3D-Composer: a software for micro-composition

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A thesis submitted in partial fulfilment
of requirements for the degree of
Doctor of Philosophy

Sydney Conservatorium of Music
The University of Sydney
2009

Statement of originality

I declare that the research presented here is my own original work and has not been submitted to any other institution for the award of a degree.

Signed: . . . .

Date: . . . .

Abstract

The aim of this compositional research project is to find new paradigms of expression and representation of musical information, supported by technology. This may further our understanding of how artistic intention materialises during the production of a musical work. A further aim is to create a software device, which will allow the user to generate, analyse and manipulate abstract musical information within a multi-dimensional environment. The main intent of this software and composition portfolio is to examine the process involved during the development of a compositional tool to verify how transformations applied to the conceptualisation of musical abstraction will affect musical outcome, and demonstrate how this transformational process would be useful in a creative context. This thesis suggests a reflection upon various technological and conceptual aspects within a dynamic multimedia framework. The discussion situates the artistic work of a composer within the technological sphere, and investigates the role of technology and its influences during the creative process. Notions of space are relocated in the scope of a personal compositional direction in order to develop a new framework for musical creation. The author establishes theoretical ramifications and suggests a definition for micro-composition. The main aspect focuses on the ability to establish a direct conceptual link between visual elements and their correlated musical output, ultimately leading to the design of a software called *3D-Composer*, a tool for the visualisation of musical information as a means to assist composers to create works within a new methodological and conceptual realm. Of particular importance is the ability to transform musical structures in three-dimensional space, based on the geometric properties of micro-composition. The compositions *Six Electroacoustic Studies* and *Dada 2009* display the use of the software. The formalisation process was derived from a transposition of influences of the early twentieth century avant-garde period, to a contemporary digital studio environment utilising new media and computer technologies for musical expression.

KEYWORDS: music, computer, electronic, electroacoustic, composition, micro-composition, geometry, visualisation, 3D, software.

Acknowledgements

My family in Australia, Canada and Ukraine has remained an invaluable source of support for my artistic and academic endeavours. I am most grateful to my wife Myroslava for her optimism, patience and support. I particularly treasure the joyful company of our one year old son Adrian... especially during the short nights of the thesis dissertation phase.

I would like to thank my mother, Dr. Claudette Berthiaume for her inspirational and precious advice, my father Yuri Zawada for his unconditional encouragement and my brother Roman for his musicality, which inspires me to explore the boundaries of creativity. I am thankful for my grand-mother's appreciation and encouragement during the long periods of reflection and concentration, even though this musical venture may locate itself at the far edge of her beloved operas!

My sincerest thanks to my supervisor Dr Anthony Hood, and associate-supervisor Dr Michael Smetanin for their quintessential recommendations during this project.

To my late grand-parents Lucette Leclerc, Edouard Berthiaume and Dr. Ivan Zawada.

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CHAPTER 1

Introduction

1.1 General aims and background

Within the framework of artistic activity, awareness of technology can generate an impulse in the artist's mind to innovate. Given that the prevailing trend favours constant expansion, the most relevant case being our universe, the rate of expansion of ideas may be correlated to the rate of technological development. In most cases, the rate of conceptual innovation actually exceeds that of technological availability. In a sense, this implies that evolution is related to, but not necessarily dependent on technology, as it is in itself a direct product of the human mind. Existing technologies are perhaps the result of a systematisation of the methods used to represent abstract concepts in the material world. Such systematic ramifications support the creative imagination, and fortunately technology also imposes some limits. Within these limitations, the incentive for the creatively inclined person is to find solutions circumventing possible technological barriers. The above dialectic brings us closer to the path of musical creativity. In this thesis, I will demonstrate how it is possible to explore the dichotomy of art and technology in the context of electroacoustic music composition. I will put forward some possible solutions in the form of software and musical compositions derived from that software.

Computers allow digital media authors flexibility in expressing and communicating artistic ideas. Whilst technology is available to control musical and sonic parameters in real-time, a tool which could represent conceptual information in the form of a visual model would allow more accurate and efficient transmission of the original musical intent. Many systems utilise more traditional notation methods to visualise musical information. Two main categories include score typesetting applications for a printed visual representation, and sequencing applications to organise musical information in a pre-determined timeline.

In order to construct a new tool to manipulate musical data, I wish to integrate new methods and techniques offered by computer music technology, interactive music systems and digital audio and multimedia software, to build a reliable and expandable framework to study three-dimensional aspects of musical creation. To demonstrate this, I will delineate the working canvas within specific notions of conceptual space. Notions of space were relocated within the scope of a personal compositional direction in order to set a new framework for musical creation. One aspect will include the representation of musical elements, their structure and generative capacity in computer assisted composition. The significance of technology is particularly important in a dynamic audiovisual and multimedia context. The formalisation process to elaborate this project was derived from some ideas of the early twentieth century. Mainly, a transposition of influences from the early avant-garde period, to a modern environment utilising new media and computer technologies for musical expression.

1.2 Description of analytical notes and portfolio

This project concerns a software application called *3D-Composer*, which is a tool for the visualisation of musical information as a means to assist composers to create works within a new conceptual realm. This methodological approach extends previous research projects and artistic developments as an electroacoustic composer. *Quadraloop*, a software for real-time audio looping was developed during the Master's degree (Zavada, 2000), and later described in (Zavada, 2004). *Quadraloop* was the basis for the latter works: *Schwermut*, *Neutron*, *Paradoxa*, *Mirage*, *Aquasonique* (stereo) and *Aquasonic* (surround version).

A general statement introduces chapter two, exposing the underlying rationalisation as a starting point for creative activity. The notion of musical and symbolic notation is presented as an anchor point to model a system representing musical information based on conventional visualisation techniques. A survey of the cultural and historical background eventually leads to a theoretical framework which forms the basis for chapter three entitled 'Geometric properties of micro-composition'.

Chapter three investigates the role of technology during the creative process and proposes a system to cope with the transformation of musical structures in three-dimensional space. The software called *3D-Composer* was designed as a visualisation tool for processing micro-compositions in three-dimensional space and to assist composers in creating and sequencing new works based on geometric transformations. A definition of *micro-composition* is proposed, and principles of projective geometry, group composition, local composition and graph theory are implemented to model a short melodic motif, which becomes the basis for a larger composition. The discussion focuses on the ability to establish a direct conceptual link between visual elements and their correlated musical output. Some compositional elements derived from geometry will be explained, along with an overview of the software, its graphical user interface, followed by a description of the *Six Electroacoustic Studies* and the work entitled *Dada 2009* all composed with *3D-Composer*.

This project was presented during the international colloquium entitled ‘Composing in the Twenty-First Century: processes and philosophies’ held in Montréal in March 2007. Sections of this thesis were refereed and published as part of the online proceedings of the OICCM Conference (Zavada, 2006) and the Electroacoustic Music Studies Conference in Paris in June 2008 (Zavada, 2008).

The software is included on CD No.1. (see Appendix G)
Six Electroacoustic Studies and *Dada 2009* are included on CD No.2. (see Appendix H)

CHAPTER 2

Confluence of *techné* and musical thought

> *«I long for instruments obedient to my thought and whim, with their contribution of a whole new world of unsuspected sounds, which will lend themselves to the exigencies of my inner rhythm... »*
>
> Edgar Varèse, 1917

This section presents some key anchor points leading to the conceptualisation of the *3D-Composer* software prototype.

2.1 Context

Experiencing and observing the current world state, one can merely assume that the human world is still in possession of its thoughts, behaviours and actions. Attempting to yield innovation whilst preserving tradition in a more socially and environmentally conscious way is a constantly growing challenge. Technology as a static and neutral entity has not yet provided adequate solutions evoking natural evolution and the sophistication of internal structures governing living organisms. 'We humans are not the end of evolution, so if we can make a machine that's as smart as a person, we can probably also make one that's much smarter. There's no point in making just another person. You want to make one that can do things we can't' (Kruglinski, 2007). Ultimately, people think of technology as something in constant evolution, but essentially, it is the human mind which independently generates formalised concepts, with the capacity of allocating precise meaning to a concrete reality. Consequently, independent critical thinking has a much greater impact on the development of our respective environments, as opposed to the technology that populates that environment.

In order to master any medium in all its dimensions and perspectives, a perfect model would be required. However, theoretical modelling becomes trivial in a world of imperfections, prone to error and misjudgement. To posit grounds from which to depart, simulation becomes a more adequate mode of representation. It is an approximation, a representation, an abstraction (Selfridge-Field, 2001). In a recent interview for the *Discover* periodical, Marvin Minsky explains that 'to understand the human mind or brain, the only way to test a theory is to simulate it and see what it does. If a theory is very simple, you can use mathematics to predict what it'll do. If it's very complicated, you have to do a simulation' (Kruglinski, 2007). The anticipated significance of simulation takes a more relevant stance in the process of creating an artistic work. By the very definition of technology[1] applied to the musical domain, the outcomes of scientific knowledge are generated by the use of a wide array of existing tools to express musical ideas. More specifically for the composer, the interest lies in the techniques used to bring a musical idea forth. Several models are proposed to describe conceptual notions in music. From a semiological perspective, Molino talks about the poietic level as the description of the production process, aesthesic level as its perception, and the neutral level as the object itself (Nattiez, 1974). Here, the object can be described as the score, the recording or software application. It is located at the junction of poesis and aesthesis – at the neutral level. Nattiez refers to a tripartition comprising interrelated analyses of the processes of production and reception framing the central analysis of the trace (i.e. the score) or material reality of the work (i.e. the sound waves) (Nattiez, 1990). Although semiological considerations are mainly analytical in describing an exisiting material reality, converse implications could provide effective creative applications for the compositional idea, its realisation in the musical score, and its auditory perception. A tripartite musical model can be a suggestive starting point and perhaps present itself as a good framework for a pragmatic approach towards constructing new compositional aggregates. With this in mind, the musical phenomenon is conceived with the following configuration: innovation, representation and communication. This is explained in more detail later in the chapter.

Another key aspect of this research project and a large portion of the thesis reveals the dichotomy between the manifestation of musical thought during the creative process while exploring the inherent musical potential of existing technology. In particular, the emerging creative process from the mind of a musician (referring to a personal approach), and the development of its underlying mechanism with respect to the *instrumentarium*[2] involved. Musical thought and creative activity are intricately linked with *instrumentarium* and are congruent with an anchored musical tradition.

[1]Technology: the application of scientific knowledge for practical purposes, from Greek: *tekhné* art or craft - technique of bringing something forth, creating (Oxford dictionary)

[2]*Instrumentarium* refers to a collection of instruments and other music technology equipment used in a composition studio.

«I like people who are not trying to catch the spirit of the time, but who create the spirit of the time... » (Ford, 1993)[3]

Pierre Boulez, 1988

There often seems to be a technological gap between the means and the idea, the moment this gap vanishes, technology potentially overcomes its initiator and the human world becomes endangered. Experiments in computer simulation of musical activity have shown that 'a great deal of thought and ingenuity is woven into the fabric of the software' and the computer program 'is dependant on human existence for its own existence (Selfridge-Field, 2001, p.215). Therefore, as a fundamental quest to understand musical intelligence, the necessity arises to innovate upon already existing comprehensive systems. New perceptions emerge from the rational construction and deconstruction of musical ideas. Atonality would have never appeared if it were not the case!

> The atonalisation of music is one step in this development, even if it has advanced music merely to a freedom of gesture which remains carved as if in stone, to its total and final mobility in the twelve-tone space, to its centre in the human; the process of development strives however towards a regular, general and strictly numerical foundation of music... At the end of this development stands the sound, sounding in, filling and moving in space, resonating around a central point, in the changing light of timbral world of cosmic proportions: a sound almost visible. (Grant, 2001, p.52-53)

Because technology is sometimes a rival to itself, there is a growing need to renew compositional techniques to expand artistic ideas and reassert their meaning in specific contexts. The formalisation of these techniques would have to depend entirely on a new set of rules to reposition oneself in a different conceptual space. Henceforth, the ramification of parameters to create new spaces has the capacity of nourishing anyone's imagination, artists and composers in particular (see section 3.1.3 Taxonomy of space). In the context of musical composition; pitch, duration, rhythm, timbre, dynamics, spatialisation are common parameter spaces. The question remains, what is the new emerging musical parameter space today? Where and how will composers redirect their listeners attention tomorrow? How will technology influence the future of music, and the music of the future?

[3] Interview conducted by Andrew Ford with Pierre Boulez when the Ensemble InterContemporain performed in Melbourne, Adelaide and Sydney in March 1988, to mark the Bicentennial of European settlement in Australia (see pp.18-28 in (Ford, 1993))

The logical step in trying to answer the above questions is to investigate the hidden dimensions of sound and music. Aside from the measurable structural and physical dimensions of sound in a musical context, and its symbolic representation allowing for human interpretation in the form of a performance, our understanding of the para-acoustic properties of sound is relatively limited and the transformation possibilities remain unexplored (dealing with the elevation of a sound source/object for example). It follows from the previous sentence that it is quintessential for a musician to understand how a particular combination of sounds affects the intellectual and emotional state of a listener and even a performer in a given context. Moreover, depending on the listening context, the transmission method and location of the performance create a paradoxically different effect on the audience. In such radically different situations, information access most likely comes at the expense of appreciation and comprehension of the original intent.[4]

2.1.1 Emergence of a methodology

During the research phase of this project, an article was co-authored in which the methodological approach discussed was intricately linked with the subject matter of this thesis. The following paragraphs were extracted from a recently published article in *Organised Sound* journal, which exposes contextual, methodological and cultural aspects of electronic music (see Appendix D for the full article).

> Electronic music locates itself in a very specific area of contemporary music systems in terms of the function and nature of the creative process. On the one hand, its appearance in music history is a direct and logical consequence of the development of twentieth century avant-garde movements, and to some extent, embodies the combined experiences of contemporary music thinking. On the other hand, from its inception in the twentieth century, electronic music operated within different parametric structures and acoustic materials, within a redefined artistic model – the world of synthesis, relying on new aesthetic realities derived from the integration of technology in the process of creating experimental art music. Electronic music has found itself at the crossroads of two different artistic philosophies, mainly, contemporary academic art music as an extension to more traditional compositional approaches, and synthesised media art forms mostly reliant on technology and non-conventional use of source materials. Electronic

[4] For instance, an electroacoustic composition by François Bayle streamed over the internet radio at a low bit-rate, loses a large portion of it's perceptual significance, it's sound quality and emotional depth, compared to a sophisticated multi-channel diffusion on the *Acousmonium*. The Acousmonium was created in 1974 at the GRM Studio in Paris. It is a loudspeaker orchestra containing eighty speakers of different sizes placed across a stage at varying heights and distances. Their placement was based on their range, their power, their quality, and their directional characteristics. In François Bayle's words, 'It puts you inside the sound. It's like the interior of a sound universe'.

music has thus progressively become an independent sphere of musical activity, where the constant transformation of the methods used to compose such music have created the need to reflect upon, question and redefine the fundamental notions of music theory and practice. These notions include aspects of musical production, performance, analysis and perception.

The eclectic nature of electronic music has conditioned the area of analytical research where in particular, conventional music analysis coexists with a wide range of disciplines such as computer music, musical acoustics, psychoacoustics, cognitive psychology and music sociology. Naturally, most theoretical works in the field of electronic music are concerned with technical aspects of the creative work (modification and implementation of various synthesis techniques, theory of algorithmic composition, sound spatialisation and localisation, integration of virtual instruments...), but theoretical notions about the process of creating and the aesthetics of electronic music remain relatively incipient. In the larger scale of music history, the current 'electronic music period' occupies a relatively small portion of time, however this small timeframe is not representational of the florescence and significance of electronic music innovations. Notably, early electronic music experiments coincided with a period of experimentation with noise and electricity... ...it is therefore possible to retrace the early stages of experimentation with non-conventional instruments back to the first uses of a new 'instrumentarium' derived from non-musical applications at odds with traditional artistic intents.

