3 and 11. Sound is spatialized over these three groups, which gradually extend from the right towards the middle of the concert room (keeping one fixed point – loudspeaker 2).

Oscillating Loop contains two different features (attack detection and loop) and performs two different loops (with potentially different speeds but that remain constant), which begin at each attack detection. This technique seems to be more effective when used to spatialize sounds in sections with a high number of attacks (rather short notes projected along short loop-paths) or in medium-slow motion sections to diversify the kind of spatial projection.
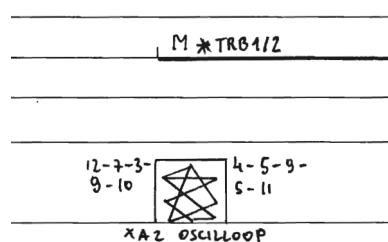
Fig. 4.45. Explication of notation example: The live-electronic voice XA2 (Ensemble 1) is spatialized using the technique Oscillating Loop (OSCILLOOP), performed alternating two loops. The first loop-path goes through loudspeakers 12, 7, 3, 9 and 10, the second one goes through loudspeakers 4, 5, 9, 5 (again) and 11.

Fixed Projection is the simplest way to project sounds through one ore more loudspeakers without any movement. This technique has essentially been used to project one ore more remote signals (instrumental sounds) without any kind of real-time transformation. In bar 136 (example below) an accumulation (addition) of both ensembles occurs:
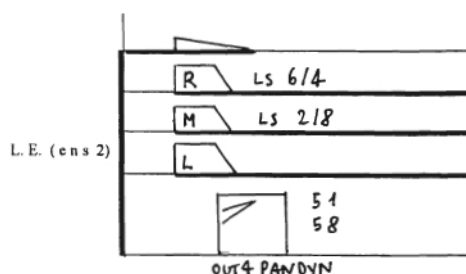
Fig. 4.46. Explication of notation example: The two live-electronic voices XB2 and XB3 (Ensemble 2) are used to project instrumental sounds without any transformation (cross-synthesis and convolution are by-passed). Two instrumental groups from Ensemble 1 (remote signals) are projected without spatialization movements (FIX) through loudspeakers 6 and 4 (Trio Right – marked with R), and through loudspeakers 2 and 8 (Trio Middle – marked with M).

Trajectory has only rarely been used and for very short parts. It performs a simple trajectory that, unlike loop, is not repeated. This however can be made of simple diffusion points or groups of loudspeakers.
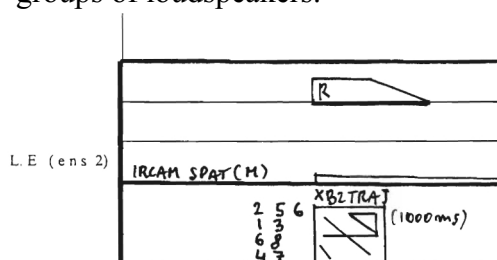
Fig. 4.47. Explication of notation example: The live-electronic voice XB2 (Ensemble 2) is spatialized using the technique Trajectory (TRAJ) running through four groups of loudspeakers. The first consists of loudspeaker 2, 5 and 5, the second one loudspeaker 1 and 3, the third one loudspeaker 6 and 8, the fourth and last group is loudspeaker 4 and 7. Once the trajectory is performed, the sound is projected stable on the last one (in this example loudspeaker 4 and 7).

The spatialization technique Loop, also broadly used throughout the piece, is used to spatialize a sound according to a trajectory (recursive) of simple or multiple loudspeakers whose speed is not controlled by dynamic or attacks. Used with groups of loudspeakers spread in the concert room (as in the example below), it gives an affect of changing sound colour (timbre), especially when performing relatively fast movements.

Fig. 4.48. Explication of notation example: The live-electronic voice XA2 (Ensemble 1) is spatialized using the technique Loop (LOOP). It projects sounds through five groups of loudspeakers: the first consists of loudspeakers 1, 10 and 11, the second one loudspeakers 6, 3 and 4, the third one loudspeakers 9, 6 and 2, the fourth one loudspeakers 1, 8 and 4 and the last group is loudspeakers 5, 11 and 3.

4.1.6 A special case of spatialisation: Directionality

Over the course of the score, at bar 114, a peculiar spatial configuration (and therefore technique) is introduced: While the rest of Ensemble 1 is not playing any substantial part or is tacet, clarinet 1 performs long notes – relatively high pitches – in an improvisational manner, moving the instrument from left to right[12] and vice-versa, as notated below the horizontal line meaning *tenuto*.

Fig. 4.49. *Ius Lucis*: score detail of Ensemble 1 (bar 114. Clarinet 1 controls sound projection with alternating left – right movements (notated with L → R → L), detected by two microphones.

The peculiarity of such sections (marked by an oval) is that the clarinet is used to spatialize sound with its instrumental gesture (movement left – right and vice-versa). In fact, synthesis sounds (cross-synthesis and convolution) follow the movements of the clarinet and are projected in the same portion of the concert hall that the clarinet sound does. In the same section, another element is used to establish a dialogue with the clarinet: The oboe player performs – also freely – a series of short quick percussive sounds (marked by a square), spatialized with the Oscillation tool. The procedure used to perform the clarinet's spatialization technique is as follows:

---
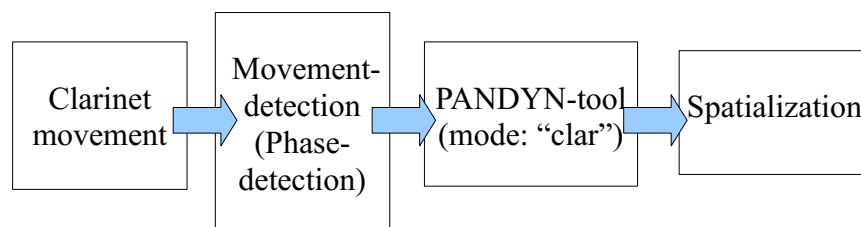
12. The notation of the clarinet movement consists of following indications: "L" (meaning "turn direction toward left") and "R" (meaning "turn direction toward right"). A gradual movement from left to right is shown by an arrow (since this section is meant as an improvisation for clarinet 1, speed depends on the performer and is suggested by the length of the horizontal line), while a quick change of directionality is shown by the two consecutive letters ("LR" or "RL").

Movement detection (between two positions) should detect a phase change in the signal coming through two microphones placed at a distance of about one meter. In the max/MSP programming patch, this detection is associated with the spatialization tool called Dynamic Panorama (PANDYN) as seen in the previous paragraph (4.1.5).

This tool, used in the mode marked with *clar* (meaning clarinet: this mode is programmed inside the *spatius~* object, see 4.1.5, Fig.4.41), operates a mapping between phase differences and loudspeaker groups, which needs to be programmed according to a left – right grouping logic. In the example below the first group, loudspeakers 10 and 11 represent the left side of the concert hall, the group with loudspeakers 3, 4 and 7 the centre, and the one with loudspeakers 9 and 12 the right side of the concert room:
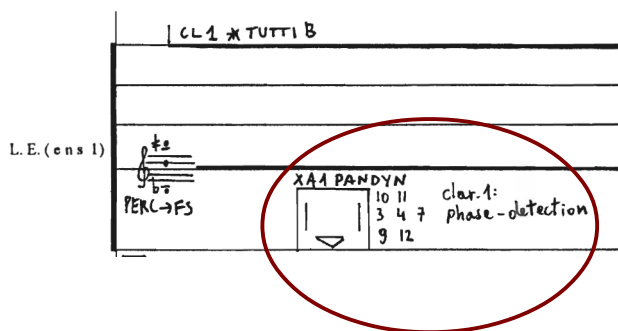
Fig. 4.50. In this example (bar 114), live-electronic voice XA1 (Ensemble 1) is spatialized using the technique Dynamic Panorama (PANDYN). When the clarinet player does not move (signal inside the normal microphone), sounds are projected through loudspeakers 10 and 11. By moving toward the right side, sounds will move toward the group of loudspeakers 3, 4 and 7. In the maximal position on the right side (playing directly in front of the right-microphone), sounds will be spatialized over loudspeakers 9 and 12.

Once the phase-detection is activated and the PANDYN tool has been launched, there is a direct correspondence between clarinet sound projection and the region of the concert hall where synthesis-sounds are heard (see Fig. 4.51).
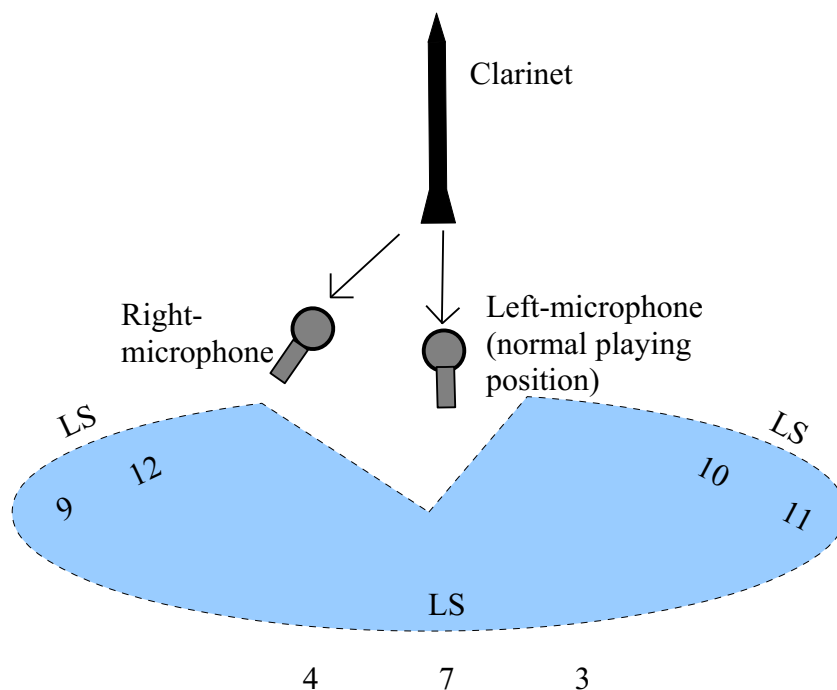
Fig. 4.51. Schematic explanation of the set-up for clarinet phase-detection: The player usually projects the sound toward the microphone on the left (microphone normally used for the whole piece). When the sections with phase-detection come, live-electronic programming automatically activates a double input for clarinets 1 and 2. The difference between the two phases (signal left and right) determines in which portion of space (loudspeaker arrangement) the resulting (transformed) sounds should be projected. This projection dynamically follows the movement (and the direction) of the clarinet.

Projected sounds (resulting from cross-synthesis and convolution) are usually a morphing of local and remote signals. In this kind of section however, remote signals are more recognizable since the musical idea consists of a movement that dislocates masses of sounds. Indeed, on the other side (Ensemble 2), instruments perform only chords (with *tremoli* or *Flatterzunge*), in order to increase the amount of sound and consequently give an impression of multiplication, since clarinet 1 is producing an effect for the full ensemble. At the level of acoustic perception, these sound masses indeed seem to be moved by the clarinet gesture.

129

Fig. 4.52. *Ius Lucis*: score detail of Ensemble 2 (bar 114), instrumental sounds projected into Room 1 by Clarinet 1.

This same procedure is used, inverted, in Ensemble 2. The corresponding section is at bar 540 of the score (last clarinet section).

Fig. 4.53. *Ius Lucis*: score detail of Ensemble 2 (bar 540), clarinet 2 controls sound projection with left – right movements (notated with L → R → L) detected by two microphones.

4.1.7 Classical spatialization method: *Ircam-Spatialisateur* (Ircam-Spat)

The last technique in the list of spatialization methods used in the work, the so-called *Spat* (Ircam-Spatialisateur[13]), offers a further spatial dimension (thanks to the high realism in simulating a new acoustic space), and is therefore a valid instrument on the palette of all live-electronic tools that are used according to a precisely defined musical task. The use of Spat in *Ius Lucis* and how it is associated with a precise formal function will be explained in the following paragraphs. The notation of this tool in the musical score (placed in the fourth spatialization voice of the Max/MSP Patch called *out4*) follows the same principles and graphic representation:
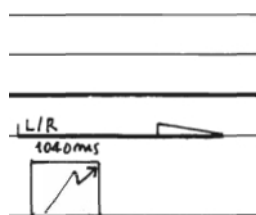
Fig. 4.54. Explication of notation example: The live-electronic voice *out4* (Ensemble 2) is projecting two summed signals (Trios Left and Right) coming from Ensemble 1. At the notated event (bar) the Ircam-Spat is launched according a pre-programmed trajectory (shown in the square) and within a certain total time (in this example it lasts 1040 milliseconds).

4.2 *Écriture*: Global form description

Having written about the harmonic and metric elements (see 4.1.3) and provided some examples taken from the score (beginning and ending), it will be useful to see the formal frame according to which *Ius Lucis* has been composed. Even if, as has been explained, the work follows a global idea of a mirror-like scheme between the two ensembles, there is an inner subdivision of sections in which diverse musical situations are developing. Seen in its totality, *Ius Lucis* can be considered to be an AB(-)A form in which the central section (B), a large contrabass clarinet solo, divides the work into two parts, functioning as a symmetry axis. Generally speaking, within the first and the last section of the work it is possible to distinguish a compositional strategy aiming to create a formal dialogue (one could call it a dialectic) between a main musical flow and other formal elements. These contrasting parts (see 4.1.6) are musically very different and therefore able to create a distinct formal subdivision by temporarily stopping or changing the course of evolution in the musical discourse. Seen in the context of a very dense musical writing, such sections have been composed to help the perception by offering a moment of redundancy or a clear marking point within a long musical development.

At the very beginning of the piece the element used as a marker to describe a new section is a situation of conjunction. After about one hundred bars, the two ensembles are heard – in the two concert halls – almost as a whole by the projection of the instruments of the remote

---

13. *Spatialisateur* is a software intended for the spatialization of sound in real-time, as well as for other applications such as post-production, virtual reality and video. Since Spat is a standard software, a detailed documentation of this tool can be found on the Reference Manual: http://support.ircam.fr/docs/spat/3.0/spat-3-intro/co/overview.html.

ensemble into each room: At bar 99 Ensemble 2 is projected entirely toward room 1 by grouping viola 2 with trombone 2, cello 2 with trombone 1 and oboe 2 with clarinet 2; in the opposite direction (room 1 toward room 2), Ensemble 1 is projected without the Middle Trio and without percussion. A distinction mark of this *Tutti* section is given also in the *écriture*: This compression of sound sources (both ensembles unified) is also underlined by the rhythmical notation. A fast quintuplet containing complex chord(s) sums up in various moments within the section, increasing musical intensity quite dramatically:

Fig. 4.55. *Ius Lucis*: bars 103 – 104. Detail of Ensemble 1 (left) and Ensemble 2 (right), the quintuplets are orchestrated vertically. Electronics are projecting Viola 2 and Trombone 2, Cello 2 and Trombone 1, Oboe 2 and Clarinet 2 toward Room 1; Trio Left, Trio Right, Oboe1 and Clarinet 1 toward Room 2.

For the sake of completeness, the corresponding formal section (bars 541–555) also presents a Tutti situation where both audiences (Room 1 and Room 2) are able to perceive a moment of unified perspective, again with the same rhythmical element (quintuplets), as shown in Fig. 4.56.

Fig. 4.56. *Ius Lucis*: bars 549 – 551. Detail of Ensemble 1 (left) and Ensemble 2 (right), some of the same quintuplets as in the previous score-example (bar 103 – 104) have been used (see Clarinet 1, Viola 1 and compare with Clarinet 2, Viola 2). In addition to transformed signals, electronics are projecting Oboe 2, Clarinet 2 and Viola 2, Cello 2 toward Room 1; Trio Left, Trio Right, occasionally Trio Middle (spatialized with *Ircam-Spatializateur*) toward Room 2.

More Tutti sections, again with a strong formal function, can be found at bar 305–311 (announcing the central part of the work, the contrabass clarinet solo) and the corresponding section, bar 343–349 (end of contrabass clarinet solo). In this musical situation, the sum of the two sound sources reaches an extreme point in its concatenation (and temporal compression). In nearly every bar of these two sections (more times in a single bar in most of the cases of the second section in bars 343–349), a new spatialization event occurs[14]. This allows a strict alternation between local and remote signals, introducing a musical gesture that thanks to its implicit drama, is useful in leading the discourse forward toward a new situation (Fig. 4.57).

---

14. This high density of live-electronic actions inside a fast section is made possible by the MIDI-keyboard used to trigger the events (programs). The musician, reacting to the conductor, presses keys with the best possible synchronization (other than a click-track, a solution that has been discarded for performance situations because it is not sufficiently musically satisfying).

Fig. 4.57. *Ius Lucis*: bars 305 – 310. Detail of Ensemble 1: Electronics project different combinations of instruments from Ensemble 2 with fixed spatial projection. At bar 308, the intersection between the two ensembles is also accentuated by the musical figure (a repeated glissando performed by Horn 1 and 2 (marked by a rectangle) to which (de-phased by a semi-quaver) the same element played by Trombone 2 is added (see also next score example, Fig. 4.58).

Fig. 4.58. *Ius Lucis*: bars 305 – 310. Detail of Ensemble 2: Here, electronics project different combinations of instruments from Ensemble 1 with the Oscillation tool. At bar 308, the intersection between the two ensembles is given by the superposition of the glissando-figures played by Horn 1 and 2 (Ensemble 1) on Trombone 2. In this kind of Tutti-section, almost the totality of Ensemble 1 is projected (except for Clarinet 1 and Oboe 1 – pausing almost the whole section). It is interesting to remark that in this case, the very characteristic elements of Horns 1 and 2 are spatialized with LOOP (fixed speed) on two trajectories inside Room 2 to enhance the perception of immersive listening.

Repeating a similar structure (with an even more dense and tight concatenation) at the end of the contrabass clarinet solo, would seem a necessary redundancy (for the listener's memory) in order to start the musical flow again. In the following score-examples (Fig. 4.59 and Fig. 4.60), at almost every sixteenth-note a spatialization action is launched (for Ensemble 1 or 2 or both at the same time).

Fig. 4.59. *Ius Lucis*: bars 343 – 349. Detail of Ensemble 1: Electronics are projecting all instruments from Ensemble 2 with *Ircam-Spat*. Percussion impulses first, repeated percussive sounds later (bar 347) are intersected with fast glissandi and ribattuti (Ensemble 2). Also, accents here are not synchronous but alternated (for instance Percussion alternates *sforzati* with Viola 2 and Cello 2 (*pizzicati*). *Ircam-Spat* performs quick trajectories (only one direction) traversing the whole length of the concert hall to increase the impact.

Fig. 4.60. *Ius Lucis*: bars 343–349. Detail of Ensemble 2: Electronics are projecting only Percussion and Trio Middle from Ensemble 1 with *Ircam-Spat*. Percussion impulses are rhythmically alternating those played by Viola 2 and Cello 2 (*pizzicati*) and spatialized on a back-forth basis. Only at bar 347 is Percussion spatialized with a complex trajectory to emphasize the drama of the tremolo (C-sharp).

Formally comparable to this kind of summation, another solution (different than the one consisting of an addition of sound sources through spatialization) has been used to join the two flows into one sole unity: conjunction through harmonic identity. At some moments of the work, the two ensembles are focused on the same pitch. This comes as a sudden, unexpected static situation after the high level of harmonic and rhythmic complexity reaching the listener. These sections, consisting of five bars each, present a high degree of transformed sounds and are composed mainly of one single pitch (rarely with octaves – mostly due to the undefined percussion instruments), the first time on the F-sharp (f#'), the second time on the C (c'''). Other pitches appears gradually once the Unison has been reached to distort in some way the static situation. Sections featuring this technique (with their corresponding sections in force of the formal symmetry) are:

from bar 147 to bar 151 ↔ from bar 503 to bar 507 (on F-sharp)

from bar 155 to bar 159 ↔ from bar 495 to bar 499 (on C-natural)

In the following example (Fig. 4.61 corresponding to bars 495–499) the high C is orchestrated according to different articulations, dynamics and rhythmic values, in advance of being crossed with another unison texture, much more quiet and with long notes.

Fig. 4.61. *Ius Lucis*: bars 495 – 499. Detail of Ensemble 1 (left) and Ensemble 2 (right). In spite of the other pitches produced in Ensemble 1, the ones focused on C-natural are dominant, also on account of the sounds produced in real-time by the cross-synthesis. (Trio Left and Right are crossed respectively with winds and strings). A symmetric cross-synthesis relation appears in the electronic of Ensemble 2. Here octaves are the only exception to unison (C-natural).

Ideally the texture of Ensemble 2 is conceived – inside the logic of real-time cross-synthesis – as an outer agent applying a force on the steady texture of Ensemble 1.

It is worth pointing out that a further, formally not completely vertically-corresponding Tutti section can be found in bars 163–172 (Ensemble 1). Here the remote ensemble (divided into three signals: woodwinds, strings with fixed sound projection, trombone 1 and trombone 2 spatialized with the Oscillation tool, all of them not transformed) is projected into room 1, while Ensemble 2 starts three bars before (bar 160) adding clarinet 2, trombone 2, viola 2 and oboe 1, trombone 1, cello 2, both spatialized with PANDYN tool. Additionally, it needs to be said that this section does not find any similitude of this kind (sum of not transformed remote instrumental sounds) in its correlating part (that is the one from bar 482 to bar 494). Seen from a more global perspective, such sections can be grouped into two (symmetrically corresponding) parts that show a less strict need for symmetrical parallelism. This means that the section running from bar 136 until bar 172 contains many different musical situations that

only partially find a rigid correlation in their symmetrical counterpart (bars 482–518). In this the latter, where metrical and tempi structures are perfectly mirrored, for musical reasons the distribution of instrumental mapping (and sometimes the quality itself of musical materials) does not exactly follow the opposite disposition as its formal precursor.

Sections featuring a partial conjunction of Ensembles 1 and 2 appear – composed and structured differently throughout the whole work – for a limited number of bars as well. This happens for various musical reasons, for example to musically challenge a section dominated by a soloist as an unmistakable signal of (imminent) change as it happens between bars 299 – 301. In this part of the work viola 1, playing a long solo from bar 233 (which is projected into Room 2), is interrupted a first time by a moment of Tutti in which all instruments of Ensemble 2 are projected and spatialized with quick movements inside Room 1:

Fig. 4.62. *Ius Lucis*: bars 298–301. Detail of Ensemble 1 (Viola 1 is the first double-system): After a long solo section, the discourse is interrupted abruptly by three quick bars (tempo is quaver = 112) in which all instruments in Ensemble 2 are spatialized, the first time at bar 299 (a fast trajectory with *Ircam-Spat* lasting 800 milliseconds), the second time at bar 300 (with the LOOP-tool).

Fig. 4.63. *Ius Lucis*: bars 298 – 301. Detail of Ensemble 2: After the Viola 1 solo section where the local instruments are performing basically an accompainment (Viola 1 is projected in Room 2), the discourse is interrupted abruptly by three quick bars (tempo is quaver = 112) in which Trio Left and Right from Ensemble 1 are spatialized together with *Ircam-Spat*. This happens twice: the first time at bar 299 (a fast trajectory with *Ircam-Spat* lasting 650 milliseconds), the second time again at the end of bar 299 (with a trajectory lasting 1040 milliseconds). These fast actions are intended to be complementary impulses to the *sforzandi* performed by the local ensemble (quick alternation local – remote).

A similar fast alternation of spatialized sounds with even more rhythmic detail can be found announcing the beginning of the viola 1 solo (bars 230–232). Here an extremely quick exchange between flute 1 and flute 2 on one side (signal called Trio Left) and cello 2 on the other side occurs, spatialized primarily with *Ircam-Spat* (next score-example, Fig. 4.64).

Fig. 4.64. *Ius Lucis*: bar 230. Detail of Ensemble 1 (left) and Ensemble 2 (right): the quick grace-note figure of Cello 2 (remote signal) is used to precede the one of Flute 1 (local) joining fully the orchestration texture of Ensemble 1. On the other side, the Flute 1 quick figure answers – like echo – to Cello 2.

In other sections of the score, partial *Tutti*-sections can be found, for instance in bars 508 – 517 (Ensemble 2). Here Ensemble 2 reaches an almost full addition of untransformed instrumental sounds (Ensemble 1 is projected divided into three signals: clarinet 1 with Trio Right, oboe 1 with Trio Left – both with fixed sound projection – and Trio Middle spatialized with the oscillation tool), while Ensemble 1 is transformed.

The same compositional strategy (fixing clear and defined formal sections with the use of characteristic and relatively easy to recognize musical contexts) finds another practical solution in those sections where a suspension of time flow occurs. This mainly happens in those sections featuring a clarinet line (long notes) with variable instrumental directivity (sound projection).

As seen already in 4.1.6 (Fig. 4.51), this appositely designed spatialization technique is also used in the service of very precise musical and formal considerations. These kinds of sections, which are musically necessary to interrupt the long evolution of the music but also to create some orientation points in the memory of the audience (such sections have been disseminated in the first and last third of the work), cuts the musical discourse not only with new harmonic material, but also with a radically different musical motion and sound quality. Easily recognizable in the approximately thirty-minute work, it is musically conceived as a moment that stops and restarts the musical flow. Moreover, the fact that it so strongly contrasts with the whole texture heard before that moment, it assumes a definite function as an orienting element in the labyrinth-like time organisation of the vast form. The kind of relationship between the two parallel musical flows (Ensembles 1 and 2) can be described as two diverging musical traits. Looking at the example of bar 114 (Fig. 4.65), if in Ensemble 1 musical tension is maintained with an alternating sound movement projected in three different sectors of the hall, in Ensemble 2 the static sounds offer a moment of rest (live-electronics are less dominant).

Fig. 4.65. *Ius Lucis*: bar 114 score detail of Ensemble 1 (upper score excerpt) and Ensemble 2 (lower score excerpt).

Finally it might be interesting to remark that, in spite of the palindromic metric and formal organisation, these sections whose durations are expressed in seconds (bars 114 and 540 for instance) have not been – exactly – symmetrically inverted (13", 10", 8" 16" and 8", 8", 10", 8", 13"). The further two plus two sections that are at bar 121 (clarinet 1) – bar 533 (clarinet 2) and bar 135 (clarinet 1) – bar 519 (clarinet 2) have different subdivisions of the same lengths (respectively 24" and 21") as shown below:

bar 121 (clarinet 1): 7", 7", 3", 7" ↔ bar 533 (clarinet 2): 12", 8", 4" = 24"

bar 135 (clarinet 1): 6", 3", 4", 8" ↔ bar 519 (clarinet 2): 2", 4", 11", 4" = 21"

This solution is intended on one hand to keep a firm point in the auditive memory of the listener (an easily recognizable sound structure together with a characterized musical gesture), that would be comparable to a signal in the syntax of this large scale music work. On the other hand, it should underline the improvisational character as well as the extrinsic identity (if compared to the strict palindromic form of the work) of this true formal separator. A certain degree of freedom (different timing[15] distribution for the notes played by clarinet 1 and clarinet 2) contributes to enlightening the overall musical discourse and supplying a further dialectic element.

Having shown the two primary formal separators of the work, the rest of the musical sections will be explained. Apart from the AB(-)A partition of the whole work, *Ius Lucis* can be divided into the following main sections:

a) Beginning (main section in dialogue with *Tutti* and solo-clarinet sections) → bar 1 – 172

b) Section (figure F) leading to a first solo → bar 173 – 229

c) Viola 1 solo (projected in Room 2 as well) → bar 230 – 304

d) Few bars Tutti (305 – 311) leading to the next section

Formal symmetry axis: contrabass clarinet solo (both rooms) → bar 312 – 342

d') Few bars Tutti (343 – 349) leading to the next section

c') Cello 2 solo (projected in Room 1 as well) → bar 350 – 424

b') Section going from the end of the solo → bar 425 – 481

a') Ending section (main section dialoguing with Tutti and solo-clarinet sections) → bar 482 – 653.

---

15. Actually, in a performance situation it is the conductor who shows the clarinet player an approximate timing (seconds).

In a synoptical graphic representation, *Ius Lucis* can be summarised as follows:
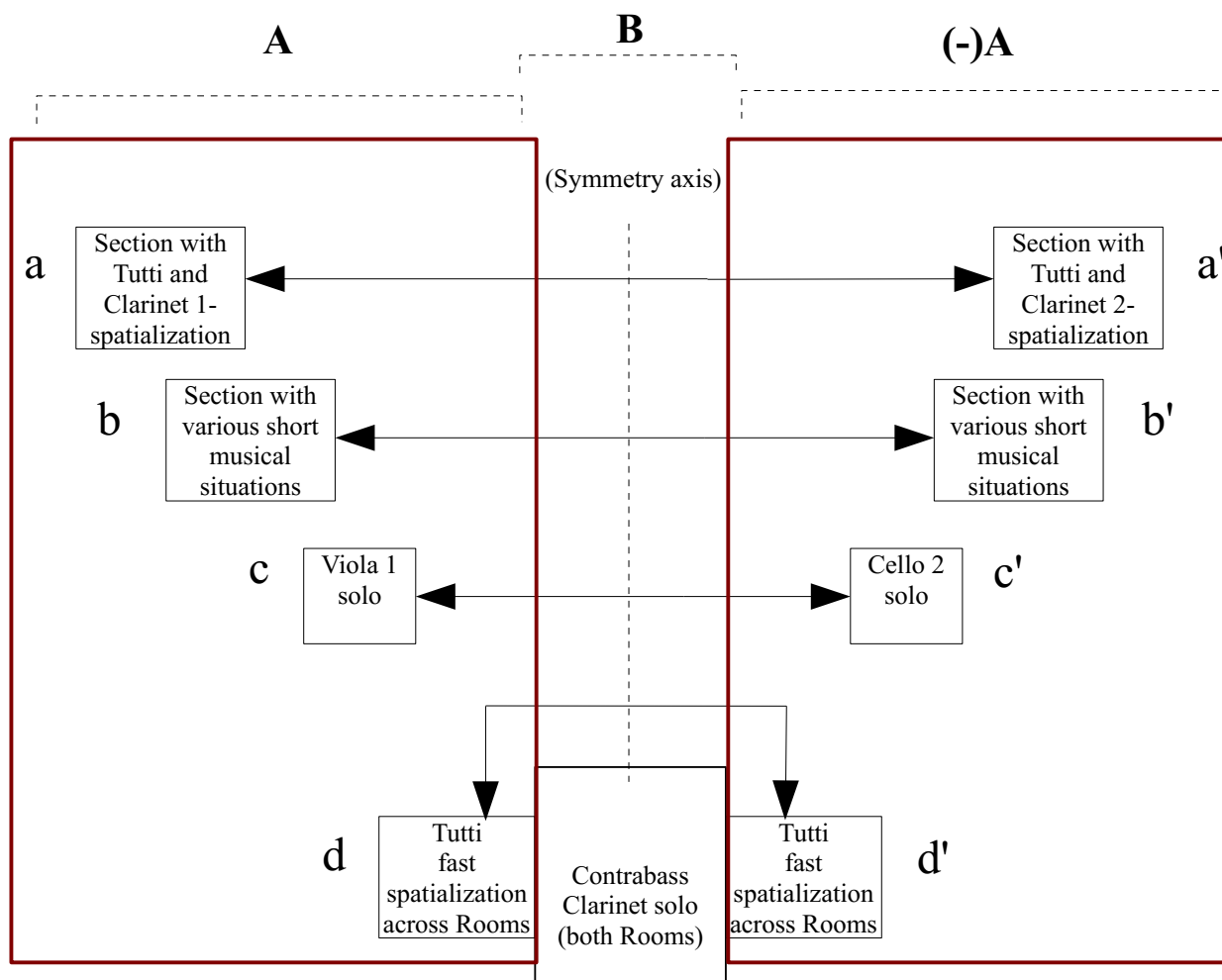
Fig. 4.66. Scheme of the global correspondences between the various sections in Ius Lucis. These are organized symmetrically almost throughout the entire work, with the Contrabass Clarinet solo serving as an axis.

The beginning section (a) is the starting point for two processes, each having different targets: In Ensemble 1 the first impulse (percussion) is the trigger that initiates a constant and non-linear accumulation process. In Ensemble 2, the dense chord (together with the high level of electronically transformed sounds, some of them having quick spatial movements increasing their emotive impact) leads slowly toward a disaggregation motion that will transform variously before ending in a very thin line. In this part of the work, in addition to the harmonic flow (that is constantly increasing in intensity in Ensemble 1), two dialectic elements play a central role (the sections of conjunction and those of temporal suspension). In Ensemble 2, the music is structured so as to show a tendency towards decreasing, but this rather slowly. Since Ensemble 2 is quite smaller than Ensemble 1, there is less room for a long reduction of instrumentation. In fact, shorter moments where only two or three instruments are still playing are quickly interrupted by full-ensemble textures or with intense counterpoint. It is interesting to remark that an apparent, initial unequal instrumentation (Ensemble 2 is without percussion) turns to be much more balanced thanks to the use of two medium-sized tam-tams (played by the trombones). These instruments are not only played

with mallets (bar 114 and following section, trombone 1), but also using a *Shertler-microphone* attached to the back side of the metal surface as a resonator (acoustically modelling a kind of Impulse-Response transformation) for the trombone sound (when in the score the indication *PLAY TOWARD TAM-TAM* appears – as in bar 1 for instance).

The next part, divided from the previous one by a relatively long Tutti-section (bars 160 – 172), starts in Ensemble 1 with an unforeseen orchestration. After a dense orchestral texture, a chamber-music-like situation dominates. Only two instruments are used at a time to introduce various musical periods, starting with clarinet 1 and viola 1 and continuing with a violin duo, each time separated by a tempo change or a new spatial distribution.

Fig. 4.67. *Ius Lucis* bar 173–178 detail of Ensemble 1: A radical change in orchestration density occurs. Clarinet 1 and Viola 1 start a short duo interrupted by the Percussion (Wood-Block tremolo), which starts a new configuration (two violins).

The second section is composed of a large number of regions where from the duo situation, the orchestration increases gradually, step by step, confirming the general tendency of Ensemble 1. In Ensemble 2, the opposite trend is also apparent. This section starts less densely but still with at least three or four instruments:

Fig. 4.68. *Ius Lucis* bar 173 – 181, Ensemble 2: The new section starts less densely, the decreasing tendency – the opposite of Ensemble 1 – becomes self evident towards the end of the section (bar 229).

Later, towards the end of section b, it is possible to see the result of a gradual but non-linear process of accumulation and increasing tension. This does not happen without confirming the chamber-music character of the part started at bar 173 however. A few melodic lines played by solo instruments keep the initial musical mood alive (in the example below, oboe 1 marked by a circle). These two contrasting elements (chamber-music and progressive accumulation of sound masses) coexist dialectically in this section, a compositional attitude confirmed by bars 210 – 213:

Fig. 4.69. *Ius Lucis* bar 210 – 213 detail of Ensemble 1: Two coexisting musical traits, the Oboe 1 and Violin 1 playing as a chamber-music part, while two bars later a violent sequence of impulses preludes the imminent orchestral aggregate (bars 218 – 221).

Looking back at Ensemble 2, it is noteworthy that in addition to a decreasing density of orchestration, dynamics are also used to continue a sort of decay of tension.

When harmony dictated an orchestration of a complex chord for the whole ensemble, a very soft dynamic was used, together with long sustained notes, as at bar 206:

Fig. 4.70. *Ius Lucis* bar 206 – 209, detail of Ensemble 2: A sudden *piano*-phrase gives a further signal of Ensemble 2 decay.

Finally at bar 222, the instrumental group is reduced to a trio and the music reaches the character of chamber-ensemble:

Fig. 4.71. *Ius Lucis* bar 222 – 224, detail of Ensemble 2: The main part, Clarinet 2, is in dialogue with Trombone 1. Clarinet 1 plays percussive sounds that are used to cross Ensemble 1 instruments (Percussion, among others). The smooth phrase played by Trombone 1 is crossed with a rhythmically moving line in Clarinet 1.

As soon as these two main trends have been musically stated through a multitude of differing and kaleidoscopic musical situations, the second section flows toward a quick signal exchange (fast spatialization between two Rooms) in bars 229–231. Here cello 2 is in dialogue with flutes 1 and 2, thanks to the *Ircam-Spat* tool, and introduces the next part of the work. The decision to spatialize two tiny musical actions (about a sixteenth-note with grace notes around) also underlines the chamber character of the second section.