Today, in a relatively sophisticated communication environment, contemporary compositional techniques and methodologies undergo important influences, which no longer uniquely depend on existing institutional or local infrastructures. Traditional musical systems are omnipresent in the transmission of socio-cultural values associated to the preservation of a certain identity; either musical, philosophical, social or cultural. Introduction of new media technologies have had a destabilising effect on traditional musical practice. Taking this particular phenomenon into account could be determinant to understand the significance and intrinsic meaning of musical creations relying on new technologies. (Zagaykevych and Zavada, 2007)

2.2 A historical platform for innovation

The fundamental notion of musical conceptualisation is linked with the natural pursuit of knowledge. Musical representation is a form of identification through which there is an implicit association with anterior knowledge. The degree of musical awareness generates new ways to improve, modify and reorganise existing musical systems. Music could have been left at rest in the trail of neo-classicism, but on the contrary, a new perspective emerged from the deconstruction of tonality: the antithesis of tonality. Nevertheless, atonality and tonality are now symbiotic in casting the evolution of music in the twentieth century. The inter-dependency and complementarity of the two concepts clearly demonstrates a facet of human nature, in its sophistication and complexity, and confirms the contradiction within art as defined by the ritualistic extension of beauty derived from antiquity. Again, the concept of music takes a universal proportion where everyone is engaged in a constantly evolving process transmitted and transmuted through many generations. 'Skryabin's metaphysical constructions were not only logical, but also graphical; he drew them out, using ruler and compass, with great diligence and accuracy. He endeavored to represent in lines and geometric figures the interrelations he intuitively perceived between the world and the individual, between God and reality, in art, religion and science' (B. de Schloezer, 1987, p.58). Within this realm, the ultimate artwork, omni-art, as perceived by Alexandr Skryabin in his unfinished work *Mysterium*, is a perfect example of a visionary artistic quest.

> *« There will not be a single spectator. All will be participants. The work requires special people, special artists and a completely new culture. The cast of performers includes an orchestra, a large mixed choir, an instrument with visual effects, dancers, a procession, incense, and rhythmic textural articulation. The cathedral in which it will take place will not be of one single type of stone but will continually change with the atmosphere and motion of the* Mysterium. *This will be done with the aid of mists and lights, which will modify the architectural contours. »* (Macdonald, 2000)
>
> Alexandr Skryabin, 1903

This evokes a spiritual extension of beauty as derived from the teachings of Greek Antiquity. It follows at once that many concepts have emerged from the quest of understanding nature, beauty and art. 'Greek thinkers were fascinated by the rotation of heavenly bodies' (Selfridge-Field, 2001, p.188). One path towards understanding the philosophical value of science through music may be Boethius' Quadrivium: the set of treaties on geometry, arithmetic, astronomy and music. For Boethius, any student who aspires to the 'summit of perfection' must pass through the study of music within the scope of mathematics, whoever neglects such studies is ignorant of philosophy as a whole (Schrade, 1947, p.189). This view would have been the modus operandi for many centuries, until the relationship of humanity with itself, and the universe was drastically repositioned with Copernican interpretation of centrality, and inter-relationship of the spheres, which offered another dimension to the comprehension of the universe (James, 1993). This allusion to a re-orientation of our points of reference is essential for re-locating a musical system which has already been established for centuries. As a consequence, it is challenging to organise musical material in a convincing way, such that it may be labelled ‘innovative’.

2.2.1 Deconstruction of a system

Concerns arose during the conference series entitled ‘The Arts in the epoch of technology’, organised by the Bavarian Academy of the Fine Arts in 1953, when philosophers, artists and scientists momentarily indicated a deep apprehension over the understanding of humanity’s existence and position in the universe after the recognition of quantum mechanics (Grant, 2001). The unprecedented impact of new media and communication was already being sensed superficially. It can be deducted that for scientists, artists, researchers, and in general for humankind, it is inconceivable to stop any form of creative activity based on the assumption of perfection. To this end, Stravinsky’s daring attempt to break from tradition during 1913’s premiere of ‘The Rite of Spring’ remains a milestone in twentieth century composition.[5] Even if the means are not immediately accessible, improvement, re-organisation and modification of existing systems are favourable options. If this were not the case, music could have been left at rest in the trail of classicism, and the concept of ‘total artwork’, Wagner’s *Gesamtkunstwerk* would have never reached its apotheosis in the late nineteenth century.

But on the contrary, a completely different perspective has emerged since, from the deconstruction of a solidly anchored system - tonality. It’s complement, or antithesis – atonality; can be interpreted as the corollary of a system offering a larger set of musical possibilities based on the ‘unlimited’ reorganisation of the same constituents. Eimert (1924) remarks that the exact number of possibilities available for ordering a twelve-tone complex is the factorial of 12 or more precisely 479 001 600. This stands from the independence of the twelve notes, or note complex, as described by Eimert. Atonal material is thus not based on a sequence of tones but on a number of tones (complex) (Grant, 2001, p.44).

Interestingly, Eimert’s approach in the early 1950’s progresses toward ‘atonal music’s *mechanical rotation of the twelve-tones* indicates that it’s principle is the absolute purity of the sounds and their connections’ (Grant, 2001, p.45). He wanted to transpose the structural ideas of Webern into a new medium which he was thought more apt than the instrumental medium (Gross, 2000). In another order of ideas, sound engineer Robert Beyer dreamt of spacialisation of music, floating sounds, indefinite

[5] Almost no musical work has had such a powerful influence or evoked as much controversy as Igor Stravinsky’s ballet score ‘The Rite of Spring’. The work’s premiere on May 29, 1913, at the Théatre des Champs-Elysées in Paris, was scandalous. In addition to the outrageous costumes, unusual choreography and bizarre story of pagan sacrifice, Stravinsky’s musical innovations tested the patience of the audience to the fullest (Kelly, 1999).

spaces – he had a vision of electronic music that was completely different.[6] Similarly, Edgar Varèse, drawn to a symbolic interpretation of the universe and space, had already prospected spaciality of sounds and musical entities earlier on (MacDonald, 2003).

2.2.2 Towards technological integration

Much of the impetus for serialism came from the need to reassess and gain true understanding on the nature of sound events, their interrelationship in time, and our perception of them, in the service of a music which would reflect the ideals of multidimensionality and unity through opposites (Grant, 2001). The confusion between theme and series [7] is sufficient evidence of the inability to foresee the sound-world that the series calls for; it is in no way thought of as being capable, by its very nature, of giving rise to a new type of structure (Jameux, 1991). 'Form and style behave in this instance like thesis and antithesis: and there is much to suggest that the time of synthesis is close at hand' (Stuckenschmidt 1977 cited in Grant 2001, p.40). Despite the formalism intrinsic to the properties of serialism and its derived atonal structures, intuition plays a definite role in the interpretation of rigid systems in the emergence of a style.

In extension to the possibilities offered by instrumental composition techniques, the interest lies in the idea of generating a unique solution where two elements, form and style, are integrated and undissociable (a new type of structure). In addition, this idea (based on a more traditionally oriented paradigm) is to be integrated with computer technology in order to eventually apply it to sound. This suggests a path to new musical form free of both thematicism and athematicism[8] as discussed by in (Ashby, 2001; Grant, 2001). Philosophical discussions on conceptuality in musical form may suggest controversy, but on the contrary, this discourse is aimed at underlining the importance of such issues in the development of innovative musical structures, and confirms the continuing need for innovation in this area, given that new technologies can contribute in the maturation of existing musical systems.[9]. In this

[6]From 1953 on, Stockhausen and Koenig came to the studio, the young composers developed a much more refined concept of serialisation of synthetic sound production (more on the foundation of the WDR studio in (Gross, 2000)).

[7]in Boulez's criticism of Schoenberg's concept of twelve-tone works, he continues stating that any logical relationship between the serial forms themselves and the structures derived from them was generally absent from Schoenberg's considerations

[8]Nonthematic musical construction making as little use as possible of repetition and variation of distinct melodies and themes http://www.britannica.com/eb/topic-40679/athematicism.

[9]You could say that in the Fifties, you had two types of Cold War. One between the Soviet Union and the United States and one between the Cologne studio and the French studio... ...the aesthetic starting points of Schaeffer were completely different from Eimert's views. Stockhausen has worked for a short time in the Paris studios. When Stockhausen entered the Cologne studio shortly after that, he behaved like somebody who didn't want to talk about Paris. That was a very human affair (Gross, 2000)

way the following axiom clearly divulges the issues at hand in terms of new creations based on the basic ingredients of musical creation. 'The isolated tone is both an end and a beginning' (Grant, 2001, p.43).

There are several levels of technological integration. Let us distinguish between two main categories of technological integration. The first category is purely practical: integration of technology to represent musical information. This can be done in one of two ways. Firstly, technology can be used to simulate the expected outcome of a musical idea. Secondly, and more commonly, technology can be used to deliver musical information in a tangible format (hopefully destined to be performed by one or several musicians). The second category of technological integration requires active involvement from its users because it deals with a more conceptual approach. Technology can assist in the construction of musical ideas with an analytical dimension. This extends upon the early ideas of the avant-garde era during which there was a transition from the spiritual to the material (see section 3.1.2). Contemporary composers are reinterpreting the same phenomenon, but through a more realistic and scientific approach, without it being necessarily a denial of tradition or breach with the past.

However, the integration of technology on a conceptual level, does not imply greater stylistic and aesthetic complexity. On the contrary, technology has the function of relocating the potential of creativity in a different realm. This new situation has a direct impact on the ability to convey several eclectic musical ideas. Suddenly, many more creative options are available. Again, effectiveness is not related to the complexity of the concept. This relies on the context, the aesthetics and the function of the technology involved. From the standpoint of innovation, the ideas resulting from the use of technology are to be supported by more substantial arguments to justify their novelty. The main reason is that technology is inherently a display of knowledge from within. So the question remains, does innovative use of technology rhyme with creative impetus, or is innovation defined solely by creating new technology? Can it be considered a mistake, for technophiles not to cease to be amazed by these objects of desire?

2.2.3 Composers and machines

> *« Nowadays musical art aims at the shrillest, strangest and most dissonant amalgams of sound. Thus we are approaching noise-sound. The revolution of music is paralleled by the increasing proliferation of machinery sharing in human labour... Our ears, far from satisfied, keep asking for bigger acoustic sensations.... »*

Luigi Russolo, The Art of Noise - Manifesto 1913

Early experiments in electroacoustic music and computer music have revolutionised the way musical information is consumed. During the later developments of electronic music, the creation of instruments relying on a different paradigm of sound production (electricity and magnetism) has had a great influence on the conceptualisation of new methods of musical creation. Usually it is the collaboration of the composer and the engineer that yields serious achievements in electronic and computer music. In the case of Edward Artemiev, his amazing 'technological versatility' makes it possible to combine the composer and engineer in a single person. Artemiev is a performing artist and a sound producer. In addition he is the author of the composition and a programmer, as well as the man to find a technical realisation for his musical ideas (Katunyan, 2004).

The human-machine relationship seamlessly became a source of inspiration for many composers over the course of the twentieth century. Even though some ideas were not proportionally adapted to a technology only in its infancy, it was still possible to subtly explore complex and challenging ideas. Most certainly, this was the case for Max Matthews, Jean-Claude Risset, Charles Dodge, John Chowning, Curtis Roads and F. Richard Moore to name a few researchers and composers linked with Bell Laboratories for example (Roads, 1996). They have all used and modified technology at the beginning of the computer era to generate musical works. Moreover, it is often the case that composers learn a great deal about compositional design through exposure to various forms of system design as born out in the practice of composers like I. Xenakis, H. Brün, and G. M. Koenig (Hamman, 2002).

Experiments in Musical Intelligence have become increasingly automatic, so they have become progressively more allied with machine activity (Selfridge-Field, 2001). In the publication 'Conversations about contemporary music' (Ford, 1993), Boulez clearly establishes some directions relative to the man-machine interface. This involves a higher level of language, a language which is more symbolic and less numerical. For instance, if you see a curve it means more to your imagination than figures. In the past, the composer had mechanical constraints which were counter-intuitive. Now, composers have the option of designing specific software solutions. This is very important for the development of creative thinking. The machine has the potential to respond to the quickness of the mind, and correspond to what the composer thinks.

2.2.4 Technological rate of change

The stylistic implications driven by technology have had a direct influence on musical aesthetics. The relations between technical innovation and artistic motivations for music-making are dynamic and often

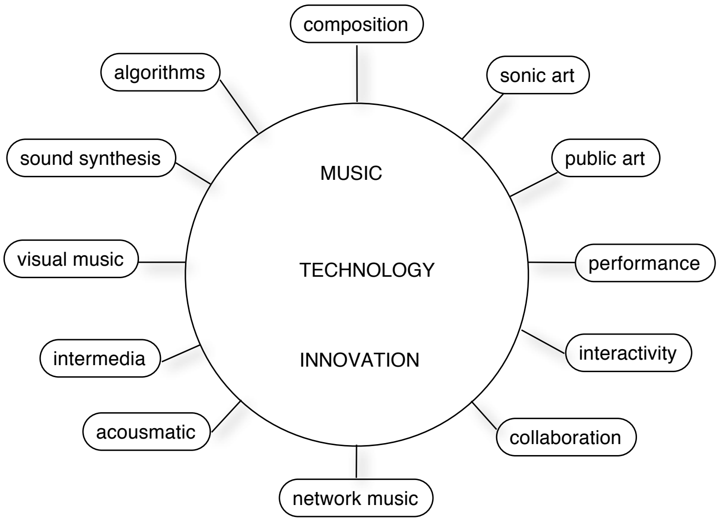


FIGURE 2.1: Organigram of derived musical activities related to music technology.

inter-related. Evidently, there is a tight relationship between musical expression and technology. For example, the length of a sound sample stored in a digital sampling instrument is limited by the size of the memory chip, this has an impact on the type and the sound quality (Moore, 1990).[10] One of the main limitations of using technology in the delivery of artistic ideas is the number of predetermined functions available within a system. Computers may circumvent these by accessing large databases. Whilst there are still limitations caused by the user interfaces in place for the effective construction of substantial artistic works, advances in software technology have now been incorporated into systems for computer-assisted composition, which have become highly sophisticated (Berg, 1996).

However, the historical value of early experiments was not undermined by the particularly limiting technological context. In most instances, the musical idea carried more weight than the cumbersome technology in place. Innovative concepts from the early computer music days still exerts a transcendental influence on the evolution of the contemporary composer's approach. This has resulted in the emergence of a more reliable compositional infrastructure established in several layers of tools such as hardware, software, controlling devices, hyper-instruments and such, and extending to related fields and disciplines supporting a unified vision of the role of technology in music (see Figure 2.1 and Appendix C.1).

[10]An excellent example of this is the Fairlight Computer Music Instrument in 1979, the first commercially available digital sampling instrument, designed by two Australian engineers, Peter Vogel and Kim Ryrie.

From the constant interaction between technology and its proponents, one can derive that there exists a correlation between the rate of technological innovation and the development of the musical idea. However, the intriguing question remains, how does the situation differ today in comparison with the early computer music era? Have we made progress in the adaptation and integration of music and audio technologies, and have these constituents affected the ability to convey a more sophisticated musical idea? Have computer innovations enhanced musical thought, or on the contrary, has the creative mind started to depend on computer innovations?

Confrontation with the machine is a normal preoccupation for today's artistic creators, and it is therefore imperative to analyse the fundamental relationship with the technology involved in order to appreciate the entire palette of expression and its broadcasting potential. Composers in particular, are faced with the challenges of rapidly evolving computer and information technologies, a key factor which has undoubtedly influenced the choice of strategies to complete the software programming. During the formalisation phase of the *3D-Composer* application, new programming techniques and systems emerged, and it was therefore crucial to keep research objectives aligned, regardless of which technology was available. It occurred to us as an idea during the research phase, that humanity is really engaged in what appears to be a constant race with technological progress. We refer here to a larger definition of the term progress, encompassing art and technique. 'Today's means of progress lies in the use of machines! It alone allows for a real extension of musical thought to include all components of the sound world' (Boulez 1957 cited in Jameux 1991, p.85).

2.3 Theoretical approach

Indeed, hybridisation of contrasting mediums and abstract thoughts are quintessential in driving progressive ideas. The conscious act of passing through a subject to discover another is omnipresent in an environment where interactions between different entities are unavoidable. Inter-disciplinary collaborations engender convincing solutions at a higher order of magnitude, thus allowing access to a new repertoire involving associative processes. Such is the case with modern compositional techniques, which now not only combine different organisational structures applied to pitch, rhythm and timbre, but may also integrate the use of computers in the elaboration of new works. From this angle, hybridisation is the key concept of the application. With science and mathematics appears a multitude of algorithms, stochastic processes, neural networks, cellular automata and other incommensurable strategies to create music and sound. In an age of ever-increasing specialisation, composing electronic music seems almost impossible, given that the necessary musical competence and technological understanding rarely are embodied in a single person (Jeschke, 2006). As a consequence, another question arises: do the proponents of these new methods of expression understand the processes, and is this knowledge absolutely necessary in the construction of a composition?