The third part (c) of *Ius Lucis* is dedicated to a large viola solo (viola 1, Ensemble 1), its symmetrically related section (c') is a cello solo (cello 2). In this section of the work, two compositional aspects are enhanced at the same time: a certain degree of independence of musical materials and a higher interconnection between ensembles reflected on the musical dramaturgy. Mapping between instrumental parts, used to design (and feed) live-electronic transformations, can be said to be more locally oriented than before. Instrumental sounds, live-electronic transformations and spatialization techniques are used more freely than in the previous sections, and this in a quite unilateral way. This aspect, which would naturally lead toward two separated musical discourses, actually results in the opposite. In spite of this punctual use of electronics (it could be defined as less symmetrical), a higher level of interconnection between the two sound worlds is created. This trend will become unmistakably manifest in the middle section (contrabass clarinet solo), where a total identity between two spaces (rooms 1 and 2) is reached. In the case of the third section, it could be said that the viola solo focuses the whole musical attention and leads the musical flux univocally. What is different here is the context in which this happens, also in relation to the use of electronics. Structurally speaking, Ensemble 1 applies a formal pressure on Ensemble 2 not only with almost the totality of the viola 1 part (which is almost always projected into Room 2 untransformed), but also with diverse other instrumental parts, developing a true extended (or spatial) counterpoint as explained in 4.1.2. The compositional approach of using phrases – or even a few notes taken from a musical context – to complete or to enrich one another as is the case with Ensemble 2 throughout the whole section (bar 230–304), explores the potentiality of such an unusual, spatially spread instrumental configuration. On the other side, Ensemble 1, because it is the place were the main musical action occurs, seems to be reflected back on itself, as the use of electronics, among other things, confirms.

Fig. 4.72. *Ius Lucis*, bars 246 – 253, detail of Ensemble 1: an example of orchestration and live-electronic transformations focused on the local happening.

As can be deduced from the score-example above (bars 246 – 253), the highly virtuosic viola solo tends to focus on the entirety of compositional elements[16]. The orchestration for instance reproduces some echo-like figures (see example above, the F repeated by clarinet 1, so as to simulate a resonance). Live-electronics transform viola sounds, crossing them with various remote instruments (here trombones 1 and 2). Often over the course of this section, spatialization projects viola 1 – untransformed – inside the same room 1.

Looking at Ensemble 2, it could be said that the general musical behaviour follows the logic of an accompaniment to the viola 1 solo part. Isolated short musical phrases, even when within the frame of a harmonic sequence, are a mirror of some figures of the remote viola, projected almost from beginning to end in room 2 (see next score-example, Fig. 4.73).

---

16. It needs to be mentioned that, In the course of the compositional process, this viola solo (composed with materials taken from room-mode analysis) was something like a first approach at musically using the data from the informatics tools explained in the third chapter.

Fig. 4.73. *Ius Lucis*, bars 239 – 245 detail of Ensemble 2: Viola 1 (soloist part) is projected without any transformation using *Ircam-Spat* (marked by a rectangle) but also crossed with other local instruments (ovals). At bar 242, there is an example of mirrored phrases coming from the solo instrument: Clarinet 2 reproduces a microtonal descending figure that is transforming Viola 1 (in Room 1) and adding a contrapuntal voice to the projected (remote) sounds.

The musical texture of Ensemble 2 in the entire section running parallel to the viola solo, is made of light, tiny elements that are sometimes also spread out in space. In spite of their initial disjuncture, these elements together with viola sounds (from Ensemble 1), gather an inner coherence by matching, underlining, joining in various ways the solo string part. This technique is also asserted by a strict pitch correlation at main points where musical periods are prolonged or where musical flow finally comes to a rest. In the next score example, the english horn (oboe 2) starts a long, chromatic ascending line (in counterpoint with viola 1) and in bar 248, in correspondence with the D-sharp of the viola, a new musical phrase begins on this same pitch. Later, the end of this new phrase (at bar 250), a B-natural is used to orchestrate a spatial movement (acoustic) through viola 2, clarinet 2, cello 2, trombones 1 and 2, going back to clarinet 2 and english horn, tracing a complex trajectory along the musicians in room 2.

Viola 1 (detail)
from Ensemble 1

Fig. 4.74. *Ius Lucis*, bars 246 – 253, detail of Ensemble 2: English Horn is in counterpoint with Viola 1 with a relatively long chromatic ascending line. The new start at bar 248 (on the D-sharp, the same pitch played by the remote viola – marked by a circle) is developed by a moment on a sole pitch (B-natural – marked by a rectangle) that is spread in space with an orchestrated complex trajectory. Dynamics are also used to enhance the spatial effect and to allow a better perception of this kind of acoustic spatialization, a rapid crescendo – diminuendo simulates a sound approaching and moving away.

It is interesting to remark that in this kind of texture, the electronics in room 2 are also quite punctual (except for the spatialization of viola 1), also bringing in diverse elements taken from Ensemble 1 for very short portions of time. This musical solution is used to differentiate, also by the mean of spatialization, the main line (viola 1) from other elements[17]. A special musical situation occurs at bar 283, where an impression of a Tutti is given, again with a momentary polarisation on the pitch A-natural. Here, for a relatively long period (about eight bars), the arrival on the pitch A-natural in viola 1 marks a point of repose for the musical

---

17. Different projection speeds underline this hierarchy: the viola solo is spatialized quite slow whereas the small fragments (from Ensemble 1) are projected definitely fast.

flow, and a unity occurs in both ensembles. Moreover, in Ensemble 2 the projected viola sounds are stopped before (bar 274), in order to be perceivable as a new, fresh idea at bar 283 (see Fig. 4.75).

Fig. 4.75. *Ius Lucis*, bars 283–284, detail of Ensemble 1 (left) and Ensemble 2 (right): Both ensembles are focused on a Unison (A natural) initiated by Viola 1 (marked by a rectangle) and underlined by all instruments with fast five- or seven-note groups. In Ensemble 2, this polarization on one pitch is consequently developed in the next bars, introducing new pitches.

4.2.1 An example of composing with room-mode analysis tools

With a short section of a dense *Tutti*-section (explained before in 4.2.) of a rather sudden and dramatic character, the next section, the core of the whole musical work, is prepared. This section, a large contrabass clarinet solo projected in both rooms, has been composed using the informatic tools designed for the room-mode-analysis explained in the third chapter and can be considered as an example of music created following this method. Within the work *Ius Lucis*, two more sections have been written on the basis of such analysis, the viola solo section from bar 233 until bar 304 and the cello solo section in Ensemble 2, from bar 350 up to bar 424. In all three cases, but strongly emphasized in the contrabass clarinet solo, this musical situation tends to be the focus of attention, since the same musical material is

projected in both rooms, whereby sometimes interpreted differently on account of different uses of the so-called global counterpoint (see 4.1.2). As a matter of fact, especially in the contrabass clarinet section of the musical work, the idea of linking spatialization to *Écriture* (musical writing, i.e. composition) is particularly apparent. Along with this particular compositional method (room-mode analysis), two elements, musical text and sound projection through loudspeakers are connected with a third element: real-time transformations. This means that the same room-mode tool (used to generate musical material) implemented in the Max/MSP platform (patch used for live-electronics during the concert), is also used to transform the solo instrument sounds. In this platform, room-mode-frequency values are used to activate several oscillators. Spatialization trajectories (along the fixed loudspeaker arrow) are connected to room-mode intensity, giving a loudness to those frequencies (oscillators) activated over the course of a certain sound movement in the concert room. In the following example (two-dimensional trajectories), the trajectory used to generate a certain musical structure, and the same one performed to spatialize the sounds during the concert is shown. In real-time means that while the spatialization trajectory is performed in the sense shown by the arrow, at each point (from 1 to 9 in the graphic below) a group of frequencies (and amplitudes) are calculated (on the basis of the room model used to generate the music text) and transformed into sinusoidal sounds. Those sounds (changing as a function of the time and speed in which such spatialization is performed) are used to transform the instrumental sound (cross-synthesis).

Trajectory for *Écriture*   Trajectory performed in concert
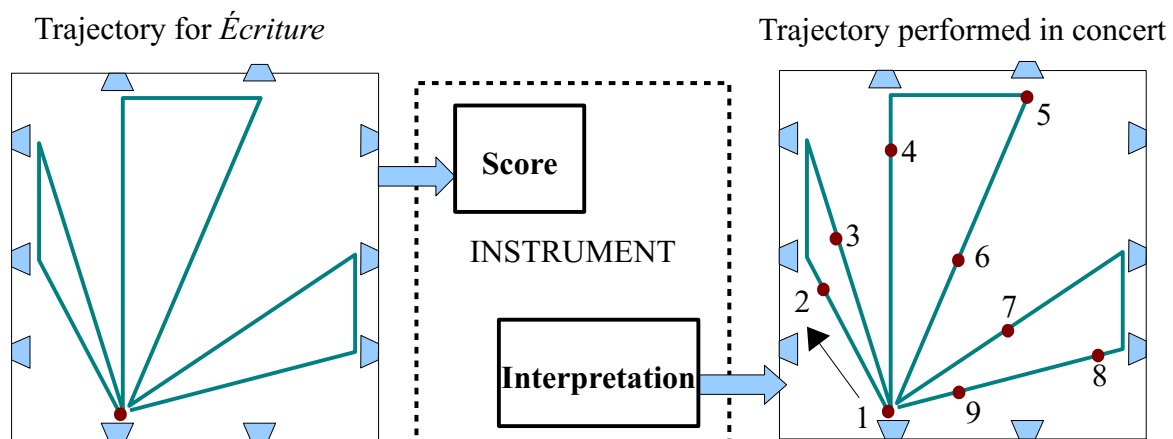
Fig. 4.76. Trajectory used to generate a music structure on the left (played by an instrument in concert) and the same trajectory performed for sound spatialization on the right; the same modal data are used to transform the instrumental sounds in real-time (played live in the concert). At each point (e.g. from 1 to 9 along the trajectory) a different pitch, dynamic (and rhythmic) material is deduced thanks to the room mode analysis.

Looking at the compositional process, it is possible to observe a triple connection:

(i)   Resonance mode data ↔ Oscillators (Resonance mode frequencies and amplitudes)

(ii)   Trajectories (used in the analysis tool) ↔ Spatialization movements

(iii)   Score ↔ Instrument

Such connections, in line with the original idea of a stricter relation between space and musical composition, are also extended from the symbolic to the actual musical happening, in particular the fact that the same trajectories used for spatialization are utilized to analyse a virtual space, asserts the idea of merging a phenomenological attitude (with which sound movements can be more appropriate or effective in certain musical – and acoustical – contexts) with an analytical method (the same trajectories are generating – or filtering – a cluster of modes to finally extrapolate a music material).
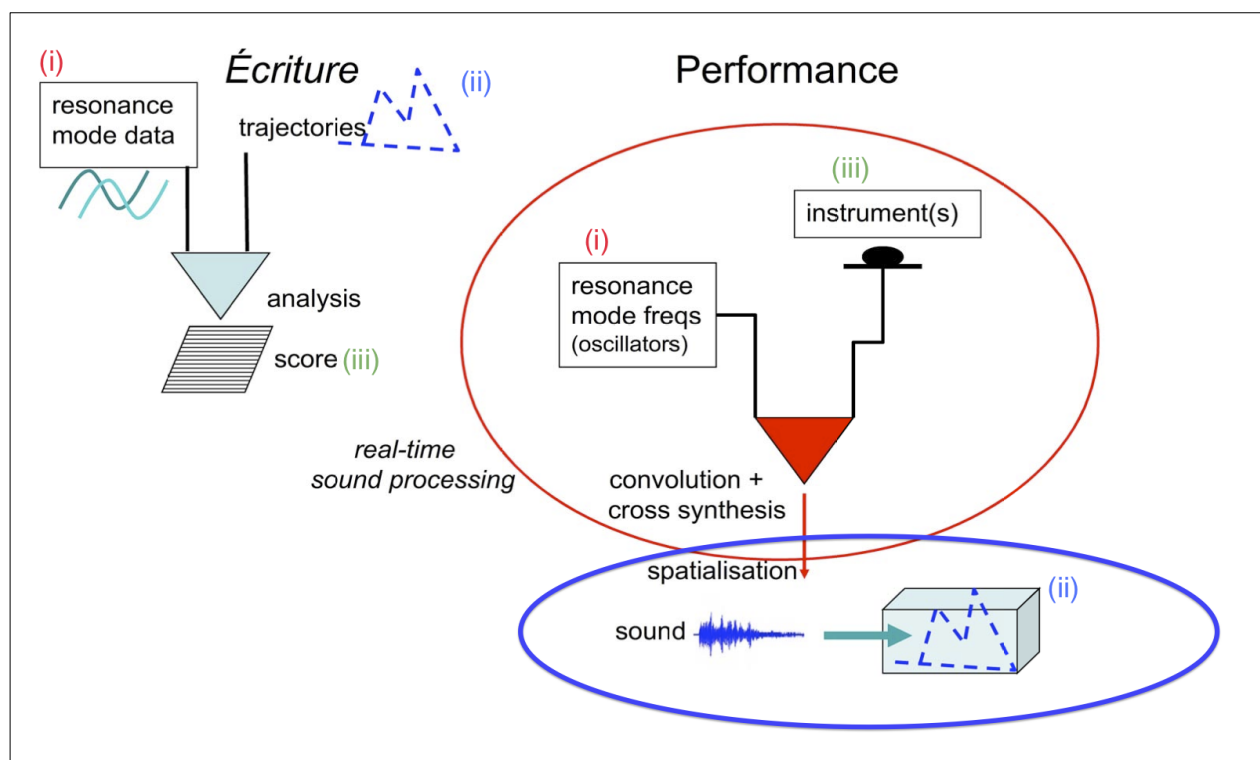
Fig. 4.77. A scheme of the different passages in the working process of *Ius Lucis*, from *écriture* to actual sound projection.

4.2.2 Examples from sections composed with room mode analysis

It must be said that if this compositional tool was going to be programmed, it had to face at the same time an already organized and conceived musical idea, already at a quite advanced state: The compositional idea was developed before the room-mode synthesis software. This is why the tool initially was used as to shape the music, helping and underlining a certain musical intention. In fact, when working with a compositional tool able to generate musical material, the first question arising for a composer is whether a higher musical aim exists before using it, which is then able to control and indicate in which direction the final result shall go. It is important to remark that since the software was developing at the same time as the musical composition, the first attempts to extrapolate musical materials from that acoustic

model simultaneously served as a test for the software itself. For this reason, the working method was a kind of work-in-progress, rather than the application of a long existing and fully developed tool for composition. This is why, if it is not always possible to show a direct and continuous mapping between analysis sketches, processes and final score, a correspondence between these three states of the work will be explained with some references to documents that indicate, with some exceptions and decisions dictated by a certain artistic freedom and expressive needs, how the working path was gradually determined.

For *Ius Lucis*, the generation of musical data itself is controlled by other aspects like the harmonic structure superimposed on the whole of the work (see 4.1.3, Fig. 4.13) or instrumental range limitations, for instance. In point of fact, for each of the three instruments used in a solo section (viola 1, cello 2 and contrabass clarinet) the virtual space(s) used as a model for the room-mode analysis have been, so to speak, accorded such restrictions. First of all, on account of harmonic needs (the overall harmonic scheme along which the entire work is built), only those pitches belonging to the chords used have been taken into account in the modal analysis (transposed to lower octaves). Of course, by lowering all pitches into a different octave register, some relations existing between the notes of the aforementioned chords needed to be readjusted, a further process that was left to the composer's judgement:

Fig. 4.78. A composition sketch from *Ius Lucis*: In this scheme, a repertoire of pitches has been built in order to tune the virtual room model to the same frequencies. The task of the software would be, at this point to organize frequencies and corresponding intensities according the trajectory (later) for the spatialization. Pitch-repertoire for Viola 1 is marked by a polygon and the sequence at the bottom refers to Cello 2.

We can thus speak, as concerns the compositional work with the room-mode analysis, about two different methodological approaches:

- An inductive method of composition (from the particular toward the general) when the space is analysed beginning with a selection of elements (frequencies in this case) and the aim is to find an integral picture;
- A deductive method of composition (from the general to the particular) when the space is analysed in its whole complexity (the entire cluster of frequencies) and gradually filtered according various criteria (most dominant frequencies, for instance).

Since in *Ius Lucis* the first method was primarily adopted, it is important to remark that the compositional work finds a kind of duality between the objectivity of data output and the subjectivity of the musical idea. There is however, in some cases, a mutual exchange between these two forces. The results of analysis are used to underline and complete in all details an existing musical idea, but sometimes it is also true that such analysis is used as a trigger for possible compositional decisions. From this perspective, outputted musical data is not read in time, but is considered as repertoire or a reservoir of numerous (musical) possibilities and solutions for what is called *Écriture.* Once an idea (or musical figure as rhythm, etc.) is extrapolated, it can be developed for a certain amount of time, independently from the rest of analysis to which it belongs. Furthermore, the time in which such analysis was made (duration of the trajectory used to generate modal data), does not coincide with musical time (actual duration of a certain musical phrase in the final score). This kind of duality can also be expressed as an interaction between the time in which raw matter is expressed and the time in which it can be best perceived (by an audience).

It is possible to observe that in the final score, the correspondence between spatialization trajectory (live-electronics) and the result of analysis (musical text, pitches etc.) generated by the same trajectory are used often disconnected. Once the whole musical material was extrapolated from the analysis of one (big) trajectory, some portions of it were used to project sounds (a solution aimed at better achieving space-perception). As seen in 4.1.5, many spatialization techniques, depending on the live-sound of the instrument, need a certain amount of time to be fully performed and perceived.

Where room-mode analysis was only periodically used for the viola solo because the musical direction was still integrated within the general formal scheme (viola 1 is playing in order to connect with other instruments – local or remote), the next two sections will be explained in greater detail in the following paragraphs. Particular attention will be payed to the growing importance that room-mode analysis achieved in the compositional process, culminating in the cello solo section.