In the colossal treatise on the Topos of Music, Mazzola describes music as a universal phenomenon of symbolic and physical, formal and emotional, individual and social, systematic and historic presence. He advances that developing a concept of music should not get off with a definition *ex machina*, but offer propaedeutic orientation tools in order to elucidate why certain conceptual mechanisms or definitions are built. Mazzola lays out a preliminary orientation for his work by establishing the fundamental activities of music. The musical realm distributes among four types of artistic or scientific actions and reflections: production, reception, documentation, and communication. These activities testify to a universally ramified presence of music in culture. Developing a consciousness of their presence in music sheds a particular light on the subject (Mazzola, 2002).

The contextualisation of ideas in the realm of artistic and scientific activity and reflection was the best approach to generate a novel solution for a personal interpretation of the musical phenomenon. Similarly to Mazzola's broad classification of musical activity, and influenced by the semiological tripartite categorisation, a scheme was established to lay a basis for a methodology of engineering an effective computer music system. 'This approach is essential to keep systems reliable and manageable, and to deepen our understanding of the capabilities and limitations of a computational account for music' (Balaban, 1996, p.108). The main elements characterising computer music systems as a manifestation of musical activity are: innovation, representation and communication (see Fig. 2.2). These elements are described in the following sections.

2.3.1 Innovation

A major source of inspiration and motivation for this research project included retracing innovative ideas of the early avant-garde period. This intentional anachronous juxtaposition has had a considerable impact on my approach towards creation and composition. There is no justification for this linkage, other than the thought that, perhaps going back to the original ideas of that epoch may suggest new avenues in a different context. To illustrate this, I refer to the doctrine of Neoplasticism, which alludes to creation and innovation as a transformation of material in all its forms. Through modern technique material is

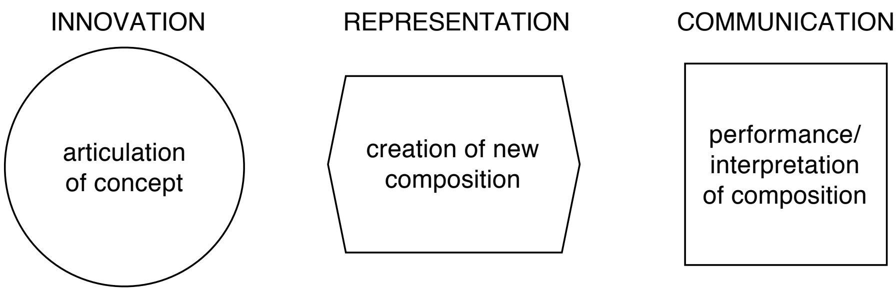


FIGURE 2.2: Manifestation of compositional activity.

transformed, denaturalised. The forms which thereby arise lack the rustic character of antique forms. Upon this denaturalisation or, better, transnaturalisation, the style of our age is largely based (Jaffe, 1967). Conversely, composers have not yet explored all the possibilities of existing tools and methods, yet they continue to propose new ways to create sounds and music. This is not necessarily detrimental to the evolution of musical discourse, but the advantages already offered by the available technology are certainly undermined by the speed at which new tools and methodologies emerge.

> One of the most interesting new possibilities afforded by the use of computers as musical instruments (though still too seldom used in computer music) is the ability for a composer to design a new notation for a specific composition and then write a computer program to 'read' (programmers say parse) that notation and generate sounds. The exploitation of a composer's fascination with new notations is then bounded only by his ability to model (program) a parser for each one. (Pope, 1986, p.160)

As mentioned in section 2.2.2, we seek a unique solution where two elements, form and process, are integrated and un-dissociable. Below is a re-interpretation (definition) of the term *innovation* within the context of computer-assisted-composition.

DEFINITION 2.1. Innovation *refers to new ways of expressing musical ideas in a dynamically evolving technological environment, and involves the articulation of concepts and processes which establish a new compositional framework.*

2.3.2 Representation

In this section, we make a parallel between music notation and representation to introduce elements of computer music. Since the inception of chant notation in the eleventh century by Guido d'Arezzo, an ever-increasing precision has been required from music notation. Symbols have been added or altered, and new musical ideas have demanded extended notational solutions (Brandorff et al., 2005). Contemporary compositional demands call for a new repertoire of signs to represent the myriad of performance techniques expected from musicians. It is also recognised that technology plays an important role in the dissemination of musical information which also results in the elaboration of new works. Such a challenging context indicates an increasing 'degree of willingness' to break away from tradition and adhere to more unconventional formatting. The advent of recording has also prompted various forms of music representation, including digital encoding of sound onto a non-perceivable medium (hard disk recording). This has changed the relevance of musical notation (Pope, 1986). Hence, a more drastic movement toward the exploration of musical instructions and representation methods creates an important schism in the development of experimental music. Music notation, much like any language, is not an absolute (Mitchell, 2007).

> The evolution of notational uses runs parallel to the evolution of forms and structures. All earlier notations seem to have shared the common purpose of preserving and safeguarding the music of a culture, whether by defining a theoretical basis, establishing the course of ritual performance, or by transmitting performing skills or the rules of the musical game. (Cole, 1974, p.9)

Music notation has a twofold nature. Firstly, it is based on a traditional and a historically proven framework (Young, 1930). 'The history of the notation of occidental music has been deeply linked to the need to transfer musical ideas from a composer to a performer' (Pope, 1986, p.157). 'Graphemic elements, such as staff, relative note head positions, accidentals... help to communicate musical concepts among musicians and theorists' (Noll, 2005, p.340). Secondly, representation and rendering are linked with the 'degree of willingness' to move away from traditional notation. In spite of the gradual and relatively conservative changes in the configuration of music ensembles[11] during the twentieth century, symbolic representation of musical information has undergone a more important transformation. A more daring palette of new signs has been invented to cope with the complexity of musical ideas. To this end, Horacio

[11] Beside the emergence of electronic instruments and development of a *lutherie électronique*, here, we refer to acoustic instruments and their combinations in ensembles involving several musicians.

Vaggione expresses the idea that there is no musical composition process (instrumental, electroacoustic, or otherwise) without representational systems at work (Vaggione, 2001). Since the development of electronic music, composers have become aware of the incompleteness of conventional notation, particularly due to the tendency to define all aspects of sound, including timbre, attack, decay, dynamic and tempo changes (Cole, 1974). Furthermore, musical representation has semiological implications but they are outside the scope of this text, which presents a contextual scheme.

With the below definition, the aim is to establish a conceptual link with the evolution of musical notation to validate and confirm the usefulness of the visualisation and representation aspects of the system. The definition implies that representation may also involve electro-acoustic instruments or other technological components such as a computer monitor to describe musical phenomena in extension or exclusive to a musical score.

DEFINITION 2.2. Representation *is the perceivable manifestation of the form, structure and conceptual nature of a musical phenomenon conveyed through a descriptive medium such as visualisation or sonification.*

Ultimately, it was not until very late in the twentieth century with the invention of the MIDI protocol in 1983, that musicians had a new perspective on the congruity of music and machine. An entire musical performance and its notation could be represented in a small data file, and shared, modified and distributed to other musicians for further enhancement (considering its low resolution output of 8 bits, the MIDI protocol is still reliable and is used in most electro-acousitc studios). It is worth noting that there has not been any major changes to the protocol since. Manipulating MIDI information with the use of software is now commonplace, but not much innovation in terms of musical representation has emerged, most software applications still rely on traditional notation and timelines to display musical information. See section 3.2.4 for a more precise discussion on visualisation.

Technology has also introduced a dynamic dimension to the customary score format. The diversity of presentation devices and new graphic interfaces have led to the proliferation of musical information in various forms.[12] This eventually leads to the idea of communication, which deals with the omnidirectional aspects of representation in all its formats, between the composer, musician and listener.

[12] Such an example was the interpretion of the score *Quartetto per archi* composed by Krzysztof Penderecki in 1960 by the Kronos Quartet. The score was visually displayed on a large screen from which the musicians were sight reading the scrolling score during the performance. The most striking aspect was that the audience could also follow the projected score. More information was provided to understand and assess the music.

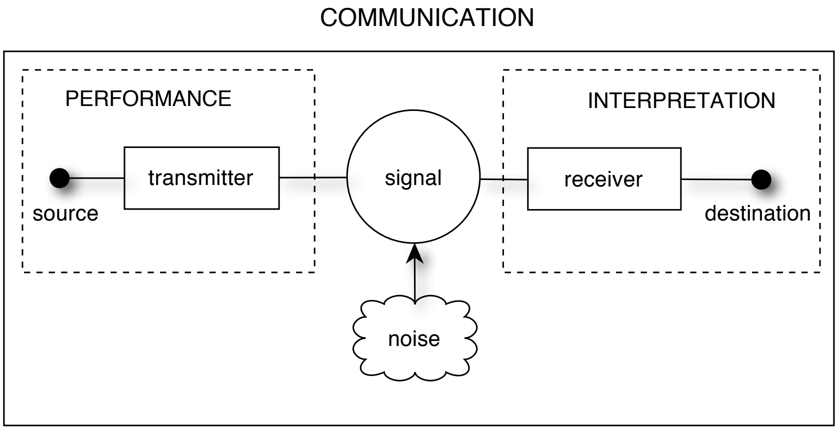


FIGURE 2.3: Classical model of communication (Shannon and Weaver 1949).

2.3.3 Communication

Communication is the foremost aspect of human development, and has implications on all spheres of human activity including composition. Transmission models of communication view communication as an instrumental act – the sending and receiving of messages in ways which individual actors are largely in rational control of. Technological infrastructures of communication should be examined for an understanding of forms of connection and integration (Holmes, 2005). In recent times there has been an evolutionary change, from previously confined notions of communication reduced to the deconstruction of the meaning itself, to an interest in the technological processes involved in communicating meaningful information. In addition to analysing the semantic value of the message, it is also necessary to take into account the communication medium and the transmission methods involved. Following communication theory, the three levels of communication are:

- technical - how accurately the symbol can be transmitted
- semantic - how precisely the symbol conveys the meaning
- effective - whether the received meaning has the desired effect

The three levels are interrelated and interdependent. Shannon's perspective is that communications systems, whether natural or constructed, are designed with range in mind rather than the individual message. From the basic notion of a simple two-phased communication model (sender/receiver), we devise a similar approach to establish a working framework for computer-assisted-composition. Within compositional activity, communication involves two primary functions: performance and interpretation. They are described as follows:

DEFINITION 2.3. Performance *refers to the act of materialising and communicating conceptual information destined to be perceived as expressing some form of musical meaning.*

DEFINITION 2.4. Interpretation *refers to the act of processing musical information with the aim of retrieving its expressive content and conceptual meaning within a defined social and cultural context.*

The above premises evoke a certain preoccupation for the medium, and the means by which musical messages are transmitted. This aspect of composition became predominant mainly with the appearance of virtual studio technology. Methods for sound creation are largely based on acquired computer skills, and reliance on readily available graphic user interfaces is seldom sufficient to pursue a personal creative direction. As a result, the paradigm of an extensible and customisable programming environment is a necessity. Taking into account the *instrumentarium* is unavoidable when conceptualising and materialising musical ideas, and remaining consistent with the entire innovation-representation-performance-interpretation chain has become a new compositional challenge. This aspect will be addressed in the next chapter.

2.3.4 Summary of definitions

A priori, a theoretical framework was established to create works within a specific methodological and conceptual realm. Such ramifications allowed the author to understand the processes of production and reception of computer based musical experiments with the idea that systematic ramifications support creative imagination and innovation. A tripartite analysis model was adopted to describe the manifestation of compositional activity in this context. Innovation was defined as the initial articulation of the concept and planning, representation was characterised by the materialisation of the new composition and finally, communication was depicted as the transmission of the materialised creative work in the form of a performance and interpretation. The compositional system based on that framework is described in the next chapter.

Chapter 3

Geometric properties of micro-composition

«There will be a day when a composer will compose music with a notation that will be conceived in terms of music and light... and that day, the artistic unity we were talking about will probably be closer to perfection... »

Vladimir Baranoff-Rossiné, 1926

3.1 Introduction

In this chapter, we will propose a methodology to cope with the manipulation of musical concepts in a geometric space during the elaboration of a musical work. A computer application was developed for the analysis and creation of micro-compositions in three-dimensional space, allowing users to visualise, analyse and transform aspects of music in ways that may influence compositional decisions and aesthetic choices. Principles of geometry were implemented to model a short melodic pattern in three dimensions. Computer technology allows complex calculations and transformations to offer a different viewpoint on the intrinsic properties of music. The ability to establish a link between the manipulations of graphic patterns in three-dimensional space and the correlated musical output will be investigated and integrated in a series of musical compositions. Some aspects of the geometric properties of compositional elements in three-dimensional space will be demonstrated, along with an overview of the different components of the software developed in this context.

Contemporaneity subsumes multi-disciplinarity; many avant-garde artists of the late nineteenth and early twentieth century already adopted such an approach through new inventions and artistic exploration. However, many concepts of this period did not necessarily flourish due to technological limitations. Nevertheless, contributions from the past remain essential in the development of innovative ideas relying on existing and emerging technologies. Whilst many techniques have emerged to effectively combine visuals and sound, they have not attained the desired artistic unity expressed by some visionaries of the twentieth century. The futurist Baranoff-Rossiné (1888-1944) expresses this incapacity to render complex ideas relying on many senses. The above introductory quote by Baranoff-Rossiné was the driving force and the main influence for embarking in this compositional project, which eventually lead to discover the omnipresence of a certain artistic universality expressed by many avant-garde composers, regardless of their connection or affinity toward a historical musical continuum.

Complexity, as a generalised state of entropy is the driving source of motivation to find simple models describing real phenomena. Within a historical musical continuum, we are constantly submerged in information-rich environments and increasingly, it is important to devise categorisation systems to filter and retrieve data according to certain criteria. The sophistication of information (of various types and importance) requires more precise algorithms to cope with such complexity. This brings us to the fundamental dilemma, which continually confronts the composer today. How can we design the necessary tools to realise the compositional idea? In this context, it can be said that musical information can be interpreted by various means, and its significance can take various new forms depending on how it is received, analysed and presented (Di Scipio, 1995).

3.1.1 Establishing a conceptual framework for the compositional process

Many composers have used ‘series’ as a tool to generate musical structures, which has helped them through the decision-making process in music composition. Such examples include the notion of ‘sieves’, defined as a sequence of integer values, which can be translated to musical or sound events (Xenakis). Similarly, ‘group composition’ is a way of exploring unknown artistic territory with specific objectives (Stockhausen). In another order of ideas, ‘local compositions’ are introduced as elementary objects of music topology (Mazzola). More recent developments include the application of string theory to define how chord structures evolve in multi-dimensional spaces called orbifolds (Tymoczko). The essence of the *3D-Composer* application is to remain purely within Euclidean space and integrate some of these fundamental concepts in the realm of computer assisted composition, with a particular focus on the analysis and modelling of the structural and generative processes of micro-composition.

To begin with, my research project relies on a pragmatic research method to define a framework for the compositional process, from which a theoretical model could be established. We hope to create a new compositional technique based on the conceptual and technical aspects of the process itself. In this instance, a creative and artistic approach is favoured toward solving a problem of a technical nature in order to open a new path of inquiry in the study of musical systems. The pragmatic model is in line with *techné*, where the process of creative development through technology and its dissemination become synonymous (Manning, 2006). Theoretical notions were implemented during the design and development phase of the computer application, but were not the basis for the construction of process. These notions appeared during the conceptualisation phase, and gradually became the backbone of materialised version of the project (see section 3.2).