4.2.3 The contrabass clarinet solo

In the section featuring a large contrabass clarinet solo, a duality between the musical idea and the result of synthesis (musical data outputted from the composition tool) can be clearly observed throughout the working process. The same can be said about a tendency to enrich the music with further elements, such as new pitches (to achieve a better melodic progression) or live-electronic elements (as result of an attention to the overall acoustic effect). However, the choice of the contrabass clarinet itself, is an aspect that needs to be discussed as well. Aside from the obvious dramatic and powerful sound quality that the instrument has, the main reason for this choice can be found in the fact that, dealing with resonance modes, low frequencies would be the principle sound matter. This is absolutely the case in the section in bars 312–342. Although, at the same time, some moments here focus on very high pitches, which for this particular kind of low instrument gather a special intense and sharp timbre. Additionally, the special characteristics of an instrument like this are particularly suited to marking a definite sectional divide in the global scheme of the form, with a passage in which a sole instrument dominates the whole musical discourse for about four minutes (simultaneously in dialogue with the remote ensemble placed in room 2). A central topic in the following examples taken from the score is – in spite of a seeming contrast – the special kind of interaction between musical material and the idea flowing together in an effective direction; two sides of the compositional work with room-modes arise. On one side is the phenomenological (room modes used to transform instrumental sound in real time, live-electronics are programmed in a way that directly connects room-mode frequencies to space movements as explained in 4.2.1, Fig. 4.76 and Fig. 4.77), on the other side is the use of room modes to generate musical text (with the analysis tools). Along these lines, this section will demonstrate how the first of these aspects is particularly dominant (the result of room-mode analysis will actually be partially used) and how the possibilities of using room-mode frequencies (constantly changing in pitch and intensity as they correlate to spatialization movements) have been used. In relation to the working strategy, this section may also be considered similar to the moment of the compositional process where the method (of composing with room-mode analysis) starts to be installed, and will be integrally used in the next section, the cello solo in Ensemble 2. Although some musical elements were already determined on the basis of instrumental, extended techniques particularly adapted to the musical context and situation, several trajectories were first used, helping to generate what would later become the soloist part. At this stage of the work, the analysis tool was tested in different ways in order to look for a possible working method. For instance, the method of transcribing room-mode analysis outputs in the form of a musical text (as initially had been done for the viola solo, though only partially used) confirms its inadequacy in this particular context. These transcriptions, (following graphic example) based on trajectories and a few main pitches used as a skeleton, were not really taken into account:
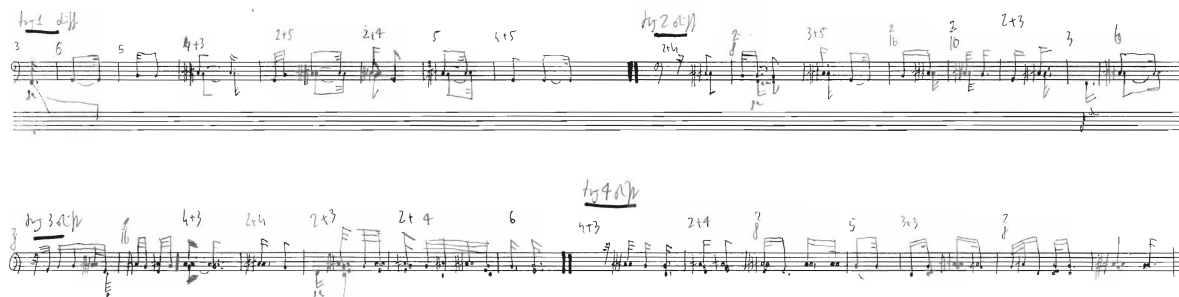
Fig. 4.79. A composition sketch from *Ius Lucis*: Some trajectories have been analyzed and transcribed. This represents a first attempt at a way of interpreting the outputted data.

The idea of normalizing outputted musical materials into metrically organized structures did not find further application in this context since this section needed to be formed in a much more open way than the preceding and following parts. As the axis of the whole composition, the contrabass clarinet solo also needed to have a very different and particular shape (in addition to its musical character) in the way it was organized temporally. For this reason, another working solution was considered: To use the analysis outputs as a reservoir of possible cells (rhythmic, dynamic, for instance) by reading and interpreting them without a fixed temporal scale or direction. Each fragment, if musically significant, could have been transcribed with slight temporal differences (durations, proportions) according to the musical needs of any particular moment. This is further justified by the fact that time quantification in the melodic and dynamic analysis tool (called minimum duration, see 3.2.4 and 3.2.5) is a value that needs to be inputted to temporally scale the whole analysis.

The working process starts here with the definition of some trajectories, which were chosen to explore the whole space (room 1). Two circles (the upper and the lowest loudspeaker squares) and six further ones were positioned in very different portions of the space, so as to be more acoustically perceivable later, when used to spatialize sounds:

trajectory 1: loudspeakers 5 – 9 – 8   trajectory 2: loudspeakers 5 – 10 – 6

trajectory 3: loudspeakers 5 – 12 – 4   trajectory 4: loudspeakers 5 – 11 – 3

trajectory 5: loudspeakers 5 – 1 – 2   trajectory 6: loudspeakers 5 – 7

trajectory circle up: loudspeakers 9 – 10 – 11 – 12 – 11 – 10

trajectory circle down: loudspeakers 2 – 1– 4 – 3 – 2

With effective space perception in mind (when used to project sounds inside the concert hall), trajectories have been chosen in such a way that each one can be clearly recognizable and each one is in fact designed along a different portion of the room (e.g. trajectory 1 runs along a front/left region, trajectory 2 along a front/right region), as the following image shows (Fig. 4.80).
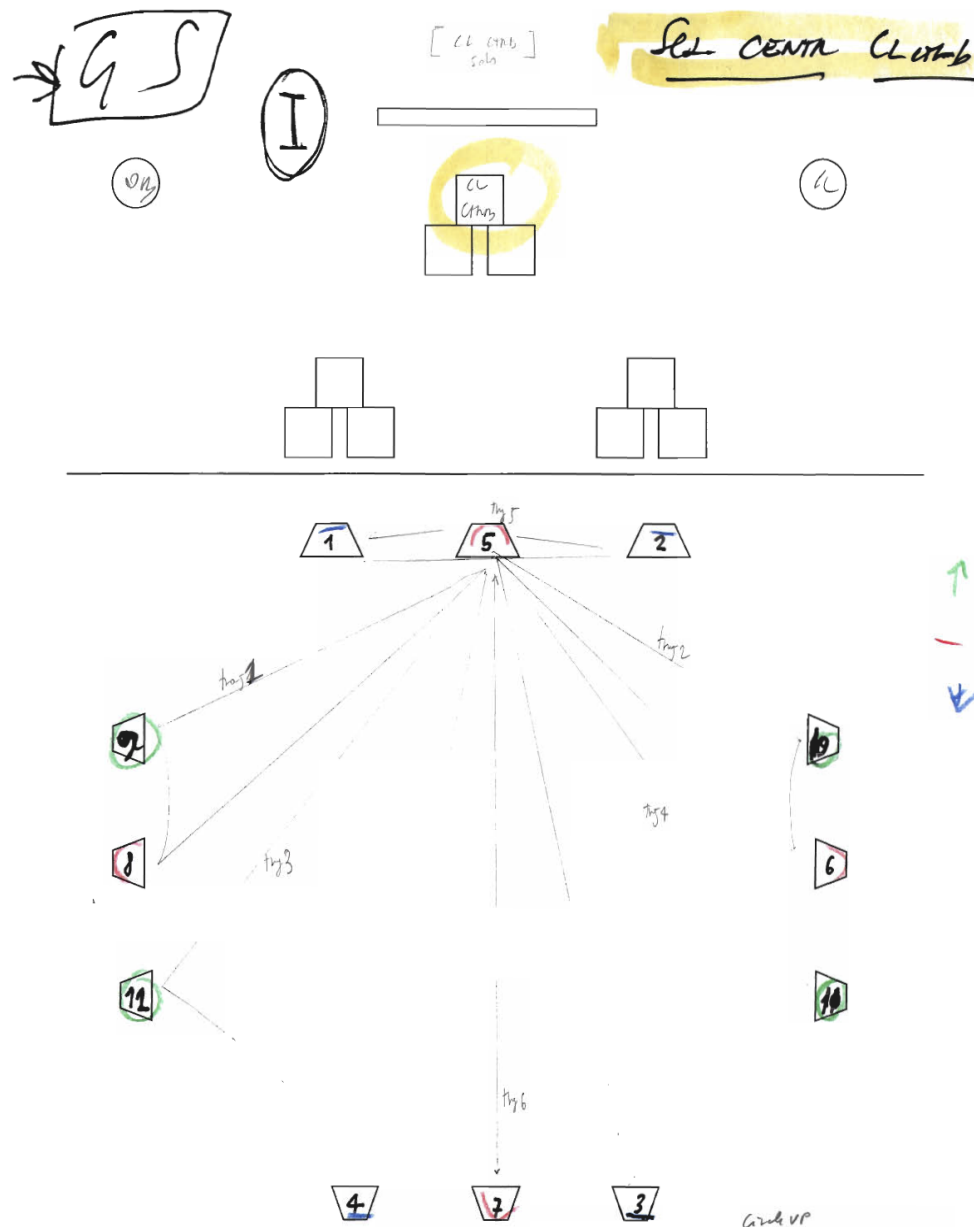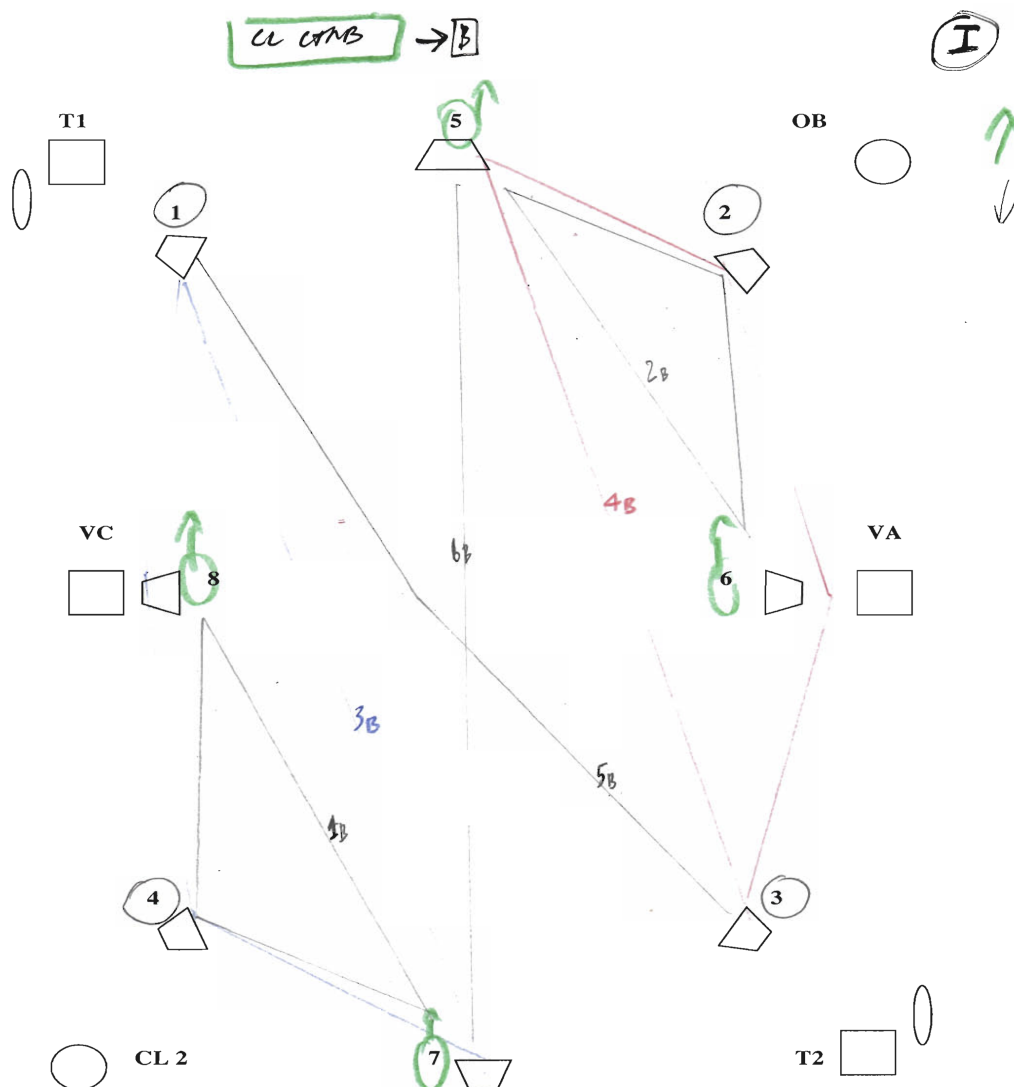
Fig. 4.80. A composition sketch from *Ius Lucis*: In this scheme, several trajectories have been traced. They are used for both room-mode analysis and sound spatialization (live-electronics).

Because it was clear from the start that this instrumental solo would be projected in both concert halls (room 1 and room 2 at the same time but with different trajectories and counterpoint combinations), the trajectories in room 2 have also been traced. It is because of the self-evident contrast arising between two analyses (the one on the room modes of room 1 and the one on the room modes of room 2, that would have given two different results therefore two different musical parts) that the decision was finally made to focus only on the room-mode analysis of room 1 (where the instrument is actually placed) to generate musical material.

In the following image (Fig. 4.81), it is again possible to visualize the same number of trajectories that were used to spatialize the sound of the contrabass clarinet (and real-time sound effects):

Fig. 4.81. A composition sketch from *Ius Lucis*: In this scheme, several trajectories along the loudspeakers in Room 2 have been traced. They are only used for sound spatialization (live-electronics).

Such trajectories, once the instrumental sound activates a cross-synthesis transformation with room modes of the same Room 2, will obviously offer a different result than the transformations (and spatialization) encountered in Room 1:

trajectory 1B: loudspeakers 4 – 8 – 7   trajectory 2B: loudspeakers 2 – 6 – 5

trajectory 3B: loudspeakers 1 – 7 – 4 – 8   trajectory 4B: loudspeakers 2 – 6 – 3 – 5

trajectory 5B: loudspeakers 1 – 3   trajectory 6B: loudspeakers 5 – 7

trajectories circle up B: loudspeakers 5 – 6 – 7 – 8

trajectory circle down B: loudspeakers 1 – 2 – 3 – 4

Once musical materials were generated and the soloist part composed, trajectories in live-electronics were fixed to those parts that they – even partially – generated. Often, these are mixed or used differently to emphasize and facilitate spatialization perception, giving special care to the range of real-time synthesis-sounds. A transposition coefficient (a *Frequency Multiplier* seen in the Max/MSP software in 3.2.1, Fig. 3.21) helps live-electronic sound transformations to integrate better with the sound quality of the soloist. Basically, oscillator frequencies (related to room mode frequencies) are transposed by one or more octaves to fit the range of contrabass clarinet. Here, some parts of this solo with their relationships with analysis results together with the way live-electronics have been programmed will be demonstrated. The first score excerpt shows a few bars (Fig. 4.82) from the beginning of the large contrabass clarinet solo, so as to offer some insight into this working process (bar 313 and 314):

Fig. 4.82. Bar 313 (left) and 314 (right) from the full-score of *Ius Luci*s, Contrabass Clarinet sounds a second and a fifteenth lower than notated (lower system).The trajectory (circle up: loudspeakers 9 – 10 – 11 – 12 – 11 – 120 – 9) used to generate musical material (room mode analysis) is used for spatialization in bar 314 (XA1 OSCIL). In bar 313 a combination of trajectory 2 and 4 (loudspeakers 5 – 10 – 6 and 5 – 11 – 3) is used for XA1 OSCILLOOP to acoustically distinguish, a different spatial movement (see circles) for each phrase. Transposition of room-mode frequencies (three octaves higher = 8) helps to create a first strong sound impact.

These two large bars (written in space-notation inside a time-frame, as is the whole of the contrabass clarinet solo) have been composed using musical material extrapolated from a trajectory (circle) between loudspeakers 9, 10, 11 and 12 (in the sketches called circle up because the four loudspeakers are placed at the highest level of elevation in the concert hall). The result of the room-mode analysis focused on five main pitches (C-quarter-tone-sharp, G-natural, F-natural, C-sharp, B-natural taken from the global chord network shown in 4.1.3, Fig. 4.13), giving a musical structure with information on the dynamic evolutions of these pitches along the chosen trajectory. Often, a free-compositional decision shapes the melodic evolution according to the five main pitches and a chord-chain found in the global harmonic network:
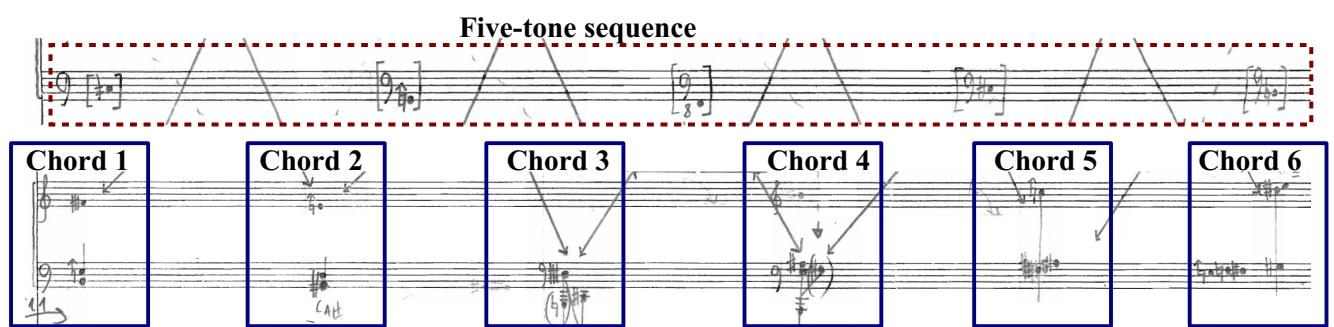
Fig. 4.83. Composition sketches from *Ius Lucis*: detail of global harmonic scheme. In the picture above the sequence of five main pitches (some of them have been used without quarter and eighth-tone inflections), in the one below a chord sequence used to shape melodically the contrabass clarinet solo.

The way in which analysis results are freely interpreted can be seen by comparing the two previous score excerpt (bars 313 and 314) with the analysis sketch itself (next picture, Fig. 4.84)

a) the aggregation of various Cs (lower system) suggest a *ribattuto* (repeated notes);

b) the dynamic evolution of the same C (from *ppp* to *pp*) suggests a crescendo leading to a stronger musical gesture (another interpretation of the same repeated notes): the multiphonic sounds with *sforzato*;

c) the pitch C-sharp is used to extend the *ribattuto* as for the C-natural;
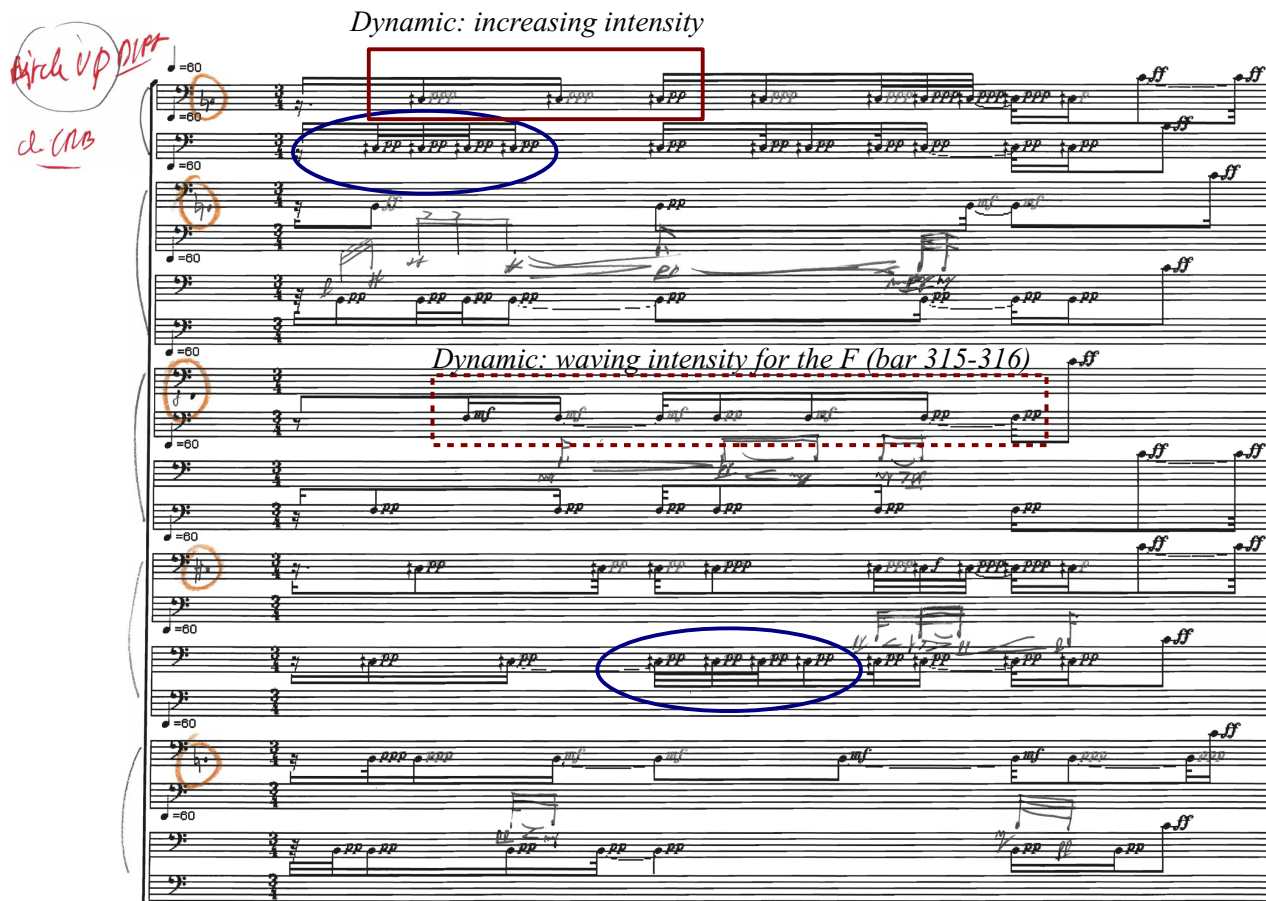
Fig. 4.84. Room-mode analysis for a circular trajectory (loudspeakers 9, 10, 11, 12) focused on five pitches (marked by hand at the beginning of each series of systems, some pitches are approximated); in the analysis of dynamic evolution, each frequency is described by two staves, the one below indicates the 0-points, the upper one the actual dynamic evolution, expressed in musical symbols (e.g. *pp*, *mf*, *ff*, etc.).

At this point, after having enunciated a very strong musical gesture (the effect of slapping multiphonics indeed produces an extremely percussive and rich sound), the musical discourse is developed producing similar complex sounds on all of the five pitches, as well as on a few additional ones (at the end of bar 314, the last slap-tones, sounding G-sharp, A-natural). The next bar (bar 315) is based on the very low F-natural (with a sharp accent – *fp*), developing with intense dynamic waves (*crescendo – diminuendo*). This information, an oscillating increase and decrease of intensity, is given by the dynamic evolution description (from *mf* – the highest dynamic within this portion of analysis – to *pp*, see the dashed rectangle in Fig. 4.84).

Fig. 4.85. *Ius Lucis*, bars 315–316. Detail of Contrabass Clarinet part. The music is focused on the low F-natural. The wave motion is interpreted with *crescendi* and *diminuendi*, but also with the gradual transformation into multiphonic sounds, dramatically expanding the spectrum as well the intensity of the resulting sound. Transposition (one octave higher = 2) underlines the dark sound-character of this phrase.

Later, a sudden change in spatialization (see dashed circles in the following score examples) is underlined by a change in the musical material that was used. At bar 318, a new musical figure (a quick melodic sequence, marked by a circle in Fig. 4.86) introduces a new musical phrase:

Fig. 4.86. *Ius Lucis*, bars 318–319. Detail of Contrabass Clarinet part. Here a new musical element appears (quick *legato* and *Flatterzunge* tones) mixed with slapped and long multiphonic sounds.

Multiple alternations of different spatialization techniques (LOOP – LOOPDYN, LOOP – TRAJ, LOOP – OSCIL) focused on two main trajectories ("circle down" and a combination of trajectories 2 and 3) characterize this group of bars. Here, analysis materials are not used anymore since the musical progression follows its own development based on a dialogue between continuous tone chains (as a permutation of the main chord sequence plus new pitches) and the slapped multiphonic sounds (on the C-sharp and B-natural from the main five tones).

A first decisive moment is reached at bar 320 (Fig. 4.87), when the first very high pitch arises. The sounding D-sharp, heard at first as steady tone (with decreasing intensity) and later developing into a *ribattuto*, as a timbre-*tremolo* with dynamic oscillations (short *crescendo – diminuendo*), is spatialized again with probably the most easily perceivable spatial movement: a circle (circle up and circle down).

Fig. 4.87. *Ius Lucis*, bars 320–321. Detail of Contrabass Clarinet part. The high D-sharp is spatialized with LOOPDYN first (decreasing dynamic means decreasing speed), with OSCILLOOP (each attack provokes a change between two loudspeaker circles) and finally with trajectories 5 and 6 joined (XA1 OSCIL).

This gesture is followed by an intensification of slapped multiphonics (based on pitches from the five-tone sequence) leading into a new moment where low tones appear again.

In bars 326 and 327 (Fig. 4.88), the idea of low, quick *Flatterzunge* tones is developed into a situation in which three elements coexist: low pitches (from the five-tone sequence) developing into quick melodic figures (*Flatterzunge*), interrupted by slapped multiphonics (with repeated patterns).

Fig. 4.88. *Ius Lucis*, bars 326– 327. Detail of Contrabass Clarinet part. Steady tones as well as multiphonic sounds are organized according to the pitches of the five-tone sequence. Several melodic configurations in the quick *Flatterzunge* are first a result of the chord sequence, thereafter a chromatic descending movement. A transposition three-octaves higher of room-mode frequencies (started before in bar 323) tends to underline the higher pitches, leaving the low tones detached and therefore increasing the effect of counterpoint between two distant voices.

Here three phrases with similar musical gestures (marked by a rectangle) are spatialized with three different techniques and trajectories. The first one (LOOPDYN) presents a longer combination of trajectories 2, 4 and "circle down", the second one (still LOOPDYN) trajectories 2 and 4 in partially different loudspeaker order, the third one, ending with a rather virtuoso musical figure (LOOPDYN), introduces a new combination of trajectory 2, 4, "circle down" with other loudspeakers. As a consequence of the constantly descending chromatic movement of the quick *Flatterzunge* tones, in the next bar (328) music stays on a very low register, supported by a spatialization technique that moves rather slowly as well (PANDYN). After this static moment, there is a decisive change of musical gesture where high tones upsurge again with a LOOP (loudspeakers, 5 – 11 – 3 – 5 – 12 – 4 as an addition of trajectory 4 and 5), dramatically relaunching the discourse on a high B-natural:

Fig. 4.89. *Ius Lucis*, bar 329. Detail of contrabass clarinet part. A new high pitch as axis of this section, together with fast melodic movements built on the chord pitches (excepting A-sharp, which is to be interpreted as a chromatic step around the central pitch B-natural).

The music focused on the high range of contrabass clarinet evolves even further when it reaches bar 330, where a long phrase based on the high F leads to another phrase on the high A-natural, building a major third interval that sounds very significant (see dashed rectangle in Fig. 4.90):

Fig. 4.90. *Ius Lucis*, bars 330– 332. Detail of Contrabass Clarinet part with spatialization trajectories changing at each notable point of soloist phrase.

Here, having abandoned the analysis sketches, the music develops in its own direction, which moves towards a clear and powerful musical gesture initiated and installed in the previous bars. Spatialization is constructed to underline this extreme richness of timbres, dynamics, registers and articulations, constantly presenting new spatial configurations (zones delimitated by three or four diffusion points – see dashed circles in the example before). The whole attention is thus focused not only on the very gestural instrumental part, but also on the impact of spatialization and the effect it produces on sound transformations. It is for this reason that not only trajectories (sequence of loudspeakers), but also their order and partitioning in space change continuously at each new phrase. With the first OSCILLOOP (bar 330), each accented low tone provokes an alternation between trajectories 3 and 2 (loudspeakers 5 – 12 – 4 and 5 – 10 – 6) and "circle up" (loudspeakers 9 – 10 – 11 – 12); a new OSCILLOOP alternates the same circle with a different combination of two trajectories (number 3 with 4, slightly modified). Then, in order to emphasize the dynamic variations between low and high pitches, a LOOPDYN introduces a complex trajectory made up of trajectory 3 that evolves along a new path (loudspeakers 5 – 12 – 4, then 5 – 10 – 11 – 12 – 9) while a similar loudspeaker path (more focused on the right side of the room) expands and varies sound-projection movements.

Later, the same high D-sharp that appeared in bar 320 confirms its attraction function, as well as its primary role within this section. This pitch closes the virtuoso part, first as long tones, interpolated with fast melodic figures and evolving toward a continuously timbre changing sound (timbre-tremolo in bar 335) with a long and gradual diminuendo (see score-example in Fig. 4.91):

Fig. 4.91. *Ius Lucis*, bars 333–335. Detail of Contrabass Clarinet part with spatialization trajectories becoming more and more complex until bar 335, where the high D-sharp – played with several dynamic nuances – is spatialized with a new LOOPDYN (see dashed circle and a combination of trajectories 2 and 4 (loudspeakers 5 – 10 – 6 – 5 – 11 – 3 – 5 – 11 – 3 – 5 – 10 – 6).

A sudden timbre change in bar 337 (underlined by a smaller transposition – only two octaves – of room-mode frequencies), introduces a new phrase developed on low sounds. Here (Fig. 4.92) the soloist mixes instrumental and vocal sounds (which are transformed by the oscillators as well), a sonority that kaleidoscopically mixes with those of the percussion (bowed metal plates with frequency shifting):

Fig. 4.92. *Ius Lucis*, bar 337. Detail of Contrabass Clarinet part with spatialization trajectories. A radically new trajectory repartition in space (upper and lower loudspeaker circles alternating, see dashed oval) reinforces this peculiar sound quality produced by a friction between instrumental and vocal pitches (F-natural – voice, against E-natural, then E-flat – instrument, see dashed rectangle).

The end of this solo section is marked by low sound textures: Room-mode frequencies that also sound lower than before (transposition is two octaves higher = value 4), and many possible ways of timbre intersection (with local and remote instruments) are explored. The contrabass clarinet solo also represents a clear example of the so-called global counterpoint. For this reason, it is interesting to see in which way it is used in room 2.

First, the instrumental sound, projected through loudspeakers, is treated as an electronic sound and therefore as a matter that can be formed freely (shortened, with additional envelopes, etc.). This means that, over the course of the solo, not only is it spatialized (and therefore transformed) along different trajectories and with projection techniques, but it also appears slightly altered, as it had to fit into a different musical context. After some moments where Ensemble 2 is used in true counterpoint (it plays a part that can be considered as contrasting in relationship with the one of the remote soloist, like at bars 316 – 318, bars 323 – 326 or bar 329), a stricter harmonic connection occurs. The high pitches played by the solo instrument are prolonged and developed by Ensemble 2, like at bar 331 (on the high F-natural), showed in Fig. 4.93.

Fig. 4.93. *Ius Lucis*, bar 331. Detail of contrabass clarinet (upper picture) and Ensemble 2 (lower pictures) with spatialization trajectories (referring to contrabass clarinet projected from Room 1). Ensemble 2 provides a counterpoint section, overlapping the steady sound (*ribattuto*).

Trajectories here become more and more complex, especially when the remote sound is overlapping with local instruments. The solo instrument and its real-time sound transformation are reinforced by a double effect: for instance a cross-synthesis with room-mode frequencies (XB1 OSCILOOP projected along trajectories circle down B and circle up B), and the *Ircam-Spatializateur* (Ircam-Spat, 2100 milliseconds) performing a quick movement from the back to the front of the concert hall (see dashed oval).

This kind of technique becomes even more integrated when Ensemble 2 overlaps with a very complex instrumental-vocal sound at bar 337 (Fig. 4.94):

Fig. 4.94. *Ius Lucis*, bar 337. Detail of Contrabass Clarinet (upper picture) and Ensemble 2 (lower pictures) with spatialization trajectories (referring to Contrabass Clarinet projected from Room 1). The solo instrument plays timbrally complex sounds (mix of instrumental and vocal sounds), merging in Ensemble 2 with some *unisoni* and microtonal inflections (Viola 2, E-eighth-tone-sharp). Again. The *Ircam-Spatialisateur* is used to project the sounds of the percussion in Room 2.

4.2.4 The cello solo

The section beginning at bar 343 introduces the last large instrumental solo of the work. As with the previous solo (contrabass clarinet), the music is shaped according data extrapolated by room-mode analyses. These are based, again, on some chosen trajectories that explore the whole space (Room 2) with the loudspeaker placed near cello 2 serving as a starting point.
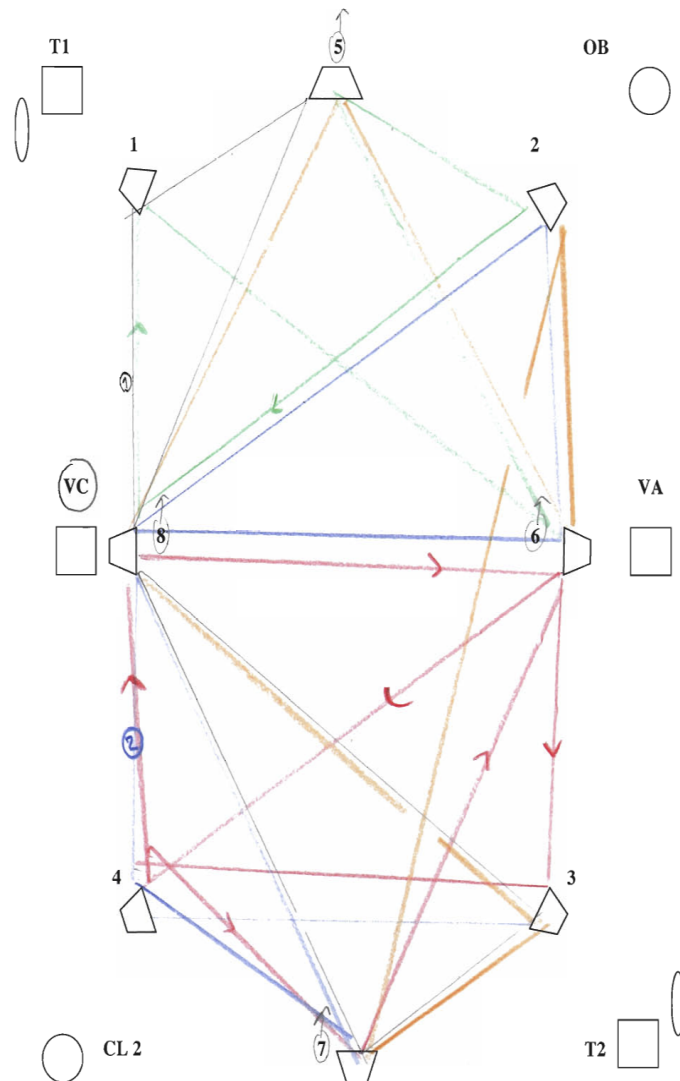

Fig. 4.95. A compositional sketch from *Ius Lucis*: In this scheme, several trajectories for Cello 2 have been traced in Room 2, they are used for a room mode analysis as well as for sound spatialization (live-electronics).