Moreover, an environment representing the dynamic nature of compositional activity was chosen to explore the generation of melodico-rhythmic content using computer technology. This would eventually lead to theoretical ramifications based on the process itself. For this to work effectively, we shall first confine this activity within a defined system, more precisely, by describing the conceptual space within the sphere of compositional activity. As Boulez suggests in a discourse on technology and the composer, it is absolutely necessary that we should move towards global, generalisable solutions (cited in Boulez 1986, Manning 2006). Here, we contend that generalisable solutions may also encompass indeterminacy, probablity and stochastics, as efficient methods for obtaining musical invention. Nevertheless, the interest lies in the idea of 'understanding the *techné* that shapes and influences how such processes are selected and applied is the much bigger and more valuable goal' (Landy 1999 cited in Manning 2006, p.83).

In addition to practical applications, a music theoretical model can be derived from the exploration of abstract musical concepts based on alternative and innovative uses of technology. From a mathematical conceptualisation model described in (Noll, 2005), the following are some conceptual ramifications which may be adapted for the purpose of composition:

- The elaboration of a consistent conceptual network and its practical usage in musical creation can add new insights to 'traditional' knowledge.

- Conceptual bridges can be created between abstract music and acoustical, psychological, and other properties based on mathematical models for the corresponding structures and processes.

- Mathematical formulations of musical facts can be relativised by constructing musical counterfacts, i.e. constructing alternative models which are not exemplified by any music.

It is worth noting that this project could have been approached from many other angles, based on various historical models for compositional analysis, which are beyond the scope of the original aims of the software development project and would require further study in conjunction with other fields. Such models include dialectical, gestalt, cognitive, linguistic, biological, combinatorics and artificial intelligence (see Selfridge-Field 2001 for a historical and philosophical overview). Instead, some mathematical notions were integrated in the application itself (geometry, projective geometry, graph theory) and are described later in this chapter.

3.1.2 The notion of space

Dealing with the notion of space has implications with respect to the coincidence of science and art. Location, structure and morphology come to mind when one thinks of space, but the perspective from which it is considered is a crucial factor. Through the works *Hyperprism*, *Octandre* and *Intégrales*, Edgar Varèse took a scientific stance toward sound in an attempt to bridge the gap between *ars* and *scientia*. He became conscious of the notion of space and referred to it as the fourth dimension in music. Varèse called this musical journey 'sound projection'. 'I think of musical space as open rather than bounded, which is why I speak about projection in the sense that I want simply to project a sound, a musical thought, to initiate it and then let it take its own course' (Schuller, 1965). Varèse was also fascinated by the instantaneity of electronic music techniques, but was not impressed by the inherent limitations of technology. 'It does not seem to make full use of the unique possibilities of the medium, especially in regard to those questions of space and projection that have always concerned me' (Schuller, 1965, p.36-37). The notions of 'sound projection' and space in music were still vague, and did not automatically relate to performance space acoustics or stereophonic/multi-channel sound projection. Rather, conceptual values took precedence over the literal interpretation of the fourth musical dimension. Varèse explains, 'when new instruments will allow me to write music as I conceive it, taking the place of the linear counterpoint, the mouvement of sound-masses, of shifting planes, will be clearly perceived' (MacDonald, 2003).

> *«A visual illustration may make clear what I mean: Imagine the projection of a geometrical figure on a plane, with both figure and plane moving in space, each with its own arbitrary and varying speeds of translation and rotation. The immediate form of the projection is determined by the relative orientation between figure and the plane. By allowing both the figure and the plane to have motions of their own, a highly complex and seemingly unpredictable image will result. Further variations are possible by having the form of the geometrical figure vary as well as the speeds. »* (MacDonald, 2003, p.140)
>
> Edgar Varèse, 1953

'Projection may simultaneously affect several musical ideas, in several dimensions and at several speeds' (MacDonald, 2003, p.140). Through his intuitive inquisition of musical space, Varèse expressed symbolically the musical concepts which he did not yet have the technological means to produce.

Similarly, Mauricio Kagel refers to the concept of projection and musical space as a continuum extending the compositional process that determines the temporal aspects of form and structure:

> Complete projection in space is not yet available in electronic music; but one can only imagine 'music in space'—a space without holes—where this complete projection in space is a constitutive element in the composition. Our present space is made up of several tracks which, with the aid of strategically suspended loudspeakers, provide some sort of substitute for an imaginary continuum. An organization of the mobility of sound by means of turning timbres will then be a specific category of the concept 'musical space'. Some of the principles of rotation explained here can be executed in space even with the primitive technical means at present at our disposal; a 'muted' spatialness does nothing to interfere with our perception of space. Although this 'muting' has proved itself a very musical business (the mute in a violin still allows the timbre of the instrument to be recognized), it is nevertheless a stage that will have to be superseded. (Kagel, 1964, p.56)

Indeed, the artistic work of a composer utilising or depending on technology (today –computer technology) situates itself at the edge of science. 'Musical processes, at least from the composer's point of view, are not situations "out there" waiting to be discovered: they are rather to be composed (since they did not exist anywhere before being composed), and hence they cannot be considered properly as modelling activities, even if they use –and deeply absorb –models, knowledge, and tools coming from scientific domains' (Vaggione, 2001, p.54). I chose to delineate my working canvas within specific notions of conceptual and musical space to remain in line with my original compositional intentions. The next section takes a look at some definitions of space.

3.1.3 Taxonomy of space

In his recent taxonomy of space in electroacoustic music, Bertrand Merlier describes the notion of space as multiple realities depending on the context involved (Merlier, 2006). In his view, space can refer to physical phenomena, psychoacoustic phenomena, musical ideas, artistic concepts, aesthetics, and sometimes, even methods or tools of performance. As a result, space can take several meanings depending on context. Here is a list of various descriptives to refine the notion of space, as listed in 'Vocabulaire de l'Espace' (published in 2006): space, absolute/relative space, acoustic space, ambiophonic space, architectural space, polyphonic space, composed space, cross-space, listening space, perceived space, external space, extrinsic/intrinsic space, geometric space, illusion space, internal/external space, mental space, ornamental space, landscape space, projection space, projected space, real space, sound space, source space, virtual space, visible space, spacing and space figure (Merlier, 2006). This opens an array of possibilities with respect to the angle taken in creating a musical work, be it instrumental, electroacoustic, multimedia, interactive, etc.

Absolute/relative space concerns the movement and position of sounds (or notes) in a coordinate system representing a specific location: for example, a vertical line can represent the relative position of a sound with respect to a listener's position (or the position of a note in a chord with respect to the root of a chord). Composed space is the distribution and organisation of fixed and/or dynamic musical elements and processes which are determined by the composer and aimed for a performance. In the context of exploring new possibilities of formal and structural configurations with the use of a computer, geometric space can be defined by a set of abstract graphical images describing real musical objects, which guide the listener (and composer) and structures the perception of music through the evolution of elements of form over time. Space figure is the visual representation of parameters relating to space, space figure also symbolises space with morphological elements such as melodic cells, motifs, groups and impulses represented on a score.

In addition to the above conceptual definitions of space, a more theoretical definition is imperative to be able to integrate these concepts in a programming environment. The following sections prepare grounds for a concrete geometric interpretation applied to micro-composition. We deliberately focus our attention on geometry, as a natural affinity toward the ideas suggested by the classical quadrivium of knowledge (where arithmetic, geometry, astronomy and music compose the higher spheres of knowledge). This may seem *depassé* in a modern digital era, but in a sense, it is useful to go back to a fundamental train of thought to generate new ideas, in a completely different context readjusted to emerging technologies. In addition, it is important to specify which branch of geometry we are referring to, as there are many interpretations depending on the area of study.

3.1.4 New trends for innovation

Musicians have often borrowed from other disciplines to extend the possibilities of musical expression. Beyond architectonic and spatial considerations, Xenakis introduced probability and calculus theory to musical composition in 1954, in order to construct sound masses both in their invention and in their evolution. As the laws of probability vary in time, it creates a stochastic dynamics which is aesthetically interesting (Xenakis, 1992). The statistical methods proposed by Xenakis came at a prosperous time when new branches of mathematics were being discovered, and, as mentioned by mathematical theorist Robert Osserman, geometry lived through a serious decline relative to other branches in the middle third of the twentieth century. ‘I would predict that with no effort on any of our parts, we will witness a rebirth of geometry in the coming years, as the pendulum swings back from the extreme devotion to structure, abstraction, and generality’ (Osserman, 1981, p.244). Stochastic methods are well known applications of mathematics to create dynamically evolving musical structures, it would also be interesting to determine how varying degrees of translation, rotation or scaling would affect musical structures. This leads to think that many aspects of geometry are yet to be interpreted in other fields of activity, supported by more relevant technology enabling a more accurate rendering of conceptual ideas, especially in computer music. The challenge today is to develop new compositional concepts that are suitable for computer music systems, with a clear and elegant formulation of the musical abstractions conveyed (Berg, 1996).

3.2 Representing music with geometry

In a recent article in *Time* magazine entitled ‘The Geometry of Music’ (Lemonick, 2006), the term ‘Geometry’ refers to higher dimensional spaces within non-Euclidean geometry. Composer and music theorist Dimitri Tymoczko applies string theory to define how chord structures evolve in multi-dimensional spaces called orbifolds, domains of much higher complexity than the usual three spatial and sometimes the addition of a fourth temporal dimension (four dimensions of the Minkowski space for example).[1] Of course, a discussion on space-time continuum is beyond the scope of this exercise, but it is worth underlining which areas of geometry exist in order to present a generic approach toward possible compositional models based on this field of mathematics.

To demonstrate the importance of confining the framework of activity to a specific discipline, see Table 3.1 for a list of subcategories pertaining to geometry alone.

[1] An orbifold (for ‘orbit-manifold’) can represent up to ten or eleven dimensions in abstract mathematical spaces.

TABLE 3.1: List of subcategories found in the field of geometry.

Algebraic Geometry	Coordinate Geometry	Surfaces
General Geometry	Geometric Inequalities	Distance
Plane Geometry	Rigidity	Multidimensional Geometry
Computational Geometry	Curves	Symmetry
Geometric Construction	Geometric Similarity	Noncommutative Geometry
Points	Differential Geometry	Transformations
Continuity Principle	Inversive Geometry	Non-Euclidean Geometry
Geometric Duality	Solid Geometry	Trigonometry
Projective Geometry	Line Geometry	

Here, the diversity of concepts relating to only one area of mathematics, demonstrates the importance of clearly defining the framework to establish a solid compositional methodology. Euclidean space (sometimes called Cartesian space or n-dimensional space) was adopted in order to keep the conceptual interpretation of music within categories closely related to the suggested model of visual representation; general geometry, coordinate geometry and projective geometry. General geometry refers to the study of figures in a space of given number of dimensions and of a given type. It is interesting that historically, geometry was constructed from setting out a small number of accepted truths or axioms, then systematically expanding the statements logically toward a more rigorous proof. A parallel will be made when discussing projective geometry a bit later. coordinate geometry relates to the three-dimensional Cartesian coordinates, conventionally denoted the x-, y-, and z-axes which are chosen to be linear and perpendicular. Projective geometry deals with the properties and invariants of geometric figures under projection, and the transformation of lines and points from one plane to another, or the content of a plane onto a line at infinity for example. The types of transformations involved are translation, rotation and scaling.

3.2.1 Projective geometry

A significant example opening the possibilities of geometry to music is the work by Lewin in 2004, where the author proposes some compositional uses of projective geometry. 'The projective plane is highly structured, and that structure can be musically suggestive in various contexts'. Lewin illustrates how various aspects of the geometry can be projected compositionally, and interprets the axioms of projective geometry in a musical context.

The mathematical axioms of projective geometry (E. Kasner, 1989; Veblen and Young, 1938):

1. If a and b are distinct points on a plane, there is at least one line containing both and

2. If a and b are distinct points on a plane, there is not more than one line containing both and
3. Any two lines in a plane have at least one point of the plane (which may be the point at infinity) in common.
4. There is at least one line on a plane.
5. Every line contains at least three points of the plane.
6. All the points of the plane do not belong to the same line.

Simplification of the axioms in a more general context:

1. Any two points lie on just one line.
2. Any two lines pass through just one point.
3. Every line passes through at least three points; every point lies on at least three lines.
4. It is not the case that every point lies on every line.

Lewin's adaptation of the axioms in a musical context (Lewin, 2004):

1. Any two notes belong to just one chord.
2. Any two chords have just one common tone.
3. Every chord has at least three notes; every note belongs to at least three chords.
4. It is not the case that every note belongs to every chord.

The above axioms are applied to a diatonic mode, these axioms are applied literally in a musical space rather than in a Cartesian geometric space. The resulting structure called 'projective plane' is therefore not treated geometrically as intended by the original axioms. However, the author notes that if one satisfies all the conditions of the axioms, one applies projective geometry. This step-by-step logical process relates to notes and chords rather than points and lines, and is visually represented in the form of a score, thus simulating the projective model musically. From a mathematical standpoint, this interpretation is a reduction of projective geometry and does not take into account spatial dimensions.

Below is a table representing projective geometry in its simplest manifestation:

If every letter in the rows represents a discipline, and every letter in the columns represent a student, we see that this particular configuration respects all the conditions for projective geometry (Lewin, 2004).

The resulting musical equivalent to the above table denoted on a staff (see Figure 3.1).

TABLE 3.2: Axioms of projective geometry applied in a general context.

	L	M	N	P	Q	R	S
A		*	*		*		
B	*		*			*	
C		*				*	*
D				*	*	*	
E	*	*		*			
F			*	*			*
G	*				*		*

FIGURE 3.1: Example of Projective Geometry applied to the construction of chords (Lewin, 2004).

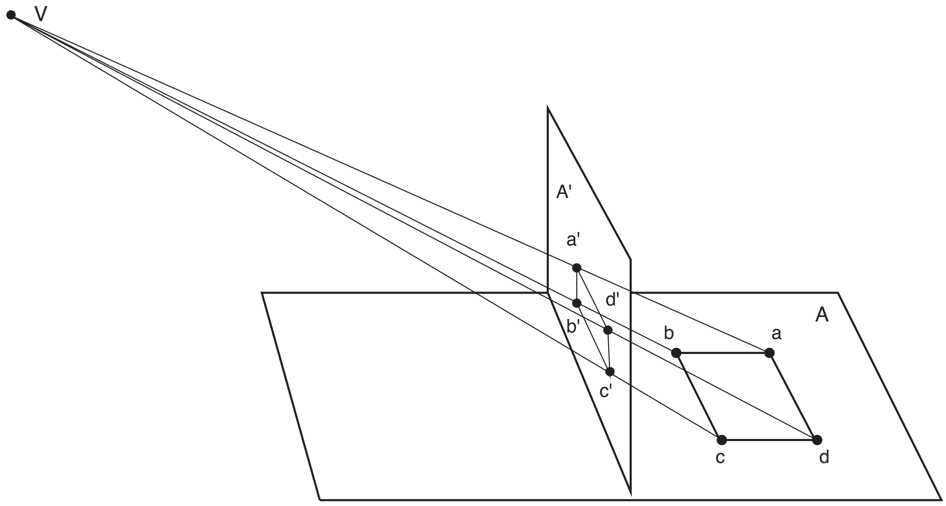


FIGURE 3.2: Representation of a projected figure of one plane onto a different plane.

From a geometric perspective, Figure 3.2 shows the projected image of quadrilateral abcd onto a picture plane, so that the images appear identical at the viewing point V. The intersection of the lines that make up the corresponding sides all intersect on one line, called the axis of projection, or the intersection of the two planes (E. Kasner, 1989). This is of particular importance for studying perspective in art.

The key issue in this project is to convey a more direct and literal interpretation of projective geometry to a coordinate system representing notes in Euclidean space. This would enable geometric manipulations of musical structures in a projective plane, and possibly in a three-dimensional coordinate system.

Projective geometry could then be applied onto a series of pre-determined values and the projected outcome could represent different musical parameters, depending on which projective plane it would be projected onto.

3.2.2 Elements of micro-composition

The notion of 'sieves' as defined by Xenakis, is a sequence of integer values which can be translated to musical or sound events such as pitches, time onsets, dynamics, densities, degrees of order, local timbres (Xenakis, 1992; Ariza, 2005). Mathematically, sieves result from a process of successively crossing out members of a list according to a set of rules such that only some remain. Scales are typical examples of sieves, where generally speaking, some elements of the twelve-tone row are missing. It has been suggested that 'sieve-theoretical models have both a pedagogical and a musicological interest for they enable the music theorist to visualize some structural musical properties in a geometric way and to test the relevance of different segmentations in music analysis. This could have a strong implication in the way to teach music theory, analysis and composition' (Noll et al., 2006, p.154).