The trajectories are as follows:

trajectory 1: loudspeakers 8 – 5 – 1 – 8 – 7 – 3 trajectory 2: loudspeakers 8 – 4 – 7 – 8 – 2 – 6

trajectory 3: loudspeakers 8 – 5 – 6 – 2 – 7 – 3 trajectory 4: loudspeakers 8 – 1 – 6 – 5 – 2

trajectory 5: loudspeakers 8 – 6 – 3 – 4 – 7 – 6 – 4

trajectory circle up: loudspeakers 5 – 6 – 7 – 8

trajectory circle down: loudspeakers 1 – 2 – 3 – 4

Pitch organisation follows the same general harmonic scheme of the whole work but uses this rather freely, combining different chords or sometimes taking parts of them to build a sort of melodic contour. However, if the main structure of this solo follows a harmonic path (as appears in the global harmonic scheme showed in Fig. 4.13, 4.1.3), the main element of this part of the composition is the use of percussive effects (*pizzicati, col legno battuto*, for instance), which have been composed to excite the same live-electronic effects used for the previous solo sections. This section has been composed using two-chord sequences, which do not always appear complete.
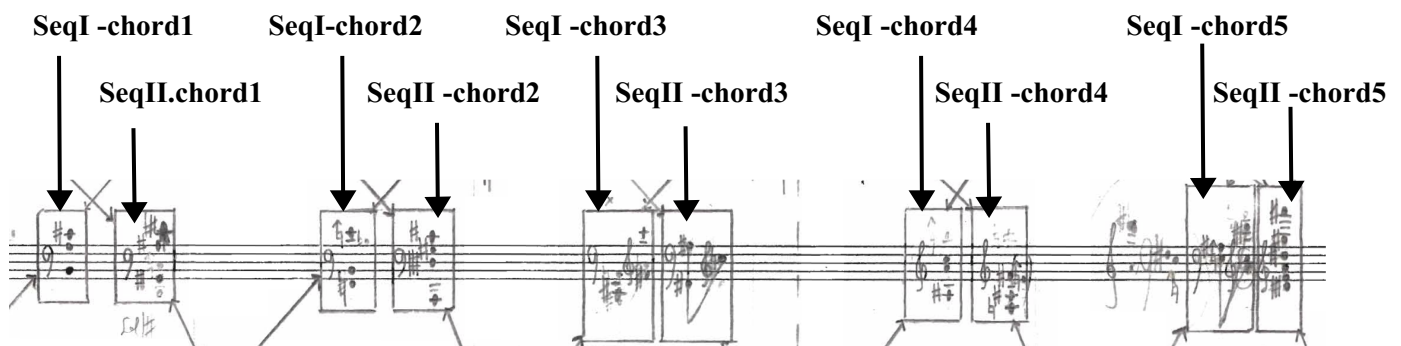

Fig. 4.96. *Ius Lucis:* hand-written scheme of the global chord repertoire (detail). This can be read from left to right (or vice-versa), or diagonally (following the arrows); each sequence, in this way, represents a harmonic path that has been used to organize melodic and harmonic structures.

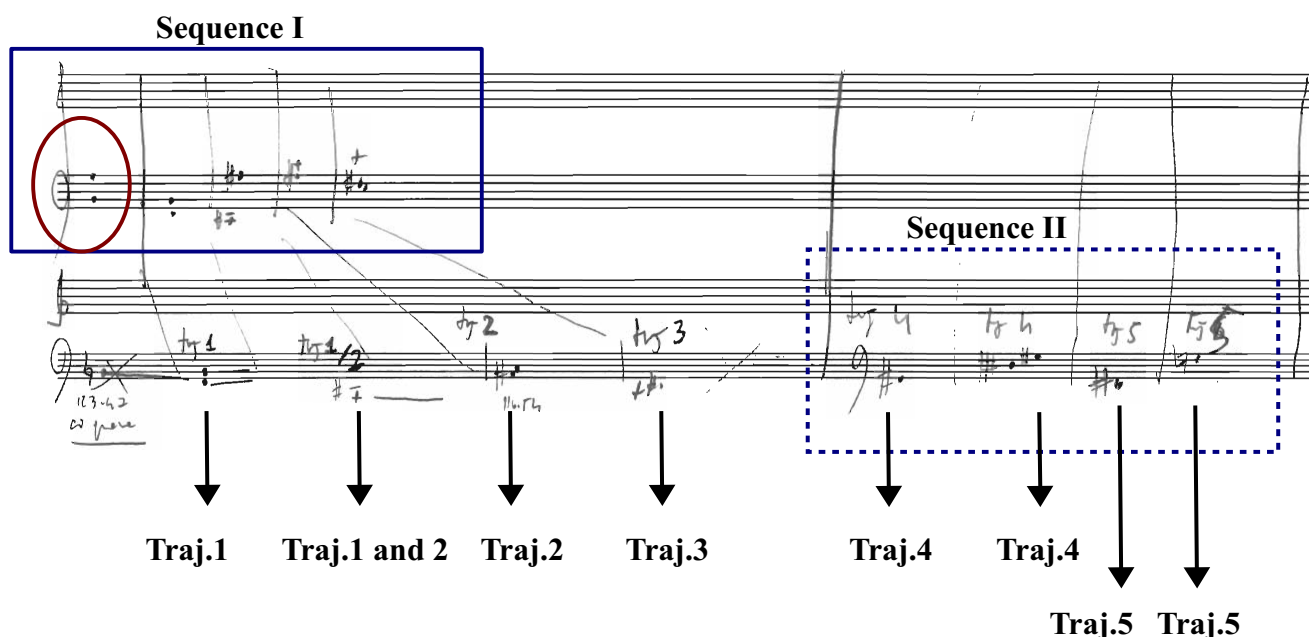On this basis, two smaller sequences (with a reduced number of tones) were identified:

Fig. 4.97. *Ius Lucis:* hand-written scheme representing two sequences used as basis for the cello solo. Frequencies from each chord of the sequences have been used – with a corresponding trajectory – to start a room-mode analysis. The first chord (marked by a circle) has not been fixed to any trajectory, since at the beginning of the cello solo the instrument provides a sort of transition from the previous section and settles a correspondence with some of the remote instruments (Ensemble 1).

At each chord of the two sequences – which could be considered akin to a skeleton – has been assigned a trajectory (from 1 to 5), which is used to trigger a room-mode-analysis (room 2), each of which forming a component of this solo. In this section, which was also the last one composed using room-mode tools, it is possible to see how the method becomes more and more defined and how the operating steps (definition of frequencies to examine, definition of trajectories, mapping frequency/trajectory and consequentially room-mode analysis) become clear. For this reason, an exhaustive number of examples (score excerpts corresponding to the complete analysis data used to compose this segment of the musical work) are provided, and with which it will be possible to see the different criteria of musical transcription and data interpretation. In fact, as will be shown, the resulting musical data is still used to suggest musical figures, dynamic and rhythmic details, or, in certain cases, even a change of timbres (various instrumental techniques). The beginning of this solo is a moment in which cello 2 slowly enters and takes a leading role in the whole musical progression. At first, in the bars [18] corresponding to the first chord B-natural/ A-natural (bars 350 – 359) – which hasn't actually been used – cello 2 connects with mutual frequencies from Ensembles 1 and 2. The role of the

---

18. Because Ensemble 1 and Ensemble 2 have two different kinds of time-notation (the first is written metrically with traditional bars, the second in space-notation), bar numeration for Ensemble 2 are not strict. Bars in space-notation that are considerably long, have the same number as those of Ensemble 1 when the musical text is synchronized. At each of these points (generally coinciding with a new phrase – or section of the cello solo) bars are marked by a number from 1 to 5, given by the conductor. As a consequence, the Ensemble 2 score has bars with non-sequential numbers (e.g.: bar 360, bar 364; bar numbers 361, 362, 363 are omitted).

solo instrument is duplicated. On one side (room 1) it is used to activate a cross-synthesis and convolution with its direct sound, on the other (room 2, where it is placed) it generates a cross-synthesis and convolution (spatialized) using sinusoids produced by a bank of oscillators with room-mode frequencies (as was the case with the viola solo and the contrabass clarinet solo) as a second signal.

Fig. 4.98. *Ius Lucis*, bars 353–355. Detail of Ensemble 2: Cello 2 joins the other instruments, which are playing something that has formally been called a partial conjunction section (see § 4.2, Fig.4.62 for example). The C-sharp (also played in Ensemble 1) is used to connect Cello 2 – by way of consonance – with the remote Ensemble 1 (in bar 355 Cello 1 and in bar 356 Horn 2 and Violin 1, playing the same pitch C-sharp).

Furthermore, concerning the pitch content of this solo section, it should be observed that, aside from the aforementioned sequences of chords, another two harmonic paths coming from the global harmonic scheme are used to provide further tones, which occur as double-stops (often with natural and artificial harmonics) or as fast groups of tones. These tend to either represent extremely virtuosic musical gestures, or simply some steady, long or short tones and sometimes create a sort of melodic profile within an otherwise generally percussive character. These additional chord sequences are as follows:
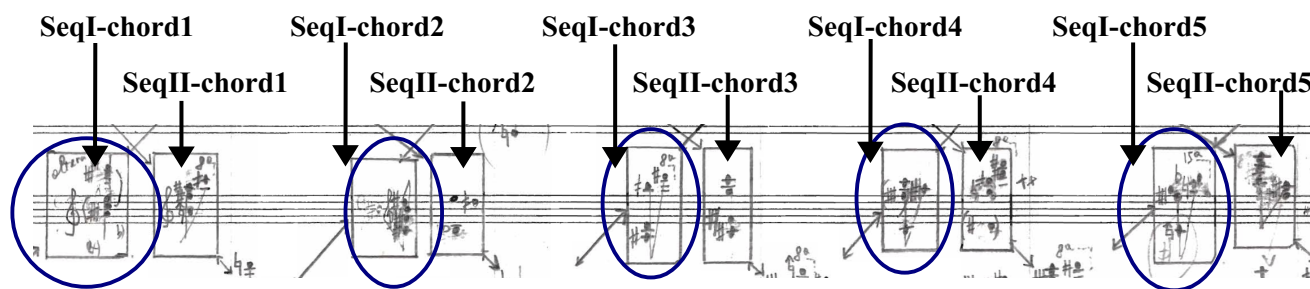
Fig. 4.99. *Ius Lucis:* hand-written scheme of the global chord repertoire (detail). The chord-box sequence marked by a circle is used to provide additional tones to Sequence I, the other one is used to enrich Sequence II.

Pitches from these chord-boxes have been added to the corresponding chords of Sequences I and II (e.g. the F-sharp and E-natural, also transposed an octave for chord 2 from bar 360 until 369; D-natural, B-quarter-tone-sharp also transposed an octave; F-sharp, also transposed an octave, for chord 3 from bar 372 until bar 380). It can also be seen that additional pitches accumulate throughout the entire solo section as needed to shape intervals and chord combinations (in bar 380, for instance, corresponding to chord 3, a D-sharp appears, which would normally belong to the previous chord, number 2).

Also an additional series of chords has been used for Sequence II that can be observed for instance from bar 401 until bar 407, corresponding to chord 2 of Sequence II (E-natural, B-flat) and coming together so far as to form a clearly defined melodic shape:

Fig. 4.100. *Ius Lucis*, bars 407 (partially), detail of Ensemble 2, part of Cello 2: a melodic figure formed with a combination of pitches from an additional chord and one pitch (C-sharp) from the chord of the original sequence.

Moving forward and delving deeper into the compositional method, in the bars corresponding to the second chord (bars 360–369, the augmented fourth F-natural, B-natural), we can observe how some elements coming from the data output have been musically interpreted by comparing the score with the analysis result (Fig. 4.101).

Spatialization (Cello 2)

Fig. 4.101. Upper picture: *Ius Lucis*, bars 359 and bar 360 (partially), detail of Ensemble 2; lower picture: sketches of room-mode analysis corresponding to the second chord and trajectory 1. The same trajectory is used to spatialize live-electronic sounds (XB1 – loopdyn).

Here, information for dynamics (dashed rectangles in Fig. 4.101) are interpreted musically as a change of timbre (in the score a change between *sul ponticello* and *col legno*). Moreover, a coincidental inflection point (see circles) of both F and B-natural, is first interpreted as a *sforzando* (dashed circle), then as a double-stop (circle). The increasing dynamic values registered in the F-natural system (upper system, marked by a rectangle) suggest various *crescendi – diminuendi* throughout this portion of the solo. Coincidence of attacks (low system) are interpreted as double-stops on the cello (F-natural – B-natural), other data (dashed rectangles) is interpreted as a timbre change (*ordinario – sul ponticello – col legno*).

Two different analysis have been made in the part corresponding to the third chord – low C-sharp and A-sharp – from bar 372 until 380, one with trajectory 1 and one with trajectory 2 (both taking only the low C-sharp into account). Two very different results, the first one quite

steady, the second one with more accentuated dynamic flexions, also correspond to two different musical flows in the score, as is shown in the following pictures. The first two examples refer to the first part of bar 372 and its corresponding room-mode analysis (Fig. 4.102), the following couple of pictures refer to bar 380 and the related room-mode analysis (Fig. 4.103).
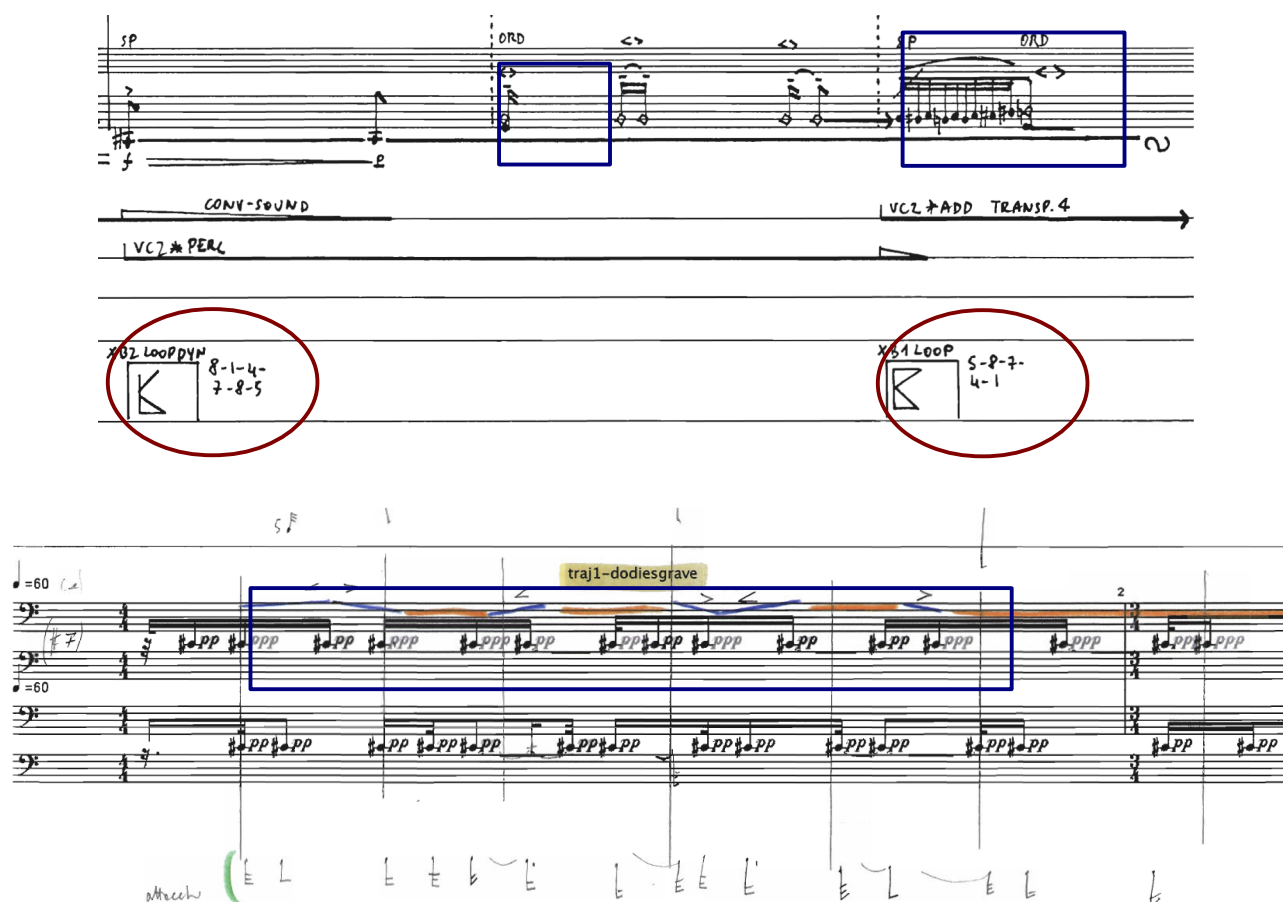

Fig. 4.102. Upper picture: *Ius Lucis*, bars 372 (partially), detail of Ensemble 2, lower picture: sketches of room-mode analysis corresponding to the third chord and trajectory 1. Trajectories for sound-projections do not coincide exactly with trajectory 1 (some other loudspeakers have been added). As a matter of fact, at the beginning of bar 372, live-electronics are programmed to make a transformation using the sound (remote) of Percussion 1. Only later (XB1 loop) does the additive synthesis with room-mode frequencies begin again (marked by circles).

In the analysis sketches, an almost regularly oscillating dynamic change (*pp – ppp – pp*, marked by a rectangle) is interpreted as a calm musical situation. Such dynamic variations appear musically as quick *crescendi – diminuendi* with some additional pitches in the form of natural harmonics or quick groups of high tones within a narrow interval. However, when the results of the analysis report a wider dynamic range (the next analysis example goes initially from *ppp* to *p*), the music changes suddenly to a very virtuosic gesture and the possibilities of musical interpretation follow different criteria. In the next example, still based on the third chord of the first sequence, we notice a further use of the analysis, where dynamic and rhythmic information converge to shape one long bar, notated using space/time proportion:

Spatialization (Cello 2)

Fig. 4.103. Upper picture: *Ius Lucis*, bars 380, detail of Ensemble 2, lower picture: sketches of room-mode analysis corresponding to the third chord and trajectory 2. This path along loudspeakers 8, 4, 7, 8, 2, 6, is integrally used to project live-electronic sounds (XB2 loopdyn).

Consequently, *sforzato* tones are intensified, almost on a regular basis as a musical interpretation of the lower system (inflection point transcription), and the constant use of *col legno* attacks (very percussive indeed) emphasize the idea of attack itself: Four impulses at different distances (as shown in the dashed rectangle) are transcribed into space notation at different distances (time) as suggested by the analysis (fragmented line).

The room-mode analysis following the dynamic evolution of two frequencies corresponding to the diminished third (fourth basis chord in Sequence I, Fig. 4.97) A-sharp/C-natural, is again made using trajectory number 2. Frequencies needed to be transposed (one octave lower) in order to fit with the room-mode content of room 2 (see following pictures). Musical gesture continues in the rather virtuosic vein of the previous phrase, interrupted on a natural harmonic F-sharp and introducing a recurring rhythmic figure (short – long, marked by a dotted circle). The ending (in the circle in the next example, Fig. 4.104), could be considered the most characteristic figure extrapolated by this page of analysis, where the regularity of the inflection point transcription (lowest system, C-natural) is musically transcribed as a regular repetition of several A-sharps, each occurrence with a different timbre (*sul ponticello* with *sfz – pizzicato – col legno – sul ponticello* with *tremolo*).