Another perspective is the implementation of series in Stockhausen's notion of 'group composition'. 'It's not just a method of disciplined composition; above all, it's a way of exploring unknown artistic territory with three primal objectives:

1. to cover as much territory as possible in a non-arbitrary way;
2. to establish coherent and artistically meaningful procedures for dealing with what one finds, and to unify these procedures wherever possible;
3. to retrieve the findings into the world of art in terms of 'works', even if this involves partly redefining the notion of art' (Toop, 2005).

In this particular instance, 'group composition' is a way of proportioning various aspects of music (as in Klavierstück V analysed in (Toop, 2005)). The number sequence 5 4 2 1 3 can represent a series of pitches occurring in this particular order, from highest note to middle 3. This sequence can be applied to dynamics and can scale loudness from the weakest to the loudest sound. Alternatively, these values can be applied to different rhythmic values ranging from one to six 32^{nd} notes. This form of parametrisation is a consequence of the quantification properties of technology. Cologne composers became interested in pre-programming certain parametric aspects of music. It was especially Koenig who developed his own set of computer programs, *Project 1*, which later led to computer-composed music (Gross, 2000).

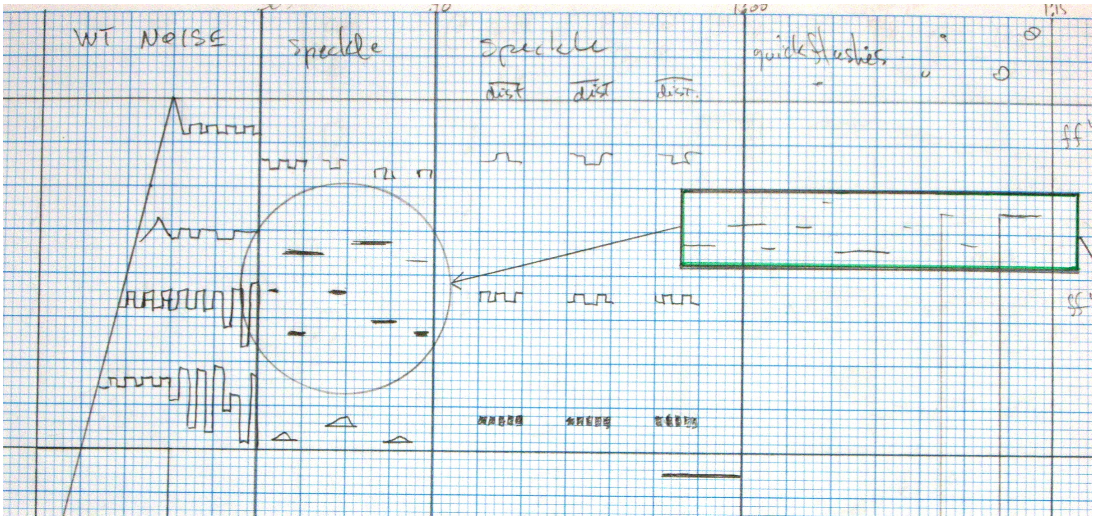


FIGURE 3.3: First draft of the compositional process which led to the definition of micro-composition.

3.2.3 Motivic abstraction

If we move a step further, mathematical transformations can include algebraic, linear, scalar, vectorial and geometric operations, including permutations. This implies a one to many functional mapping allowing for a flexible treatment of various data sets, with the unique condition of assigning the resultant values to musical parameters. In other words, the source data is not necessarily intended for musical purposes. This opens a debate on which types of values can be considered as musical, and which types of values are of no musical relevance. 'Generative music, in the broadest sense, includes any sort of procedural, rule-based system for generating and producing solutions, variations, procreating material' (Beilharz, 2005, p.5). The intention therefore, is to use the same melodic pattern to generate new musical material in the way self-similarity or generative music occurs. However, the quest for innovation lies specifically in the idea that visual representation of musical material should be transformed geometrically, regardless of any traditional notation conventions. As a result, the exploration phase lead to the unavoidable necessity to define micro-composition. The sketch in Figure 3.3 represents the first idea, as a method of creation. It unveils a musical process rather than a musical idea: a composition based on transformations and evolution of musical material. The draft was started on a graphic sketch pad and it was quickly established that, if we were to transfer the idea directly to a score, it would not be possible to transform the material on the actual score.

Certain transformations are not possible with traditional staff notation, and the introduction of computer technology is paramount in this context. The challenge involves conveying abstract musical information in a different form of visual representation. In his article entitled Translation – Rotation, Mauricio Kagel was concerned with the presentation and design of musical passages by geometrical means. 'The fact that the structure of a piece of music can find an analogy in the visual representation only makes wider the gaps between idea, representation and realization' (Kagel, 1964, p.32). Kagel continues by stating 'naturally, a technical process must be found which can provide an insight into the investigation of the function and effect of translating and rotating' (Kagel, 1964, p.33). The impetus is therefore to create an application, which would allow us to understand the *techné* which links the geometric transformations to the compositional idea. In an attempt to merge musical developments with technological aspects, the aim is to find a relevant generic solution to create a universal and reusable musical system. By extrapolating the relationship between notes on a musical staff, the notes loose any temporal relationships and become a new entity for musical creation. 'If we investigate the figure divorced from the musical stave the earlier distance between the notes is no longer an expression of temporal sequence'. 'The isolation of the figure from its complementary relationship to a musical process serves for an experiment' (Kagel, 1964, p.34).

Another major influence for the initial formalisation process came from Mazzola's Topos of Music (Mazzola, 2002), which introduces the concepts of scales, chords, meter, rhythms and motives and proposes theoretical models for composition including topologies and a classification theory for musical objects. Musical objects comprise of local and global compositions. Local compositions are introduced as elementary objects which form a basis for the construction and transformation of larger musical structures. Ultimately, the mathematical areas of categorisation and group theory are applied to create a topological landscape for music theory and analysis (Mazzola, 2002).

Inspired by this formal and methodic approach, an application was created to map values from a three-dimensional space onto MIDI note numbers to explore new musical textures and generate organically evolving motivic structures. Such a system would provide compositional material and would cover a vast array of possibilities in a non-arbitrary way. At a later stage, a purely geometric approach could be extended toward a wider analytical scope, to develop a theoretical framework for the intrinsic properties of micro-composition.

3.2.4 Visual representation of musical concepts

For many contemporary composers, the invention of new vocabularies and grammars is a significant part of their method in musical problem-solving. Di Scipio observes that 'as a form of art, electroacoustic music emphasizes that the artist's work includes the making of the object as well as the invention of the techniques suitable for its making' (Di Scipio, 1995). With the emergence of high-speed digital computers and the development of computer graphics comes the ability to structure time with visual materials. Abstract animation extends the possibilities of temporal design and brings challenging new problems to those working in the time-based arts. As a new resource, abstract animation, too, will require grammatical tools in order to be effectively used. For the composer, the need to develop and codify new compositional methods has extended into the visual domain (Evans, 1992).

The problems of experimental music composition lead to problems in representation, where data structures and algorithms reflect experimental musical premises for defining compositional processes and models of materials (Hamman, 2002). In fact, there also exists a connection between a computer-generated model and the computer program that generated that model. When implementing a mathematical formula in the programming language, programming computer graphics provides a dynamic visual concretisation of the mathematics involved (Dickson, 1992). The action of condensing abstraction into visual form as an aid in understanding the abstraction is studied in the field of scientific visualisation (Schroeder et al., 2004).

Here are a number of advantages of visualisation (extracted from Ware 2000):

- provides the ability to comprehend huge amounts of data;
- allows the perception of emergent properties that were not anticipated;
- often enables problems with the data itself to become immediately apparent;
- facilitates understanding of both large-scale and small-scale features of the data;
- facilitates hypothesis formation.

Many idiosyncratic computer methods exist in relation to the sound-image connection and visualisation strategies for displaying musical data. Below is a summary of three projects closely related to the idea proposed with *3D-Composer*.

One such application using 3D graphics for computer-aided music composition was suggested in the Master's thesis by Gretchen Dickie. The document includes an extensive list of projects and music visualisation related applications (Dickie, 2004). The software project is envisioned as an environment where users with varied musical backgrounds can create music by 'sculpting' 3D objects that subsequently have their spatial characteristics mapped to sound parameters. The application offers a scene composition window. At the stage of publication the project remained a simplified prototype.[2]

The project was initially designed in Squeak,[3] an open source full-featured implementation of the powerful Smalltalk programming language and multi-platform environment. Squeak includes libraries and virtual machine plug-ins for advanced multimedia including 2D, 3D, and real-time sound and music synthesis. Unfortunately some of the listed systems are already obsolete due to the nature of changing computer technology. Many of the systems are also pixel based, which means they do not implement object representation in a three-dimensional environment rendered by a graphic engine such as the one described in the thesis.

Anna Gerber and Andrew Brown from Queensland University of Technology experiment with a method of creating visual representations of music using a graphical library for *Impromptu* that emulates and builds on Logo's turtle graphics (Gerber and Brown, 2006). The focus of the project is on compositional structure, typically understood as the organisation of musical notes or sonic objects over time. Using a set of turtle graphics primitives, the experiments are based on creating simple visualisations that use paths, shape, colour, line thickness, and transparency to focus on particular musical attributes. Visualisation of melodic contour, dynamics, note interval paths and triads form the basis of the visualisation library. Issues of user-interaction and musical creation remain to be defined. Currently, the *Impromptu* system allows visualising existing musical content and is a representational rather than a compositional tool.

As noted by the authors, there is a large amount of research involving the visualisation of timbre, from oscilloscopes to spectrograms. This brings an important point which distinguishes this type of research on a conceptual level, rather than utilising visualisation techniques for analytical or empirical grounds. The main categories found in the types of graphs which emerged from the Logo turtle drawing system were the following:

[2] Similarly, the thesis mentions a text entitled 'Composing Music Using 3D Computer Graphics' by Ray S. Babcock which introduces some interesting questions: 'What would be the mapping between a 3D computer object and a musical characteristic? Individual sounds could be modified by squeezing or morphing the 3D object that generates that sound etc.'

[3] Squeak and Smalltalk: About Squeak programming language http://www.squeak.org/

- graph-like paths such as the melodic contour example;
- relative paths, where the length and angle of the next path segment determined by musical attributes;
- stamp-based visualisations, where a template function is parameterised with the attribute being visualised to determine the position, size, colour and even the shape of the template.

Peter Mcilwain and Jon McCormack from the Centre for Electronic Media Art at Monash University devised an alternative approach to enable the user to configure nodal networks that generates music in real-time. The project named *Nodal* deals with the structural properties of networks, including spatial graphs applied to musical parameters.

> The initial concept behind *Nodal* was to create a method of generating music via a network in which the output of a node is a musical note (defined by MIDI note parameters). Time between note events is determined, and represented, in a graphical form by the length of arcs between the nodes. The design brief was that the software should generate music in real-time so that it could function as a module or plug-in with other software such as MIDI sequencers and programs such as Max/MSP (Mcilwain and McCormack, 2005).

The authors suggest the network is configured without a fixed goal in mind. Instead the focus is on emergent properties of a particular network structure. In addition, the nature of real time interaction facilitates easy experimentation and play with a complex system. Thus, they recognise that networks can create musical textures that would be very difficult to calculate otherwise (Mcilwain and McCormack, 2005).

'The brain is a powerful pattern-finding engine; indeed, this is the fundamental reason that visualisation techniques are becoming important' (Ware, 2000). In summary, visualisation aims at presenting information so that structures, groups, and trends can be discovered among hundreds of data values. The idea to retain in relation to the field of visualisation and its potential use in music is the following: 'if we can transform data into the appropriate visual representation, its structure may be revealed' (Ware, 2000).

3.3 Software: 3D-Composer

For the composer of the twenty-first century, the notion of artistic tangibility will be more adequately expressed through various computer models of abstract musical concepts. In a sense, the computer rendered model is a conceptual metaphor of the intended musical idea. The computer is therefore a suitable tool for organising musical information with the methods of synthesizing, sequencing and processing time-based events. Nevertheless, the notion of musical conceptualisation itself, as a starting point for musical creativity, is much more difficult to simulate with an appropriate model.

> Computer music software can also encode ideas that reach beyond any individual implementation of them. Computer music software's offerings are of two types. They empower the user directly through their presentation as a working environment; but also, they encode advances in computer music practice. The software designer's most direct challenges are to make the software useful to a wide variety of tasks and to make it last as long as possible. (Puckette, 2002)

The proposed software, *3D-Composer* is an attempt at recreating and reorganising musical elements from the onset of musical creativity, with a particular emphasis on the visual organisation of musical structures. The compositional process is therefore perfectly integrated in the symbolic representation of the musical idea, which implies in this particular case, that the musical idea and the derived process are inter-dependant. This software is therefore devised as a communication tool for the purpose of musical development based on the pre-established conceptual notion of innovation, representation, performance and interpretation. Let us take a closer look at how musical information is organised in this context.

3.3.1 Defining micro-composition

What follows from the aforementioned examples and discussions, is a definition for micro-composition, which is essentially a pointillist interpretation of musical events such as 'group composition' and 'local composition', with the difference that the values of a numerical sequence are not only permutated to generate new sequences, as is the case with most serial methods, but are also transformed and rotated as a whole to generate new musical material as described in Kagel 1964.

DEFINITION 3.1. *A* micro-composition *consists of a range of ordered values called* nodes*, representing real numbers which can be mathematically altered to generate new musical material solely based on that original set of values.*

For the purpose of this definition, let $M = \{n_0, ..., n_m\}, n \in \mathbb{R}$ be the non-empty finite and unordered[4] set of nodes in a micro-composition of length $len(M) = n_m$. Given a music composition S we consider a finite collection of micro-compositions in S that we denote $M(S)$.

The micro-composition will undergo transformations (morphisms) which are located in a three-dimensional space, such as a rotation by θ degrees in the direction of the$x, y, z - axis$, respectively. These are projected onto a two-dimensional surface (e.g. the computer display (see Fig. 3.4). Three-dimensional spaces are referred to as Euclidean space, or Cartesian space and are denoted by $\mathbb{R}^3$. Every node contained in a micro-composition consists of a point (also called a vertex) in Euclidean space such that $a = (a_x, a_y, a_z) \quad in \quad \mathbb{R}^3$. Every point in space is a set of values associated with the three dimensions of space.

We shall denote the following variables to describe the transformations:

- $a_{x,y,z}$: a point in 3D space
- $k_{x,y,z}$: the location of the camera
- $d_{x,y,z}$: translation of point $a_{x,y,z}$: into the camera coordinate system
- $\theta_{x,y,z}$: the rotation of the micro-composition
- $e_{x,y,z}$: the viewer position in the camera space
- $a'_{x,y}$: the projected coordinate on a 2D plane (computer display)

The main transformation that a micro-composition will undergo is a rotation around one or more axes, in the x, y or z direction. A rotation is a transformation in a plane or in space that describes the motion of a micro-composition around a fixed point. We assume that the viewer is located in the same position as the camera, at coordinate $k = \{0, 0, 1\}$, typically, the user would be looking at the centre of the display which corresponds to coordinate $a = \{0, 0, 0\}$. The following rotation matrix $\mathbb{Q}_{rot}$ is used to transform the coordinates of $M = \{a, b, c\}$:

$$\mathbb{Q}_{rot} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos -\theta_x & \sin -\theta_x \\ 0 & -\sin -\theta_x & \cos -\theta_x \end{bmatrix} \begin{bmatrix} \cos -\theta_y & 0 & -\sin -\theta_y \\ 0 & 1 & 0 \\ \sin -\theta_y & 0 & \cos -\theta_y \end{bmatrix} \begin{bmatrix} \cos -\theta_z & \sin -\theta_z & 0 \\ -\sin -\theta_z & \cos -\theta_z & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (3.1)$$

[4] Ordered sets belong to set theory, and are more useful for analytical purposes (see description of set theory and Forte's labels in (Mitchell, 2007)).

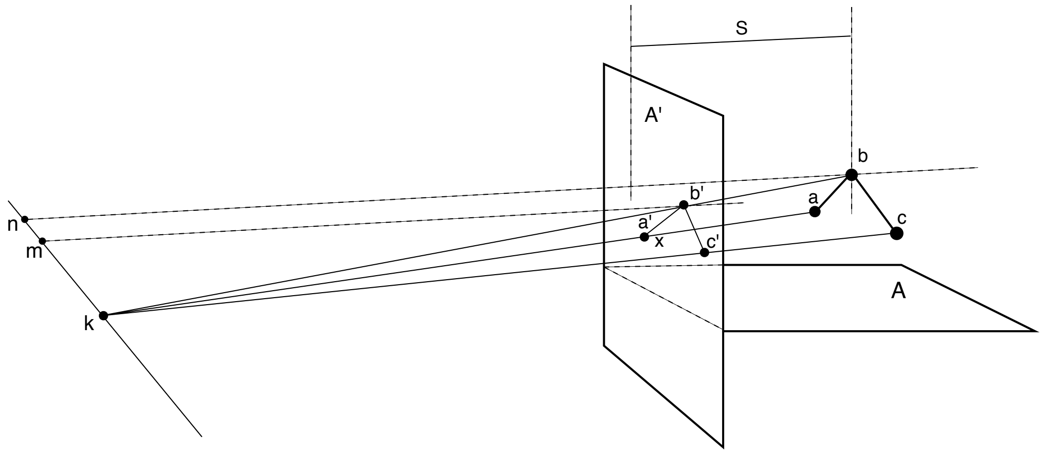


FIGURE 3.4: Difference between object coordinates in 3D space and resulting projection on 2D screen A' from the point of view of observer at V.

Multiplying the rotation matrix by the coordinates of the micro-composition in the new coordinate system defined by the position of the camera generates the following equation:

$$\begin{bmatrix} a'_x \\ a'_y \\ a'_z \end{bmatrix} = \mathbb{Q}_{rot} \left(\begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix} - \begin{bmatrix} k_x \\ k_y \\ k_z \end{bmatrix} \right) \tag{3.2}$$

We assume the viewer is always located at point k because this is not a virtual environment, the viewer remains in the same position relative to the display when using the application. This leads us to differentiate between different types of coordinates. There are four coordinate systems commonly used in computer graphics. The four coordinate systems are: *model, world, view and display*.[5] The model coordinate system is the coordinate system in which the model is defined, typically a local Cartesian system. The world coordinate system is the 3D space in which the models are positioned. Each model may have its own coordinate system but there is only one world coordinate system (Schroeder et al., 2004). The view coordinate system represents what is visible to the camera. And finally, the display

[5] Model coordinates are sometimes referred to as object coordinates and world coordinates are also referred to as the scene (Schroeder et al., 2004).

coordinates are the window coordinates (i.e. within the computer application). Equations 3.3 and 3.4 should be considered if the viewer and camera are not in the same position. The new set of screen coordinates a'_x, y are dependant on $e_{x,y,z}$ as follows:

$$\begin{bmatrix} f_x \\ f_y \\ f_z \\ f_w \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & -e_x \\ 0 & 1 & 0 & -e_x \\ 0 & 0 & 1 & 0 \\ 0 & 0 & \frac{1}{e_z} & 0 \end{bmatrix} \begin{bmatrix} a'_x \\ a'_y \\ a'_z \\ 1 \end{bmatrix} \tag{3.3}$$

and

$$\begin{aligned} a'_x &= \frac{f_x}{f_w} \\ a'_y &= \frac{f_y}{f_w} \end{aligned} \tag{3.4}$$

Coordinate systems are delineated by orthogonal axes. Usually the x-coordinate increases horizontally to the right, the y-coordinate increases vertically upward, and the z-coordinate increases into the display, away from the viewer. World coordinates (also called a scene) represent the overall environment in which some objects may be located. This constitutes the main reference and starting point for any computer imagery. One may ask which universe are we in? The viewer's coordinates correspond to the observer's (computer user) point of view in relation to world. Camera coordinates are determined by where the camera is placed relative to the viewer, and how it is aimed at the world. The image rendering engine for the entire scene is set by the camera coordinates. Coordinates for one object are also referred to as the local coordinate system. This describes how the object itself is constructed locally: it is a self-referential coordinate system. There may be several objects in a virtual world. Every object in a scene has its own location and a new set of coordinates for every location within that scene.

Extrapolating these ideas with musical context, a micro-composition contains a set of coordinates representing nodes (eventually pitch classes). This determines the internal structure of a micro-composition. Morphing of the internal structure of the micro-composition occurs when the relative position of one or more nodes changes. Colourful music emerges when nodes are transformed in world coordinates, either locally with isolated nodes, or, globally for entire micro-compositions. This can be accomplished with the rotation matrix in equation 3.1. Beyond conventional transformations (transposition, inversion, retrograde, fugue, counterpoint, canon, etc.) motivic elements of the micro-composition have an internal dynamic structure, and when rotated along any of the three axes, the resulting projection engenders interesting compositional combinations.

In some cases, successive transformations may produce identical musical material (i.e. 360° rotation). A group of transformations is a set of transformations of space, with the property that the successive application of two transformations is equivalent to another transformation in the set (their composition), and any transformation can be cancelled by the application of another transformation (its inverse) (see Visual Mathematics Glossary, 1992).

3.3.2 User interface

The graphic user interface affords easy access to conceptual and parametric aspects of the technique implemented. The user interface is designed in the graphical programming environment Max/MSP/Jitter,[6] (see Figure 3.5). The choice and layout of user controls allows a fluid reorganisation of musical elements in the Cartesian coordinate system. The main interface contains a display area showing the micro-composition (on the left) as well as control parameters facilitating geometric transforms (on the right). The navigation panels found below the main display allow the user to navigate in 3D space to analyse the structure of the micro-composition and visualise elements from various camera positions and perspectives. Aside from potential analytical value, navigation has no musical implications at this moment, and has limited viewing angles.

The musical structure is independent of the time factor, not taken into account due to the complexity of the visualisation application. The reason for this is twofold. Firstly, manipulation of the micro-composition generates musical material over time, but time is not represented, as such, in the main user interaction window or in the form of a timeline. That is intentional, to dissociate musical elements from conventionally linear representations over a predetermined timeline. Instead, the focus is on the geometric transformations of micro-compositions creating countless melodic contours, when combined with rotation speed and variable translations, and becomes a new form of musical variation. Timelines

[6]Max/MSP is a graphical programming environment to create software in the fields of music, sound, and multimedia. Using a visual toolkit of objects, the user connects objects together with patch chords to build modular interactive systems. The basic environment called Max, includes MIDI, controller messages, user interfaces, and timing objects. Built on top of Max are hundreds of objects for signal processing. This part is called MSP (for Max Signal Processing), which is a set of audio processing objects that do everything from interactive filter design to hard disk recording. Jitter is a set of matrix data processing objects optimized for video and 3-D graphics. See www.cycling74.com for more information

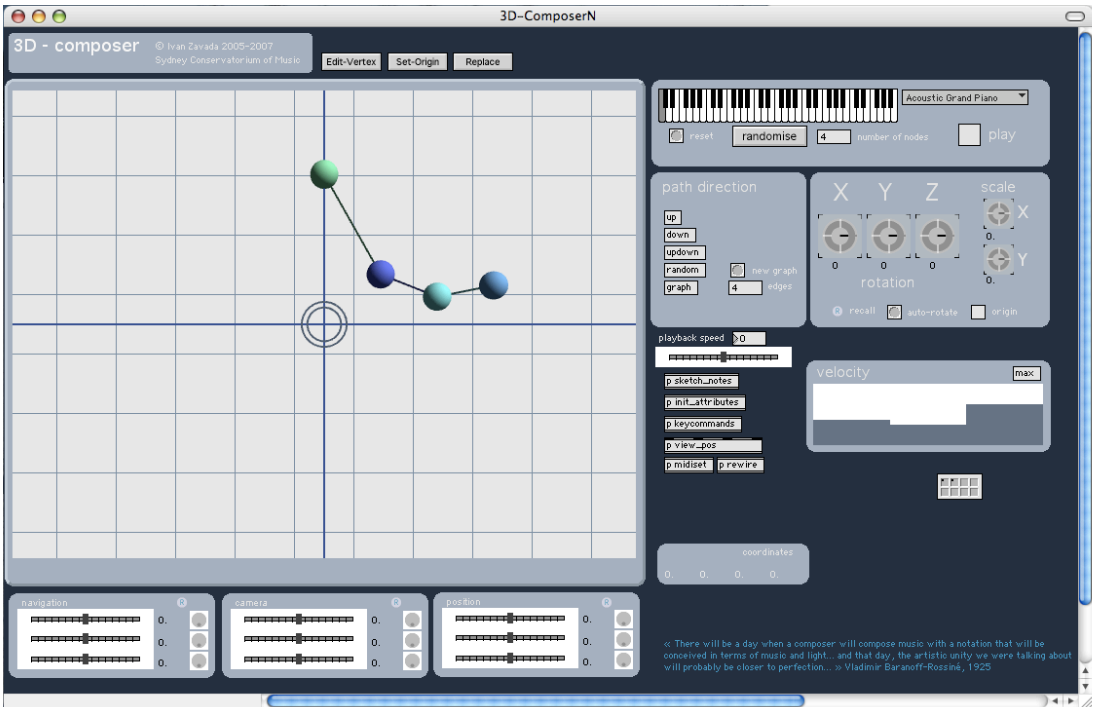


FIGURE 3.5: Graphic user interface for the *3D-Composer* application.

and object/event notations are obviously very useful for generating performance scores and/or music compiler note lists (Pope, 1986), however, the intention of using a non-linear mode is to represent higher structural elements. Secondly, time structures can be derived from the intrinsic properties of micro-composition. For example, the tangent/slope from one node to the next could be mapped to a set of predetermined durations. Alternatively, the rotation gradient of the structure could be mapped to a time-dependant variable, thus generating rhythm. In this version of the *3D-Composer* prototype, meter and rhythm are dealt with separately, and manually (with conventional compositional decisions relying on the desired aesthetic and genre).

Notes represented by small spheres are instantiated with the help of a keyboard or by selecting a random values according the number of notes desired in the micro-composition. The main controls consist of three rotational knobs each representing the x,y,z axes respectively. The rotation of the knobs reach a full circumference of 360°, after which the structure returns to its original position. The coordinates of the rotation are determined by the user, and can be set to any note position within the micro-composition. An additional scale factor determines the (pitch) range on the vertical axis, and the playback speed (compression/expansion) on the horizontal axes. The z-axis is reserved for instrumentation, currently set to

16 MIDI channel numbers. The above parameters can be automated for rotation in space, thus generating notes on a discreet time interval in milliseconds determined by the user. Melodic output is directly proportional to the speed of rotation on any axis, due to the quantising effect of the playback tempo (triggered by a metro object in Max/MSP). The speed of rotation will produce various note patterns, but always acts on the same micro-composition structure (unless it is modified by the user).

Variations include translation on the vertical axes (arpeggio effect), compression or expansion (i.e.smaller or larger intervals) to yield musical structures over fluctuating interval limits. The level of indeterminacy is limited and can open new avenues toward non-tonal harmonies. The user takes part in the creative process by imposing some flexible limitations on the musical structure. This results in a ‘geometric mode’ rather than a strict compliance to serialism or stochastics for example, and is not audibly atonal nor random in its aesthetic. The modes are engendered by the original configuration of the micro-composition. The level of consonance and dissonance vary according to the shape of the micro-composition, the more constrained the shape, the more dissonant it will sound. This is true only if the micro-composition is mapped onto discrete note events. If, however, they are mapped onto sound events or micro-intervals, various types of melodico-rhythmic cells and interesting textural material may result.

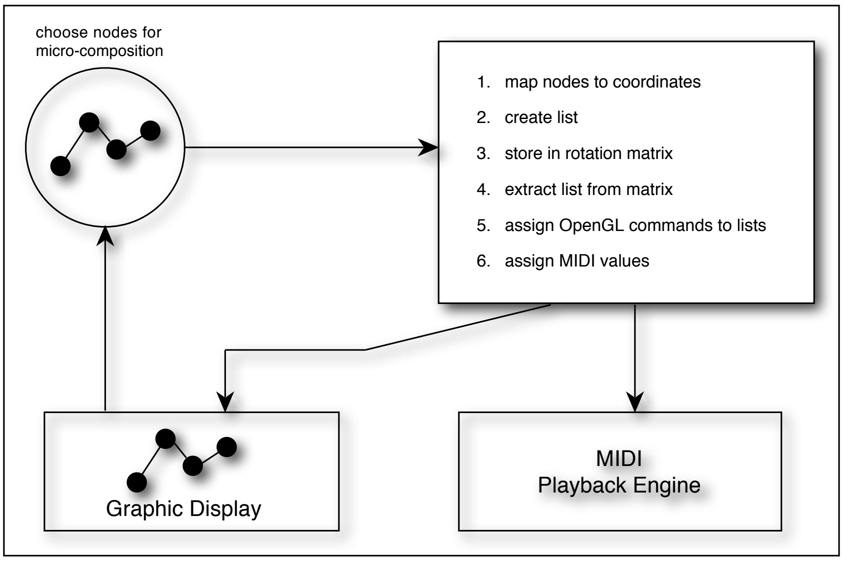


FIGURE 3.6: Data management cycle for displaying micro-composition.

First, and foremost, the key aspect of the application lies in the capacity to constantly update displayed visual information (see Figure 3.6). Hence, data management becomes an issue because every component is described in an array of at least eight values to render the spheres representing nodes: xyz-coordinates, RGB colour components including transparency (alpha value) and radius of the spheres. The more notes in the micro-composition, the more memory and processing power it requires to render complex visual information in three-dimensional space. This is inherent to the design of the application, which strongly relies on the graphic engine of the computer and OpenGL, a standard graphics specification to generate images in 3D.

Aside from aesthetic and musical considerations, data management was the most difficult aspect of this project. This was due to the fact that Max's fundamental design does not deal with issues of data management (Puckette, 2002). The concept of modelling a micro-composition may appear simple at first, but the implementation and elaboration of such a system is indeed much more complex. Data management and storage was handled in four ways before choosing the most efficient solution.

Solution 1

The first method involved using conventional data objects found in Max/MSP/Jitter. For anyone familiar with this programming environment, the collection object is the most versatile solution for storing indexed information such as integers, floating point numbers, characters and strings. There are several additional access functions and even some sophisticated sorting methods. The main issue with this solution was dealing with constantly changing lists of floating point values, which would interact in real-time with the OpenGL display in Jitter. Due to the large number of values being constantly updated, this caused an overflow of information. Information would need to be retrieved from the collection, sent to the display area, then clear the collection and replace by new values coming from the display. It is easy to notice the possibility of a data loop and eventually a program crash when updated too quickly. Before blaming the computer, or the programmer... further options needed to be investigated.

Solution 2

Several objects in Jitter deal with data storage in two or more dimensions. One such object is jit.cellblock, which manages two-dimensional storage and viewing of information. Data is organised in rows and columns and the object accepts the various data types (integer, floating-point, character, string). There are a number of settings available to change the structure of the object. The output consists of a row/col/value list, and must be treated accordingly (i.e. slice the content of the list to extract what is needed from the list). This becomes a tedious process when, as previously described with the collection object, coordinate data must be updated and replaced. This ended up as a very ugly patch, and was discarded due to inefficient data handling.

Solution 3

The third solution involved an external object designed to be integrated within Max/MSP/Jitter, called iCe Lattice.[7] Lattice is a data storage and retrieval object in the style of a tracker channel. The user is presented with 16 000 patterns each capable of storing 2 147 483 647 rows which can each record or play 255 pieces of information in the form of floats, ints, strings, lists, send messages and meta-commands. This sounded very impressive at first. Data presentation and management were much more elegant than the previous two options. However, manipulating values going to and from the Lattice object involved similar methods as the previous two options. This is explained by the patching required to communicate with the OpenGL graphics display.