Spatialization (Cello 2)

Fig. 4.104. Upper pictures: *Ius Lucis*, bar 383 (divided in two parts, as edited in the score), detail of Ensemble 2, lower picture: sketches of room-mode analysis corresponding to the fourth chord and trajectory 2. Trajectories for sound-projections do not coincide exactly to trajectory 2 (the order of loudspeaker sequence has been slightly modified).

Referring to the next examples (corresponding to bar 389, see Fig. 4.105), the ending of Sequence I (fifth chord from the Sequence I) was used as skeleton for the cello solo (three-tone-chord: low E, low F-sharp, C, only the first two of which have been used in a transposed form) and is associated to trajectory 3 (loudspeakers 8 – 5 – 6 – 2 – 7 – 3). This part starts with a pulsating figure (on three different timbres, *pizzicato – col legno – sul ponticello*) coming from the initial regular rhythmic structure of the F-sharp (lower system, F-sharp, marked by a square) and evolving into a crescendo (upper system, E-natural, marked by a square)

A particular dynamic value (*ff*) found in the course of the dynamic evolution of the F-sharp is transposed into a very sharp instrumental action (a double-stop *sforzato,* followed by a *ricochet,* marked by a circle in the next example). The next five repeated F-sharps are founded almost literally in the lower system (each one reinforced by a left-hand *pizzicato* and with another timbre), up to the last *crescendo,* which leads to a fast double-stop (with a melodic movement of a minor second) with *tremolo* (marked by a dashed rectangle).

Spatialization (Cello 2)

Fig. 4.105. Upper pictures: *Ius Lucis*, bar 389 detail of Ensemble 2, lower picture: sketches of room-mode analysis corresponding to the fifth chord and trajectory 3 that has been used integrally and in its original form to spatialize electronic sounds.

Thus far, analysis data start to be interpreted more and more accurately and the compositional method would seem to reach a point of concordance between musical necessity and the analysis data provided by the room-mode composition tools.

Continuing with the second harmonic path (Sequence II, see Fig. 4.97), the next analysis is made using trajectory 4 (loudspeakers 8 – 1 – 6 – 5 – 2) focusing on one sole pitch (low G-sharp), which belongs to the first chord of this sequence. Analysis data are used almost integrally, as four significant dynamic points (*f* with gradual *diminuendo*, gradual *crescendo* up to *f*, steady dynamic with *diminuendo* and a last *crescendo* up to *mf*) have been used almost in their original forms (see next pictures). At the point of the last dynamic evolution of the fragment (*crescendo* up to *mf*), analysis text was stretched (compare the two dashed rectangles of the next examples in Fig. 4.106), as the musical text has a longer dynamic evolution where fast groups of *tremolo*-tones (played *col legno*) appear.

Fig. 4.106. Upper pictures: *Ius Lucis*, bar 395 detail of Ensemble 2, lower picture: sketches of room-mode analysis corresponding to the first chord of Sequence II and trajectory 4. Sound-spatialization is programmed for the same trajectory (XB1 loopdyn), then an additional live-electronic effect (cross-synthesis with Percussion) is introduced with a slightly different spatialization (the order is changed and loudspeaker 5 is replaced by loudspeaker 7 for XB3 pandyn).

Despite previous examples in this and other solo sections, where dynamic values have often been rescaled (when they were moving in a very narrow range, from *ppp* to *pp* for instance), in this case they are used, with few exceptions, in their original form as reported in the analysis data. It is possible to observe in this portion of musical text that inflection points translated into attacks, have also been interpreted with high fidelity within the analysis sketch (see dotted circle). At the beginning, after the first tone played *f* (double-stop low G-sharp and A- natural harmonic), three inflection points reported on the lower system are integrally transcribed as three attacks in form of *ricochet*-tones (with different timbres: *col legno – sul tasto – ordinario*). The same happens for the following double-stopping tones (marked with the musical indication *pulsando*), as they refer to the next three attacks (the last being much longer then the preceding two).

The second chord of Sequence II features two pitches (D-three-quarter-tones-sharp and G-sharp) as main frequencies that, explored again through trajectory 4, give an analysis result as shown in the next group of images (Fig. 4.107):

Fig. 4.107. Upper pictures (two score excepts): *Ius Lucis*, bar 401 and bar 407, detail of Ensemble 2, lower picture: sketches of room-mode analysis corresponding to the second chord of Sequence II and trajectory 4. Sound-spatialization is programmed for the same trajectory (XB1 loopdyn), then an additional live-electronic effect (cross-synthesis with Percussion) continues with a different spatialization trajectory for XB3 pandyn).

The same regular pulses as found in bar 389, are introduced in this section (bar 401, *pizzicato* and bowed *sul ponticello* G-sharp). Here a greater quantity of additional pitches are added until they form a definite melodic shape (see dashed rectangle). Frequently resulting chords are played with accents and *sforzati* as an interpretation of the lower systems (inflection points analysis): For instance the three G-sharp/A natural dyads (marked by a square). In this part, because of the need to vary the musical development of the solo part, only some outer shapes suggested by the analysis were used (the two *crescendi* marked by a circle as a general dynamic information taken from both G-sharp and D-three-quarter-tones-sharp systems). From the following chord 3 of Sequence II only one pitch (low F-sharp) is analysed with trajectory number 5 (see next pictures, Fig. 4.108):

Fig. 4.108. Upper pictures (two score excepts): *Ius Lucis*, bar 412, detail of Ensemble 2, lower picture: sketches of room-mode analysis corresponding to the F-sharp from the third chord of Sequence II and trajectory 5. Sound-spatialization is programmed for the same trajectory (XB1 oscil emphasizes the series of attacks).

The first rhythmic element at the very beginning of bar 412 is a result of the series of inflection points at the beginning of the analysis sketch (marked by a circle). These are reiterated in order to continue the idea of regular pulsations and are developed almost throughout the whole part. Main dynamic developments from dynamic room-mode analysis (upper system) are translated into longer *crescendi* (see rectangles), while a very characteristic *ff – p* dynamic (dashed rectangle) is interpreted as a radical change of musical intention with a *sforzato* followed by a pattern (*p – pp*) developing slowly up to *mf*. This moment marks a clear ending of the cello solo, also underlined by the other instruments of Ensemble 2 entering with a chord that opens into a higher register with a wider range (see next picture, Fig. 4.109):

Fig. 4.109. *Ius Lucis*, bar 417, detail of Ensemble 2: instruments start to introduce the next big section of the work, thanks to an increasing harmonic shape.

As for the last chord (of which only one pitch, the F-natural is taken into account) and its related room-mode analysis based on trajectory number 5, analysis output on this chord is only partially used because it marks the end of the cello solo. In fact, if the first half of the dynamic analysis is translated into a pitch evolving in timbre and loudness (see Fig. 4.110), the end of bar 420 clearly prepares a sort of upbeat (crescendo, see dashed rectangle) to trigger the next tutti section and therefore follows different musical criteria.

186

Fig. 4.110. *Ius Lucis*, upper picture: bar 420, detail of Ensemble 2, lower picture: sketches from room-mode analysis used very marginally for the end of the cello solo. Only the F-natural is shaped according the analysis (see circles). Spatialization is organized according trajectory 5 (XB1 oscilloop, loudspeakers 8 – 6 – 3 and 8 – 4 – 7).

CHAPTER 5

DISCUSSION AND OUTLOOK

5.1 Final considerations

To conclude this study, it will be useful to underline some of the main points that have been addressed, to look at the practical and theoretical results and finally to examine possible further developments of this inquiry.

As has been seen in the previous chapters, this study has three foci:

- A theoretical reflection on the role that space (seen as a real or virtual tridimensional room) can have in musical composition, referring to some prototypical compositions and the corresponding aesthetical concepts;
- A software that allows a physical analysis of space by allowing a calculation of room modes for rectangular rooms (used as primary compositional element), which is used as a practical tool in musical composition;
- The analysis of a musical composition that inverts the usual order and hierarchy of musical materials, allowing the parameter space to be considered the primary source of musical material, by way of the proposed working method.

Having seen the experimental nature of the methodological and operational solutions that have been introduced (for the aim of musical composition), a series of possible questions will also be listed in order to project this inquiry toward further paths.

5.2 Theoretical achievements

The first aspect on which this research focused its attention is an apparent tension between two very different compositional attitudes, which have here been merged into a sole theoretical (and musical) approach unifying the concept of space on the sonic and on the notation level. Alvin Lucier's musical concept (in particular his work *I am Sitting in a Room* as seen in 2.2.4) clearly focused on the performative side (perception of space-related phenomena) and Edgar Varèse's precisely notated scores (an attempt to notate spatiality in a metaphorical way) each embody a part of the central question of this research: how can space be an independent musical parameter; how is it possible to analyze it and compose not only with it but through it in a discrete, precise way.
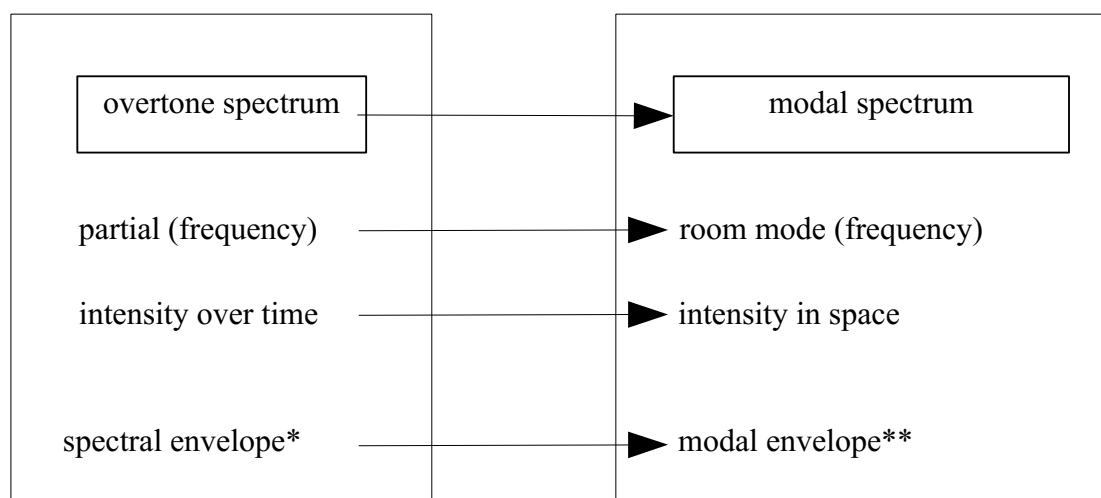
The answer provided by the present research comes out of a unification of two contrasting aesthetic positions of music history. The first refers to the empirical experience of perceiving an acoustic phenomenon (Alvin Lucier), thematized and musically underlined. The second, the composition technique used by Edgard Varèse, verges on an attempt to notate a musical score that attempts a spatial quality of harmonic structures, symmetrical chords, interval projections and all those geometrical transformations applied to musical notation, representing a possible metaphor for spatiality.

From these premises, this thesis tries to give an answer to the question by proposing the use of one space-related acoustic phenomenon (resonance modes) as starting point to measure a tridimensional space, and to transform this data into musical material, which would then be possible to notate as a musical text. It has been shown in fact that, from the point of view of this inquiry, two musical and methodological orientations (Lucier, Varèse) seem rather complementary than contradictory, because they both contribute to defining a more effective compositional approach. Finally, it has been explained how the musical use of spatialization (as localization and/or movement of sound sources inside a performance space, used as tool to filter and discriminate musical materials from the analysis model) is integrated into these two orientations with an essential function. According to this three-step model, the problem of space in musical composition has not been reduced to only one of its aspects, so that the complementarity between Varèse's and Lucier's approaches appears to be even more valid as a direction in which to bring thoughts on the subject.

Circumscribing the field of this research to physical space (analysis of a rectangular room) had an important consequence: space is not intended as a category for the sonic appearance of music (or sound), but as the source of the musical score. In other words, by considering a virtual or real tridimensional space as an object (or initial musical material) to discover and analyze on the basis of its resonance modes, its function is very close to that of a sound spectrum for spectral composers. As has been shown, a complex of room modes with all its frequency information can represent (each mode associated to a frequency, having different loudnesses according to position in the space) analog information as an acoustical sonogram. It is for this reason that the present study can complete and integrate a reflection on a musical element (spatiality) that Spectralism did not really address and, at the same time, can further our understanding and knowledge of the potentials of this parameter for musical composition.

In the second chapter (2.5.3), this parallelism is clearly expressed by a graphic in which the ensemble of acoustic (and musical) information represented by resonance room modes is compared to a spectrum (graphically translated by a sonogram), where analogies can be drawn between partial frequencies and room modes, each denoted by frequency and intensity.

Additionally, going further in this analogy, we can infer that also the spectral envelope (development of a spectrum in time) can be associated to a modal envelope (development of a modal spectrum in the space). This means that the graphic seen in the second chapter (Fig. 2.9) would look as follows:

overtone spectrum	→	modal spectrum
partial (frequency)	→	room mode (frequency)
intensity over time	→	intensity in space
spectral envelope*	→	modal envelope**

* frequency/amplitude relationships at a certain $t = time$
** frequency/amplitude at a certain $s = point\ in\ space$

Fig. 5.1. Schematic representation of analogies between a sound spectrum (analysis) and a room-mode analysis.

The aim of this theoretical approach would be then not to artificially reconstruct acoustic phenomena, but to use these to shape a possible working model that could be able to open different paths for artistic and aesthetical research and musical production. One could as well draw parallels here to Spectral composers who, by orchestrating the frequencies found in the sonogram analysis with acoustic instruments, did not intend to imitate the starting material (faithfully reproducing a timbre), but to go beyond that with the musical result (each instrument playing was obviously adding its own timbre to the overall sound) by operating in this way with a complex sound-synthesis process made of several acoustical components (orchestral instruments, for instance).

190

5.3 Software and musical utilization

The second point on which the present study has focused its attention, which at the same time builds the technological answer to the main question of the research, is the software developed to calculate room modes (programmed in Max/MSP, updated in Max5) and to translate them into symbolic notation (programmed in Open Music).

It must be said that, although modal calculations on tridimensional room models are also possible with the help of Modalys[1] software, the advantages of using a software platform based on Max/MSP have been considerable. Ultimately, Max5 was used for both the compositional analysis work and for the live-electronic transformations, allowing to have the same kind of data used for the preparation work as for the actual performance (concert patch). In fact, even though this software permits several operational approaches (that can be used for further musical project), for the precise aims of the work *Ius Lucis* this connection between preparation work (pre-compositional analysis, shaping of the musical structures to be used) and the real-time performance (with all the live-electronic transformations planned to be used), was of capital importance (see Fig. 5.2).
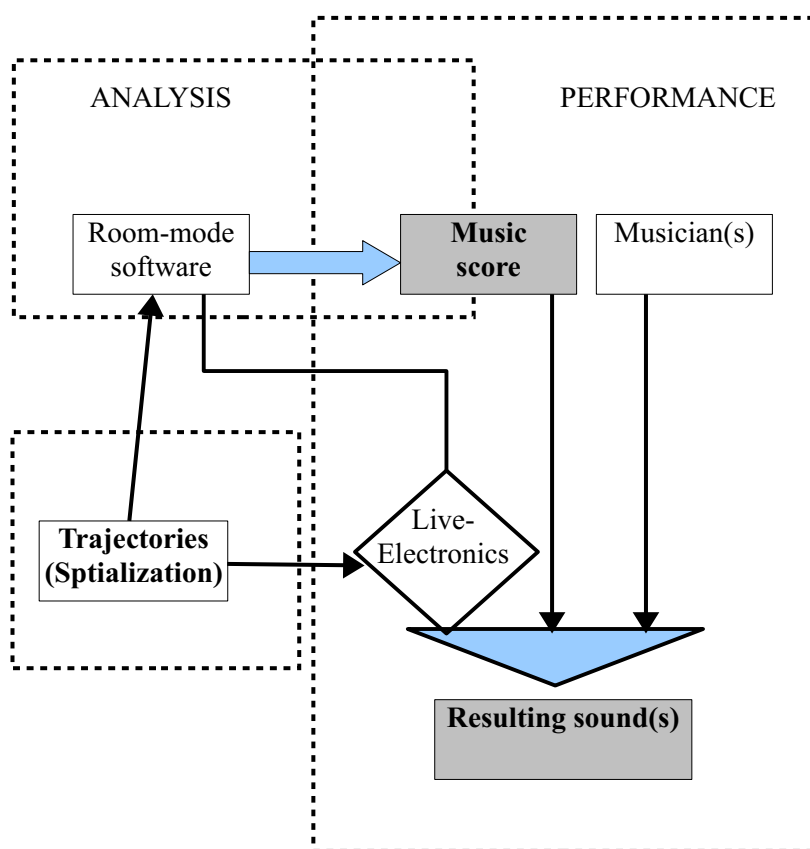
Fig. 5.2. Schematic representation of the working flow in *Ius Lucis*: The room-mode software used during the preparation work generates musical material (score). This is performed by musicians and at the same time, instrumental sounds are transformed (real-time) with the same room-mode data used for the compositional work. As trigger of the whole analysis, trajectories, are chosen freely within the possibilities offered by the loudspeaker position network.

---

1. Text code-based software developed at I.R.C.A.M. to create virtual instruments starting from simple physical objects like strings, plates, etc., making them interact with each other. In recent years this software has been enriched with tridimensional objects as well.

The software allows a room-mode analysis of a simple, rectangular room (by entering its dimensions) and outputs, with the musical notation translation operated by the Open Music software, the following data:

- A list of frequencies (corresponding to the room modes) detected at each point on the basis of those most prominent (in terms of loudness). By filtering this data it is possible to extrapolate only one frequency per point in order to obtain a melody from the series of points belonging to a trajectory;
- A list of loudness values (for each frequency – or room mode) that can be read and interpreted as a dynamic evolution;
- A list of durations calculated on the basis of the gaps between zero-points (notches) of each room mode (frequency) that can be interpreted as rhythmical information.