Solution 4

The question remained, how to deal with musically intended data (i.e. space coordinates) in the most efficient way to incorporate data storage, management and exchange in the same process. Object oriented programming promised to be a more versatile data management environment. This model proved to be particularly efficient, and allowed room for expansion within Max/MSP/Jitter. The core of the system is the external called *pyext*, which provides a full integration of the Python scripting language into Pure Data or Max/MSP/Jitter. Python is a dynamic object-oriented scripting language that can be used for many kinds of software development. Python supports procedural, functional, and object-oriented techniques, and also provides an extensive library of modules for use in music.[8] With the *pyext* object one can load Python modules and execute the functions therein. Python classes can represent full-featured pd/Max message objects. The *pyext* object was specially compiled by Thomas Grill to be compatible with Python 2.5.[9] Among recent musical projects, Python was used for 'One Laptop Per Child' (OLPC) to create the *Tam Tam* suite, an application for music and sound related activities designed for children by Jean Piché and his team (Piché, 2007).

Although graphic user interfaces (GUI) offer a more user-friendly interface than do textual interfaces, there are still some operations, such as iterations or conditionals, that are better accomplished with a script than with a graphical interface (Dechelle *et al.*, 1999). Illustrations of this are the UNIX shell, Java, Python, Javascript, PHP or Perl scripting and programming languages. A Python script was written

[7] A complete overview of the iCe objects can be found at http://www.dspaudio.com/software/ice/ice_overview.html

[8] See the following website http://wiki.python.org/moin/PythonInMusic for music related projects such as audio players, ear training, csound interfaces, audiovisual programming frameworks, mp3, midi...

[9] Thomas Grill designs commercial as well as open-source software for technical acoustics and media installations and performance http://grrrr.org/ the external is available at http://grrrr.org/ext/py/

and integrated in Max/MSP/Jitter with *pyext* (see Appendix A.1 for the full Python script called by *3D-Composer*). The Python integration phase required a serious time investment which was well rewarded by the resulting efficiency of the final algorithm. Issues of design, complexity and data management were considerably reduced. Another important advantage for the choice of Python was the seamless integration of the module implementing basic graph theory (see section 3.3.3). From the following enumeration of tasks, it is easy to understand why lower level programming can alleviate programming complexity, that aspect was brought about in (Gerber and Brown, 2006) and (Mcilwain and McCormack, 2005).

1. choose nodes for the micro-composition
2. map individual nodes to cartesian coordinates
3. join coordinates into a list of floating point values
4. send to *pyext*
5. store into array of numbers
6. place into rotation matrix
7. assign new coordinates
8. concatinate into lists of cartesian coordinates
9. assign OpenGL commands to coordinates
10. assign MIDI values to coordinates
11. output list to visual display
12. play MIDI notes

The OpenGL command to draw the sphere on the display (see Figure 3.5) is:
`glcolor 0. 0.53149606 0., sphere 0.05, bang`, which is derived from the first line of the numerical matrix stored in the script read by *pyext*:

$$\begin{bmatrix} 0 & 0. & 0.53149606 & 0. \\ 1 & 0.2 & 0.17716535 & 0. \\ 2 & 0.4 & 0.0984252 & 0. \\ 3 & 0.6 & 0.13779528 & 0. \end{bmatrix} \tag{3.5}$$

The colour scale is mapped over the entire range of an octave, and the swatch can be programmed according to a specific colour-scale relationship. Many colour systems exist in relation to notes and

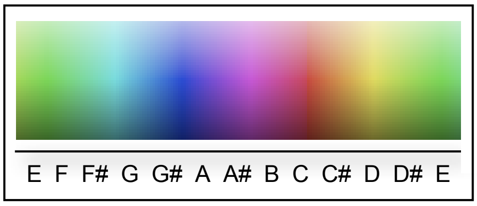


FIGURE 3.7: Implemented colour-scale relationship for micro-composition nodes.

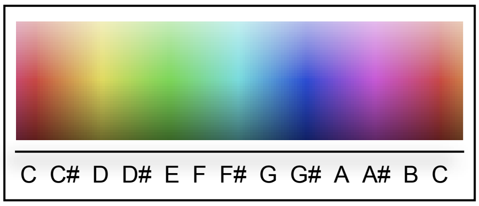


FIGURE 3.8: Alternative colour-scale relationship for micro-composition nodes.

frequency values. For example, Skriabin's colour-sound correspondence is based on the circle of fifths. His correlations are based on the equivalence of 'complexity' of tonalities and colours; colours at the red end are 'simpler' than colors at the blue end (Galeyev and Vanechkina, 2001). *Klangfarbe* (or colour of sound in German) is another interesting type of parametric association, and could link the notion of *timbre* to micro-composition. For the purpose of this prototype no particular mapping system was preferred. The suggested colour-note relationships shown in Figure 3.7 and Figure 3.8 are therefore arbitrary.

The notation equivalents for micro-composition are mapped according to the display area of the application. The x, y-coordinates of the viewer span from $(-1, 1)$ in the upper-left corner to $(1, -1)$ in the lower-right corner (see Figure 3.9). The camera is positioned further out to enable the user to see several octaves.

As the counter i increases, the x-coordinate increases by a step-wise function in the positive direction (to the right):

$$x = i * 0.2 \tag{3.6}$$

Source code: `x_coord=self.counter*0.2`

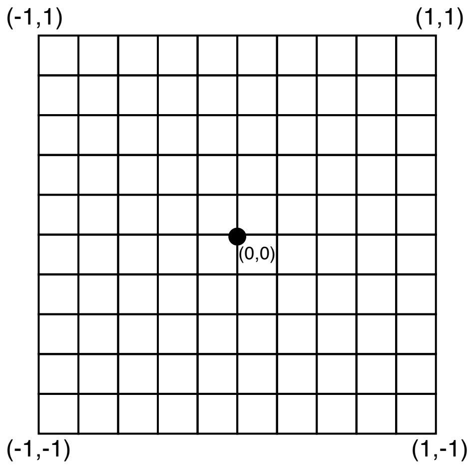


FIGURE 3.9: Display coordinates.

The y-coordinate on the other hand, is assigned a value according to incoming MIDI note values $(0 - 127)$, which are mapped onto the viewing area defined by the x, y-coordinates of the display, and the camera position set to a predetermined coordinate. The centre of the display is set to $(0, 0)$, and the camera position is $k = (0, 0, 2)$ for the purpose of this demonstration, which allows the user to see a span of 2.5 octaves as follows[10]:

$$y = 2 * n_{oct} * (\frac{note\ in}{127} - 0.5) \tag{3.7}$$

Source code: `5*(i/127.-0.5)`

And finally, the resulting playback note values are defined by:

$$note\ out = (\frac{y}{2 * n_{oct}} + 0.5) * 127 \tag{3.8}$$

Source code: `noteout = (y_coord/5.+0.5)*127`

[10]The explanation for such an odd number of octaves is to allow a micro-composition spanning over one octave to rotate freely around the origin, and the user will be able to see the entire micro-composition even during the transformations. the camera position can be changed to view micro-compositions over larger or smaller intervals.

There are five playback options for the micro-composition to allow variations as the micro-composition cycles through all the nodes.

1. forward - cycles through all the nodes in order from the origin, regardless of the angle of rotation
2. backward - cycles from last node towards the origin, regardless of the angle of rotation
3. forward and back - cycles through the entire micro-composion, from the origin and back
4. random - plays any node stochastically, in any order
5. graph - allows for the generation of simple graphs determining the order in which notes are to be played (see next section)

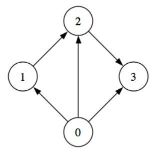
3.3.3 Graph theoretical approach.

To integrate graph theory in micro-composition, let us first define what is a graph. A famous precursor to graph theory is the Königsberg bridge problem.[11] A thorough introduction of graphs may be found in (Rodrigue, 2007; Chartrand, 2005; Diestel, 2005; West, 2000), where connectivity and paths, graph colouring, edges and cycles, and planar graphs are explained. We will cover basic notions in this section, with respect to the implementation of graphs in the software prototype.

A graph is defined as a set of points which are connected by lines. There are several names for points and lines; we will use vertex and edges for this description. The mathematical representation of a graph is $G = (V, E)$ or $G(V, E)$, where V represents a vertex; a terminal point or an intersection point of a graph. An edge E is a link between two vertices and is an abstract representation of the movement between the vertices. The order of a graph is determined by the number of its vertices. Table 3.3 contains an example of a graph of order 4 with 5 edges connecting the graph. The vertices are connected by arrows, which means it is a directed graph. The path may be one of the following: $(0 - 1 - 2), (0 - 2)$ or $(0 - 3)$. Graphs are useful to schematise sets of data or networks which may vary in complexity, and the visual representation in the form of a graph allows a succinct analysis of a complex phenomenon. In addition to their quantitative properties, graphs also present a qualitative idea of the musical vocabulary utilised by the composer (Peusner, 2002). The orientation of the graph is of no relevance, it is the connections and relationships between the nodes which bear meaning. For instance, there are different kinds of graphs, directed and undirected. Directed graphs (also known as digraphs, have directional links between the

[11] The Königsberg bridge problem asks if the seven bridges of the city of Königsberg (left figure; Kraitchik 1942), formerly in Germany but now known as Kaliningrad and part of Russia, over the river Preger can all be traversed in a single trip without doubling back, with the additional requirement that the trip ends in the same place it began. This is equivalent to asking if the multigraph on four nodes and seven edges (right figure) has an Eulerian circuit. This problem was answered in the negative by Euler (1736), and represented the beginning of graph theory. (Weisstein, 2008)

TABLE 3.3: Example of a directed graph $G(V, E)$ of order 4.

Order	**Vertices**	**Edges**	**Graph**
4	V=0, 1, 2, 3	E=(0, 1), (0, 2), (0, 3), (1, 2), (2, 3)	

vertices, either in one or two directions. For undirected graphs, the edges have no direction, which means a and b are related but the order is of no importance, we can refer to them as (a, b) or (b, a).

Graphs can also attach values to the edges, valued graphs include information describing the weight or importance of the connection. Non-valued graphs attach no numerical value to the connecting nodes. A graph may contain a subgraph, so many possibilities arise in terms of combinations generated by one graph. Common classes of simple graphs include: complete graph, cycle graph, empty graph, gear graph, prism graph, star graph, wheel graph, oriented graph, undirected graph, directed graph and network.

The next important aspect of graphs is the path. A path is an alternating sequence of vertices and edges, beginning at one vertex, ending at another. They need not be the same vertices. However, the same vertex may not be visited more than once. The degree of a vertex is denoted by the number of incident edges. Due to this fact it is important to note that there can be several paths on the same graph. This important aspect for the generation of simple graphs has been taken into account for creating micro-compositions, which adds a variable dimension to the order of the notes being played. However, the path changes are not displayed in the main window due to software limitations.

The structure of the graph is determined by the order and the size of the graph; the number of vertices and the number of edges. In the case of *3D-Composer*, it is the Kuratowski criterion which is applied to determine the maximum number of edges allocated to a graph. For instance, a graph containing 4 vertices has an order of 4, and can have anything from 0 edges to 6 edges (see Equation 3.9).

$$\begin{aligned} n_{edges} &= n_{vertices},\ for\ n < 3 \\ n_{egdes} &= 3 * n_{vertices} - 6,\ for\ n \geq 3 \end{aligned} \tag{3.9}$$

TABLE 3.4: Comparative table of graphs versus probability.

Order	**Total number of distinct graphs**	**Total number of possibilities**
1	0	1
2	3	2
3	15	6
4	105	24
5	945	120
6	10 395	720
7	135 135	5 040
8	2 027 025	40 320
9	34 459 425	362 880
10	654 729 075	3 628 800
11	13 749 310 575	39 916 800
12	316 234 143 220	479 001 600

Appendix B.1 lists all graphs of order one through to order six, with varying sizes or number of edges. It is important to note that the listing represents only one pass for the selected orders. If someone was to run the graph module again a different set of paths would result, but their order and size would not be affected. The maximum number of distinct paring patterns for graphs is determined according to the recursive product equation $\Pi_{i=1}^{n}(2i-1)$ which translates to the results in Table 3.4. In comparison to Eimert's original observations on the maximum number of possibilities offered by the twelve-tone complex (see section 2.2.1), graphs offer a much higher number of options. This quantitative comparison is not indicative of the musical value associated with these combinations. Further study is necessary to add a qualitative aspect to the evaluation of a graph theoretical approach. One aspect remains clear however, with graphs it is possible to use a smaller number of nodes to generate a larger set of options.

The graphs in *3D-Composer* are generated using NetworkX, a Python module for the creation, manipulation, and analysis of the structure, dynamics, and functions of complex networks. NetworkX is built to allow easy creation, manipulation and measurement on large graph theoretic structures which are called networks. Functions and classes return the required information to the programmer. NetworkX was used to generate random graphs of various orders and sizes. It is interesting to note that there is a considerable difference with using randomly generated graphs, as opposed to randomly generate discrete numbers intended for musical purposes.

3.3.4 Musical applications and electroacoustic considerations.

The software developed herewith addresses two fundamental questions for the construction of a new musical aesthetic. The first is to transcend the conventional tonal system (representation), and the second is to integrate electronic and computer means in the performance and transmission of a new aesthetic (innovation and communication). This dual function is maybe derived from the post-serialist preoccupation to extend modernism whilst preserving a transcendental link with tradition, but the intention of this transformational system is not to re-create or re-combine the ideas of some twentieth century composers, rather, the intention is to retrieve important and influential ideas of the avant-garde as a good-fit model to construct a methodology to compose new works.

As discussed in previous sections, recent advances in electroacoustic and computer music have introduced many concepts from other disciplines. In his article entitled 'A Few Remarks on Algorithmic Composition' Martin Supper divides the selection or construction of algorithms for musical applications into three categories (Supper, 2001):

1. modelling traditional, non-algorithmic compositional procedures;
2. modelling new, original compositional procedures, different from those known before;
3. selecting algorithms from extra-musical disciplines.

This project situates itself at the junction of categories two and three. The intent is to model a new compositional procedure different from previous examples dealing with geometric properties of music. Although the relationship between geometry and music have been discussed for several centuries now, the motivation is to propose a different construction for an algorithm or compositional procedure, aided by the computer to integrate extra-musical elements (3D visualisation, projective geometry, graph theory...).

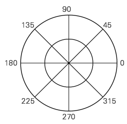
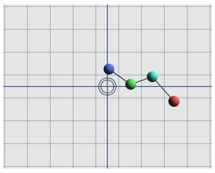
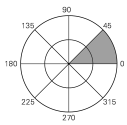
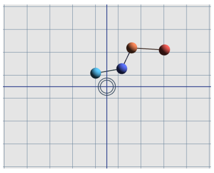
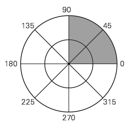
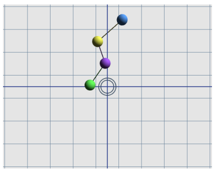
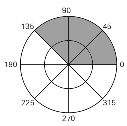
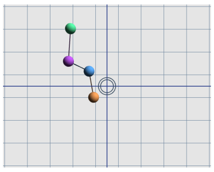
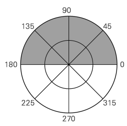
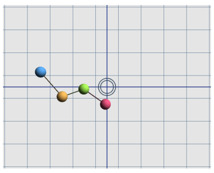
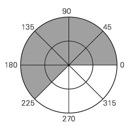
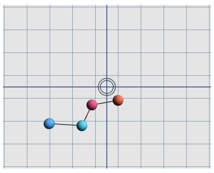
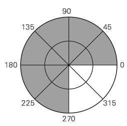
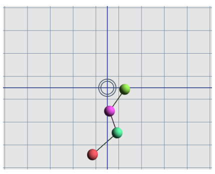
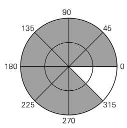
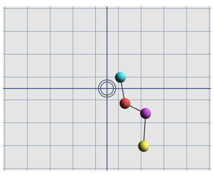
This resulted in some six studies demonstrating both limitations and efficiencies of *3D-Composer* as a tool to generate and transmit musical ideas. As such, one would need an extraordinary imagination to score a 225 degree rotation of a melodic motif in three-dimensional space. On the other hand, 180 degrees could represent a simple retrograde function, and a rotation around the $x - axis$ would represent the inverse function in terms of a series of a notes. One justification for extending transformations and rotations to other portions of the unit circle (which fall between conventional retrogrades, transpositions and inverse functions) is to represent the flow of music without a defined reference point such as a key or measure structure, in order to attain a certain dynamic malleability of the musical material. In other words, visually look at the musical construction in occurrence of transformations, generating interesting musical images and textures. The nodes of the micro-composition can therefore be mapped to notes and sounds, in accordance to the aims of the composition. Table 3.5 demonstrates how a simple micro-composition generates different patterns when a rotation is applied to the original input.