The ways that this data can be used in musical composition depend on practical needs or musical intentions. Furthermore, a sound-rendering[2] connected to the tridimensional room visualizer allows a direct feedback of the frequencies (and their loudness) at each point in the virtual space. This tool could potentially be useful, for instance, for connecting movements in space (real movements captured by body sensors) with direct sound interactions, and belongs to a number of aspects that could be possible to develop further for future artistic projects.

5.4 Composition methods

Over the course of this study it has been explained how proficient and interesting an operating process (like the one used by Stockhausen to compose the electronic sounds of the work *Kontakte*) that establishes a profound interdependency between all musical parameters concurring in the constitution of a music work can be.

This procedure, which has been called oblique compositional process (starting from one element – the rhythm in the case of Stockhausen's work – to shape all further musical parameters), not only makes connections within the various musical parameters (and therefore musical information), but also leads the general working process to possible unforeseen solutions.

As we have said, by inverting the generally accepted hierarchy notation – sound – space dimension, the floating chart could look rather like space dimension – notation – sound. Since the work with trajectories (movement of sounds in space) has been of central importance to the description of a process operating with resonance modes (first trajectories filter the complex collection of room-mode data, then in performance situation are used as well to spatialize sounds), it is possible then to formulate the method as follows:

---

2. It consists, in the Max5 interface, of a sinusoid synthesizer.

ANALYSIS (COMPOSITION)   PERFORMANCE

room modes → spatialization → score	→	room modes (transformations)→ spatialization
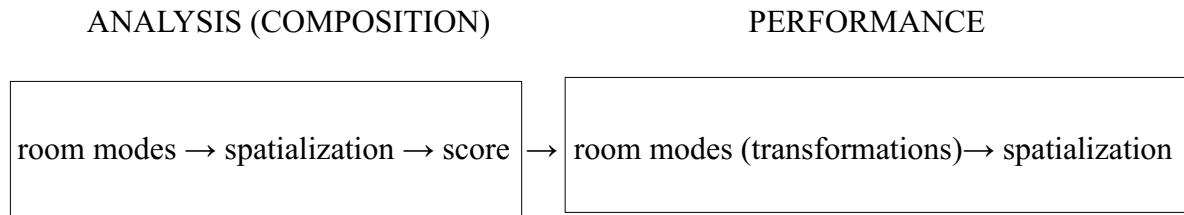
This shows also the special role of musical notation in this method (the score is at the middle point of the oblique compositional process) and the fact that the use of spatialization also has a direct influence on the shaping of the musical text, participating even more actively in the formation of the musical work. As for the direct results of such analysis, it has been shown how data coming from room-mode analysis can be interpreted according different perspectives, and, in the case of the work *Ius Lucis*, how this has been interpreted and transformed to fit into a pre-existing harmonic structure. We have also seen the necessity for a strong interpretation of room-mode analysis data, as well as their musical transcription throughout the working process description on the basis of some sections of the work *Ius Lucis* (chapter four).

A few approaches have been discussed from the methodological point of view (see the analysis of *Ius Lucis,* particularly the sections concerning the contrabass-clarinet and the cello solo). On the basis of how extensively this software is used in the compositional process, various operational approaches can also be foreseen:

- An extensive use of the room-mode software without any additional (musical) information that might concern rhythmic, melodic or harmonic structures;
- A punctual use of the room-mode software that occurs during some parts of the work or for selected tasks to shape some elements within a pre-existing harmonic, melodic or rhythmic context.

The second solution, as has been shown in the fourth chapter, has been chosen to compose some sections of the analyzed piece of music. In this process, which can be considered as a synergy of arbitrarily chosen material and room-mode analysis, the latter is controlled by a series of already existing pitch information.

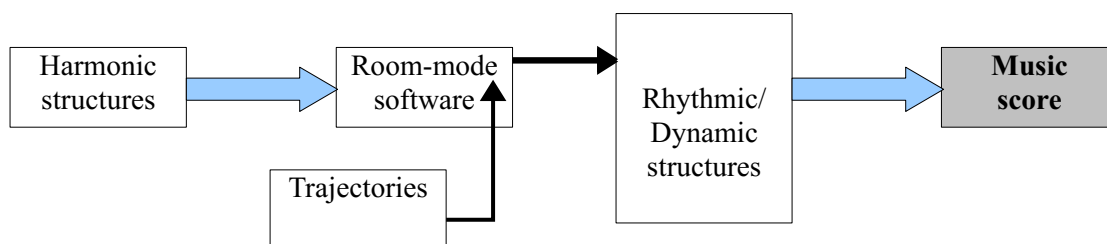Fig. 5.3 Schematic representation of the synergy between already existing pitch information (arbitrary harmonic structures) and room-mode analysis in *Ius Lucis*: The room-mode software is partially used to shape rhythmic and dynamic musical structures. The same trajectories used for the analysis have also been applied (with some changes) to the spatialization of the sounds (real-time electronics).

With this solution, the virtual tridimensional model did not provide pitch information because it already existed as a part of an overall harmonic scheme. Rather, it has been used to observe the dynamic behavior of those frequencies (transposed one or more octaves) belonging to the scheme. We have seen in the fourth chapter how this procedure was used, which different degrees of interpretation can exist during the transcription process, and how much the model can have an influence on some deciding aspects of the compositional work. This solution again reflects, in the case of *Ius Lucis*, the fact that the software was created during the actual work, so that the process would also be a practical test for the software itself.

As to the first approach, the one with an exhaustive use of the room-mode model, it is interesting to underline here a true inversion of common compositional hierarchies. Having a tridimensional space as the actual starting material for the musical work, implies further profound consequences for the working process:

- Space (virtual room) can be shaped with realistic or non-realistic dimensions, a decision that has an influence on the range of frequencies (smaller rooms have higher resonance mode frequencies);
- Many different spaces (virtual rooms) can be chosen for different sections of the work in order to have a series of shapes changing along the time-line of the musical work;
- As far as the musical work allows, a polyphony of different shapes can be used simultaneously, interacting or overlapping.

Moreover, since trajectories also play a central role in room-mode analysis, they can be used (as already shown in 3.2.2) in different ways. The premise, as far as practical experience has allowed thus far, is that such trajectories occur along a loudspeaker[3] array, so that the higher the number of projection points, the better and broader the ensemble of solutions:

- A trajectory can be transformed geometrically (compression, expansion, rotation, etc.), however this solution might require a high number of loudspeakers if such trajectories are used, untransformed, for sound projection (spatialization);
- By leaving the constraint of tracing trajectories along the loudspeaker points and designing complex trajectories inside the tridimensional room-model, virtual spaces can be analyzed in the totality of their potential, a solution that could surely be useful for works without electronics. This method would exhaustively uses the potential of the software and would reflect the so-called oblique compositional process, because space would independently shape pitch, rhythm and dynamic information.

---

3. In the work *Ius Lucis*, trajectories (for room-mode analysis) have been designed along loudspeaker position in order to link them with sound spatialization.

5.5 Projections and possible development

If regarding practical applications we have already pointed out some directions along which it could be possible to use this method, there are also a few potentials concerning software and methodological developments.

First of all, up to now only simple shaped spaces have been taken into account (for evident calculation limitations inside the virtual tridimensional model). The next possible step would be, for example, to explore spheric or half-spheric spaces or, generally speaking, complex tridimensional shapes. Also, imagining additional architectonic elements within a certain room (columns, walls, etc.) would be an interesting further aspect to explore, especially when working with displacement of sound sources (acoustical ones) in a concert space. Going further in this direction, several theoretical considerations could be addressed on the relationships between music and architecture that, in accordance with the perspective of the present study, are not merely of a metaphorical nature but rather interconnected. One example for all, the musical exploration of existing architectures (analyzed in the whole complexity of their elements – column, walls, balconies), from churches up to modern buildings, would bring further at the same time the knowledge on this subject as well as the artistic research.

Finally, at the end of this study, it is crucial to underline that the relationships between spatiality and musical composition, at least to the best of our current knowledge, cannot be covered in full by only one theoretical aspect or only one technological and aesthetic approach. The subject (as has already been emphasized) because of its inherently vast nature, presents a multitude of facets, each of which bearing an essential weight on the understanding of the matter. Speaking about artistic production each acoustic aspect of spatiality, as we have seen, can be thematized and musically developed into an outstanding work that focuses, for instance, exclusively on spatialization rather then physical properties of a room or further room-related acoustic aspects.

The attempt to join room-mode-analysis together with the work on spatialization can be considered as a first step toward a broader approach to space as compositional parameter, however, it is thinkable that further conceptualization and aesthetic point of views can provide new solutions to this problem.

BIBLIOGRAPHY

Benade, Arthur. H. *Fundamentals of Musical Acoustics*. New York: Oxford University Press, 1976.

Beranek Leo L. *Acoustics*. New York: McGraw-Hill Book Company, 1954.

Bernard, Jonathan W. "Varèse's Space, Varèse's Time", in: *Edgard Varèse Composer - Sound Sculptor – Visionary,* edited by Meyer, Felix and Zimmermann, Heidy. Woodbridge, Suffolk: The Boydell Press, 2006.

Bioteau, Alain. "Toucher L'espace", in: C*ompositeurs d'aujourd'hui – Emmanuel Nunes*, edited by Szendy, Peter. Paris: L'Harmattan, Ircam / Centre Georges Pompidou, 1998.

Chouvel, Jean-Marc et Makis Salomos. Foreword to *L'espace: Musique / Philosophie*. Paris: Edition L'Harmattan, 1998.

Dalhaus, Carl. *Schoenberg and the New Music*, Cambridge: Cambridge University Press, 1987.

Dalhaus, Carl. *Schönberg und andere*, Mainz: Schott, 1978

Daubresse, Éric. "Le projet informatique. De l'élaboration à la collaboration," in: *Compositeurs d'aujourd'hui – Emmanuel Nunes*, edited by Szendy, Peter. Paris: L'Harmattan, Ircam / Centre Georges Pompidou, 1998.

Diatkine, Coralie and Jean Bresson. "OpenMusic 6 User Manual. Document Version # 1." *Ircam / Centre Georges Pompidou.* (n.d.).

Dufourt, Hugues. "Timbre et Espace." In *Le timbre, métaphore pour la composition,* edited by Jean-Baptiste Barrière. Paris: Ircam - Bourgois, 1991.

Fichet, Laurent. *Les Théories Scientifiques de la Musique aux XIXe et XXe Siècles.* Paris: Librairie Philosophique J. Vrin, 1996.

Grisey, Gérard. "Structuration des timbres dans la musique instrumentale," in: *Le timbre, métaphore pour la composition*, edited by Jean-Baptiste Barrière. Paris : Ircam - Bourgois, 1991.

Grisey, Gérard. "Vous avez dit spectral?". In *insit*'. Paris : Lemoine, 2000. Quoted in Guy Lelong, "Enjeux théoriques," in *Le temps et l'écoute,* ed. Danielle Cohen-Levinas. Paris: L'Harmattan, 2004.

Gronemeyer, Gisela and Oehlschlägel, Reinhard. *Alvin Lucier Reflections, Interviews, Scores, Writings.* Köln: Edition Musik Texte, 1995.

Haselböck, Lukas. *Gérard Grisey: Unhörbares hörbar machen*. Freiburg: Rombach Verlag, 2009.

Hyde, Martha M. *Schoenberg's Twelve-Tone Harmony – The Suite Op. 29 and the Compositional Sketches*. Ann Arbor (Michigan): UMI Research Press, 1977.

Jaffe, Christopher J. *The Acoustics of Performance Halls*. New York: W.W. Norton & Company, 2010.

Jouhaneau, Jacques. *Acoustique des salles et sonorisation*. Paris: Lavoisier, 2003.

Jot, Jean-Marc, and Terence Caulkins. "Spatialisateur Reference Manual." *Ircam – Centre Georges Pompidou,* (June 2008),

Le Corbusier. *Le Modulor. Essai sur une mesure harmonique à l'échelle humaine applicable universellement à l'architecture et à la mécanique.* Boulogne : Èditions de l'Architecture d'aujourd'hui, 1948.

Macombie, Robin. *The Works of Karlheinz Stockhausen.* London: Oxford University Press, 1976.

Manoury, Philippe. *La note et le son – Écrits et entretiens (1981 - 1998)* Paris: L'Harmattan, 1998.

Motte-Haber de la, Helga. *Die Musik von Edgard Varèse – Studie zu seinen nach 1918 entstandenen Werken.* Fulda: Wolke Verlag, 1993.

Murail, Tristan. "La révolution des sons complexes," in : *Modèles & Artifices*, edited by Pierre Michel. Strasbourg : Presses Université de Strasbourg, 2004.

Murail, Tristan. "Spectres et Lutins," in : *Une pensée musicale.* Paris-Montreaux : Edition des archives contemporaines, 1984. Quoted in Laurent Fichet, *Les Théories Scientifiques de la Musique aux XIXe et XXe Siècles.* (Paris: Librairie Philosophique J. Vrin, 1996).

Nauck, Gisela. *Musik im Raum, Raum in der Musik*. Stuttgart: Franz Steiner Verlag, 1997.

Nunes, Emmanuel. "Temps et spatialité," in: *Les Cahiers de l'Ircam*, Volume 5. Paris: Ircam – Centre Georges Pompidou, 1994.

Roads, Curtis. *The Computer Music Tutorial*, Cambridge, Massachusetts: MIT Press, 1996.

Schaeffer, Pierre. *Traité des objets musicaux: essai interdisciplines*. Paris: Édition du Seuil, 1977.

Schönberg, Arnold. "Komposition mit zwölf Tönen" [1935], in *Stil und Gedanke. Aufsätze zur Musik*, edited by Ivan Voitech. Frankfurt am Main: Fischer Verlag, 1976.

Schroeder, Manfred R. "The 'Schroeder frequency' revisited" [1996], in *Journal of the Acoustical Sociaty of America* 99/5, 3240 - 3241.

Wood, Alexander. *The Physics of Music,* revised by Bowsher, J.M. London: Chapman and Hall, 1975.

MUSIC SCORES

Stockhausen, Karlheinz. *Gruppen* für drei Orchester – Universal Edition Wien.

Emmanuel Nunes. *Quodlibet* – Ricordi München.

Valerio Sannicandro. *Ius Lucis* per due ensemble in due sale – Edizioni Suvini-Zerboni Milano.

ONLINE DOCUMENTS

Gérard   Grisey,   "Note   de   programme   Les   Espace   Acoustiques,"   n.d.,
http://brahms.ircam.fr/works/work/8954/#program (accessed on October 5th, 2012).

Grisey,   Gérard.   " Note   de   programme   Les   Espace   Acoustiques. "   n.d.,
http://brahms.ircam.fr/works/work/8954/#program (accessed on October 5th, 2012).

Peter Szendy, "Programme du concert Emmanuel Nunes, le 13 février 1992, Centre Georges
Pompidou," n.d., http://brahms.ircam.fr/works/work/10856/#program (accessed October 5th, 2012).

Szendy, Peter. *"Programme du concert Emmanuel Nunes, le 13 février 1992, Centre Georges
Pompidou,"* n.d., http://brahms.ircam.fr/works/work/10856/#program (accessed October 5th, 2012).

Peter Szendy and Emmanuel Nunes, "programme du Festival d'automne à Paris, cycle Emmanuel
Nunes," n.d., http://brahms.ircam.fr/works/work/10871/#program (accessed October 5th, 2012).

Szendy, Peter and Emmanuel Nunes. "Programme du Festival d'automne à Paris, cycle Emmanuel
Nunes," n.d., http://brahms.ircam.fr/works/work/10871/#program (accessed October 5th, 2012).

Ircam   -   Centre   Georges   Pompidou,   "AudioSculpt   –   Description,"   n.d.,
http://anasynth.ircam.fr/home/english/software/audiosculpt (accessed October 21st, 2012).

Ircam   -   Centre   Georges   Pompidou.   "AudioSculpt   –   Description."   n.d.,
http://anasynth.ircam.fr/home/english/software/audiosculpt (accessed October 21st, 2012).

Ircam   -   Centre   Georges   Pompidou,   "Open   Music   –   Description,"   n.d.,
http://repmus.ircam.fr/openmusic/home (accessed October 21st, 2012).

Ircam   -   Centre   Georges   Pompidou.   "Open   Music   –   Description."   n.d.,
http://repmus.ircam.fr/openmusic/home (accessed October 21st, 2012).

http://forumnet.ircam.fr/fileadmin/sites/forumnet/fichiers/recherche/om/kernel/OpenMusic-6-
Documentation-2403.pdf (accessed October 21st, 2012).

http://support.ircam.fr/docs/spat/3.0/spat-3-intro/co/overview.html (accessed October 21st, 2012).

Stockhausen, Karlheinz. "Hoch-Zeiten Programme." *Stockhausen-Verlag,* 2002,
http://www.stockhausen.org/hoch_zeiten_programme.pdf (accessed October 21st, 2012).

http://www.philippemanoury.com/?p=340

http://www.falstad.com/modebox (accessed October 21st, 2012).

Fig. 2.7. Graphical examples of the three kinds of room modes in a simple shaped room (courtesy of
Mc Squared System Design Group, Inc, http://www.mcsquared.com/modecalc.htm).

*As impossible as it is to define it in words, I can say that the origins
of my music are deeply immersed into the idea of space, an aspect
that I have researched and whose powerful poetry never stops
to influence my musical thinking. Such path has leaded myself
and my music through very diverse experiences by conceiving
works like IUS LUCIS, FORCES MOTRICES, FIBRAE, STRALI.
A constant curiosity toward a strict interaction between acoustic
instruments and live-electronics has lead me to share the expertise
of some among the most interesting institutions in Europe
(such as IRCAM, ZKM, GRM, Experimentalstudio Freiburg)
and abroad, meeting bright and devoted people, both researchers
and musicians, who allowed me to collect many precious
experiences for which I will always be grateful.*
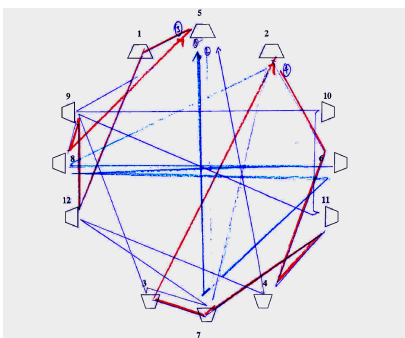
Cover: Ius Lucis (2006/2007), realization sketches

v a l e r i o s a n n i c a n d r o . e u