Since *3D-Composer* deals with the exploration of a simple sequence of nodes embodied in a micro-composition, it is possible to create instrumental works as well as sound based works. Current configuration allows direct MIDI playback, either from within the Quicktime MIDI Synthesiser, or through the operating system's OS X Core MIDI technology which allows communication between any MIDI based application or external MIDI devices. The latter solution is the most versatile for the purpose of this demonstration. A vast array of software samplers and virtual synthesisers make it possible to effectively explore various musical applications for the current prototype.

The texture and the timbre of the sounds are therefore determined by the virtual *instrumentarium*. The sound palette does not remind us specifically of a *concrète* aesthetic. In fact, some studies allude to an instrumental paradigm to illustrate possible avenues for further exploration. Although the option of triggering sound objects is always present, the scope of the works was limited to a more direct implementation of micro-composition. The Six Electroacoustic Studies on CD No.2 were created with *3D-Composer* sending MIDI messages across Core MIDI to Logic Pro 8, a studio production environment for musical sequencing and sound recording. Before describing the actual studies, the following discussion locates the works in the electroacoustic context.

Often in electroacoustic and experimental music, sound texture (microsound) overrides melodic and rhythmic structures mainly based on pitch, loudness and duration. Much of the recent interest in the analysis of electroacoustic music lies in the morphology of sound as well as the notion of timbre, often referred to as a fourth parametric dimension to describe musical phenomena. Moreover, electroacoustic music, musique concrète and acousmatic music have a common transformational chain (transduction of electrical energy to acoustical energy). This allows for a systematic categorisation of sounds made from electrical and electronic devices (oscillators, capacitors, amplifiers, random noise, filters...). Although *3D-Composer* was conceived on the basis of a discrete notational paradigm, it's use can be extended toward the electroacoustic medium. Because both electroacoustic and computer technology is the modus operandi to express musical ideas, with the use of 3D-Composer prototype, principles of

TABLE 3.5: Rotation of a micro-composition.

Degrees	**Rotation** in degrees	**Notation**	**Micro-composition**	**y-Coordinates** relative to centre
0			G-E-F-C	0.159 0.019 0.090 -0.136
45			F#-G-C-C	0.123 0.166 0.357 0.338
90			E-D#-A-G#	0.015 0.415 0.215 0.615
135			A-E-G-C	0.229 0.531 0.137 -0.102
180			F-C#-D-B	0.136 -0.090 -0.019 -0.159
225			F#-F#-B-C	-0.338 -0.357 -0.166 -0.123
270			B-A#-E-D#	-0.615 -0.215 -0.415 -0.015
315			F#-B-C#-A	0.102 -0.137 -0.531 -0.229

micro-composition and geometric properties of music are applied to several aspects of sound generated by a computer, including the integration of MIDI to trigger musical events.[12]

The term electroacoustic has hitherto caused much debate, especially with the need to categorise works and associate with a particular style or genre within the eclectic arena of electronic music, and music in general. Two aesthetic tendencies have emerged from electroacoustic music.[13] 'The more "abstract" approach is concerned with developing discourses of sound types and timbres; the other favours recognisable "real-world" sounds (including other music), a more radiophonic approach, which can border on the documentary, and is sometimes referred to as anecdotal music' (Emmerson and Smalley, 2007). The compositions included in this portfolio mostly adhere to the former aesthetic tendency, in which abstraction of the sound source is a primary concern. Attention to structural aspects of sound events are the basis for further transformations and aesthetic decisions. The listener perceives the music without seeing the sources or causes of the sounds. In addition to sonic and perceptual qualities of electroacoustic music, conceptual aspects of the compositional process were also considered, as well as spatial considerations as outlined in section 3.1.3. These references address aspects of surrealism,[14] reinforcing the transcendental character for sonic exploration.

As composers, therefore, it is necessary to imagine intrinsic aspects of the musical material itself, with the intention of grasping the conceptual value of the work, as a linear projection of a common musical experience tending toward musical innovation, representation and communication. To locate this work within a vast collection of stylistic diversity, I propose a personal interpretation of electroacoustic music with the following premise:

DEFINITION 3.1. *Electroacoustic music is a surrealist voyage in our immediate sound environment, be it human voice, instrumental music, industrial noise, synthesised sounds, incidental sounds, plants, animals and any other natural or artificial sound source. Through this voyage, the composer tries to grasp the intrinsic nature of sound, and the spatial and temporal organisation of these individual sonic entities or sound objects is how the composer reflects the artistic and abstract mind.*

[12]Categories such as computer music, music informatics or digital music techniques are just as appropriate to describe the music which can be derived from using the *3D-Composer* prototype.

[13]Emmerson and Smalley propose the following definition of electro-acoustic music in the Grove Music Online resource: 'music in which electronic technology, now primarily computer-based, is used to access, generate, explore and configure sound materials, and in which loudspeakers are the prime medium of transmission. Acousmatic music is intended for loudspeaker listening and exists only in recorded form (tape, compact disc, computer storage)' (Emmerson and Smalley, 2007).

[14]previously evoked by Trevor Wishart in relation to the perception of sounds in a given spatial reality (Wishart, 1985).

CHAPTER 4

Composition portfolio

4.1 Six electroacoustic studies

All compositions were mixed for stereo configuration. The mixing was performed on Genelec 1032A bi-amplified monitoring system at the Sydney Conservatorium of Music, The University of Sydney. The studies demonstrate the possibilities of the *3D-Composer* software and are intended for concert performance. The performance medium is stereo CD.

The works are intended to be diffused on a multi-channel surround system with the audience seated in the centre of the diffusion set up. The stereo output is to be distributed and spatialised through a mixing console sending signals to a minimum of eight speakers located equilaterally around the diffusion space. The performance and spatialisation should take into account the size and acoustic characteristics of the diffusion space.

4.1.1 Study No.1

Study No. 1 is written for a keyboard synthesised instrument. The piano sound is chosen for its familiarity and clarity in demonstrating the variability of a particular technique offered with *3D-Composer*. Although the sound of a piano is indeed familiar, the composition reaches a point where the concept of micro-composition is applied to sound, as an object, to illustrate the versatility of the technique. A three node micro-composition *E-D#-C#* sets the initial pitch mode as a compositional and aesthetic choice. The main parameters addressed are rotation and speed of the micro-composition, where the juxtaposition of rotation and speed form the basis for the structure. Rotations comply to a strict 45 degree selection within the unit circle (i.e. only multiples of 45 degrees over the entire 360 degree circle are used) to generate additional pitch material based on the first three node micro-composition. The playback speed of the micro-composition was determined by the variability of the performance in real-time, and was rehearsed until the juxtaposition matched the original intent of the study. The first section progressively increments through the eight 45 degree steps and exposes the pitch characteristics of rotation in three-dimensional space. The second section relies on the original micro-composition as a basis for further rotations, predominantly in the third and fourth quarters of the unit circle (270, 315 degrees). Speed and intensity progress into a static state at which point frequency filtering (notch filter) is used to intensify a forward movement ending in paroxysm. Performance at such speed and intensity is hardly achievable with musicians, and the music gradually transforms into a sound object in the electroacoustic sense. This fact is emphasised to underline the capacity of illustrating musical and conceptual ideas with technological means, otherwise not possible.

4.1.2 Study No.2

Temporal organisation of sound events is a crucial aspect for creating a work to be perceived over a specified time. Rhythm, even if minimal, is essential to give a sense of time. As such, rhythm has driven much of the music until now and has characterised aesthetic dimensions, as well as stylistic and cultural attributes of musical expression. With electroacoustic music, rhythm takes a modern dimension due to human activity involving different objects and a variety of sounds coming from so many heterogeneous and distinctive sources. The rhythmic scope of this study reminds us of 'Idle Chatter Junior', composed by Paul Lansky in 1999. In a conversation with Francis Dhomont on electroacoustic music, Lansky expresses his point of view on the sounds that surround us in everyday life: 'I like the sort of randomness... ...the arbitrary and strange qualities that you find, its almost like a kind of rhythm that you couldn't make up if you were trying to invent your own' (Aumüller, 2002). The key aspect of Study No. 2 is in fact, that rhythm is set by the varying playback algorithms offered within *3D-Composer*, implementing basic patterns such as forward, backward, forward-backward, random and graph theory. The interplay between these fundamentally different pattern configurations enhances the flow of the musical sequence. Without graph theoretical and geometric implications, the software would not provide the necessary edge for rhythmic and musical variety. For the purpose of this study, no alterations were made on the actual sounds in terms of dynamics or timbre, instead, the focus was on the progression of the rhythmic cells. It is worth noting that repetition, if eliminated on a note-by-note basis, would create a completely different musical effect. A simple algorithm to avoid repeated notes would result in a different listening experience, but the aim of this study is to illustrate how melodico-rhythmic contour evolves with different cycling patterns applied to a micro-composition.

4.1.3 Study No.3

Simple waveforms can be used to analyse the physical characteristics of sound. Sine tones are sometimes used to describe partials and their relative strength in a complex tone. It could be interesting to follow the movement of the nodes of a micro-composition by listening to the relative movement of simple waveforms generated by each node. In so doing, an irregular pattern was noticed, which was not easily detected by other means such as analysing the algorithm in the Python script, or by observing the transformations of the shapes in the viewing window of the software. A triangular waveform was used to generate a richer sound, in addition to test if the partials would create interesting spectral effects. Study No.3 starts with a rotation of a micro-composition. At time 0:40 minutes, a peculiar shift occurs in the structure of the sounds. Each waveform suddenly changes frequency according to a relocation of the respective nodes of the micro-composition. This phenomenon lasts until time 0:55 minutes, and reoccurs at 2:09 until 2:31 minutes. The rotation completes 360 degrees at 3:14 minutes. Interestingly, the first occurrence of the frequency shift is at about one quarter of the rotation. The second frequency shift appears at three-quarters of the full rotation which ends at 3:14 minutes. This implies that at approximately 90 and 270 degrees, when the micro-composition crosses the y-axis, the order of the nodes changes progressively as the nodes cross the vertical axis. This corresponds to a progressive retrograde shift in the micro-composition and occurs only twice as the rotation completes its full circle. At 3:21 an improvisation section further explores rotation angles and different micro-composition configurations with varying portamento effects, intentionally ending with a disguised cadence leading to a major triad. Besides evident structure changes, slight beating occurs only if the micro-composition is condensed within smaller intervals, which indicates that on a discrete twelve tone scale, spectral modulations are secondary when implementing this technique.

4.1.4 Study No.4

This reflective study is a choir/orchestral simulation exhibiting at times, cluster-like structures, and more conventional chord constructions representing the position of the micro-composition. A systematic 10 degree rotation was used every 8 seconds until the entire 360 degree circle was covered. Various angles could generate completely different chord progressions. Because of the rotations leading the micro-composition back to its original position, it creates a mirror-like canon in thirty-six even steps. The sound texture and formal elements of this study are reminiscent of Ligeti's *Atmosphères*, insofar as the various stationary sonic masses appear and disappear in a sequential manner. Orchestral coloration is limited in the case of a MIDI interpretation of course, but the structural chord progression yields an interesting creative potential. In this electroacoustic study, the micro-composition is based on the following notes *Ab-C-D-F-G-Bb*, which gradually transform in a similar manner to Table 3.5, until the last chord is reached at 350 degrees *G-Bb-C-Eb-G*. Intentionally, the rotation does not reach 360 degrees (equivalent to the original position at 0 degrees) in order to avoid a sense of resolution. The chords are spread out over a three octave range and in total there is an average of thirty simultaneous notes being played by the strings and choir. The last chord structure contains five notes instead of the original six due to the fact that when more than one node in the micro-composition has a similar value, the resulting MIDI output quantises the values within that chord and only different values are retained. Microtones would be possible only with MIDI pitchbend values mapped to various micro-intervals. This option would require a specific compositional framework. Theoretically, any micro-interval can be assigned with the type of transformations applied to micro-compositions, and could engender specific musical effects according to a scale chosen by the composer (and determined by the Python script with a different mapping).

4.1.5 Study No.5

In addition to determining melodico-rhythmic structures, micro-compositions can be used to simulate patterns created by the physical movements of a musician, or the components held by a musician such as mallets, a bow or other objects used for triggering sounds on an instrument. These motion patterns could be used to compose segments suited for a particular instrumentation. A 2, 3 and 4 node micro-composition moves within wider intervals simulating the movement of two hands sweeping across the four octave range of a marimba. In the second half of the study, sections were duplicated with the help of a sequencer to add extra voices. Rhythm was created by changing the speed at which the notes cycle through the micro-composition. Chords were triggered by the 'Chord' button in the graphic user interface of *3D-Composer*. All the rotations and notes derived from the micro-compositions were unaltered. No editing was performed on the resulting pitches or MIDI notes. Formally, the sections are distributed according to different micro-compositions, that is, a section consists of one micro-composition and several rotations performed on that micro-compositions. At time 2:50 a second voice is introduced after which a third voice joins in at time 3:18 and a fourth lower voice at 3:46 minutes. Noticeable fluctuations in the sequence timing occur as a result of the rotation calculations. None of the events were quantised to demonstrate the technical difficulty involved in manipulating micro-compositions in real-time.

4.1.6 Study No.6

Since electroacoustic techniques rely on technology and equipment, aesthetic outcomes are necessarily driven by the methods used (i.e. software/hardware tools). The sonic aspects of this study are determined by the virtual instruments and samplers offered in the Logic Pro 8 environment. A palette of industrial sound objects was selected to create an ambience of reconstruction and exploration, even including a siren, a symbolic link to the inclusion of non-traditional sound objects (such as *Ionisation* by Edgar Varèse), but located at a distance to evoke detachment yet symbolic association with the avant-garde spirit of what was then, modern times. The study introduces two main micro-compositions, which are implemented through the graph theory module of *3D-Composer* creating an irregular rhythmic structure of 11 beats which trigger various sound modules at varying playback speeds. There are four parts to the study, first is the presentation of the material; second is setting the rhythmic component of the micro-composition and transposing this material to different sounds. At 1:54 minutes the micro-composition is developed into a rhythmic counterpoint, broken by the siren at 2:40 minutes, which creates a bridge to the melodic progression in the third section, a melodic episode created with geometric rotations of a micro-composition. In the final section, the same musical progression is analogously reinterpreted with different sound objects creating a sense of harshness, demonstrating contrasting sonic possibilities for the same progression. The movement gradually reaches full stop and is punctuated by a sonic boom at a distance.

4.2 Electroacoustic composition: *Dada 2009*

Dada 2009 highlights several important aspects of the way in which 3D-Composer can be used to generate sonic and musical material. The main possibilities include thematic, melodico-rhythmic and timbral evolutions constituting the profile and structure of the composition. Some compositional techniques involve layering and superpositions of textures engendered by augmentation and reduction of intervallic ranges triggering sounds and melodic contours. This exposes the elastic properties of the micro-composition as the main algorithmic generator.

The title *Dada 2009* evokes a certain renewal character spawning the initial idea of exploring unknown musical and perceptual qualities by generating or triggering events within a purely Cartesian three dimensional space, veering away from the traditional notation system. This sound exploration is governed by the self-generating elements created by various parametric changes of the micro-compositions, the fixed set of nodes generating variable structures over time, thus creating a musical form intrinsic to these generative elements themselves. From these musical reiterations, more specifically the looping of the micro-compositions, a certain order and series of set patterns emerge. This musical gesture represents a sonic landscape of the current cultural world state, where organised sound is created from non-organised sonic material. In its initial state, a pure sound has no function, until it is placed in the context of time where the functions attached to these individual sonic entities foster a musical and even extra-musical meaning. Allegorically, it is similar to viewing objects through a lens, focussing on particular objects by adjusting the depth of field and giving the impression that an object stands out. This is accomplished by bringing out specific textures, timbres, melodies, harmonies and rhythms in the presentation of the sonic material.

The form consists of A-B-A, where A includes an introduction of the sonic textures and layers, B presents four different techniques, mainly parametric variations of sound synthesis elements, melodic movement, harmonic progressions and stratified sound textures. This leads to a re-exposition of the initial theme, which I intentionally do not call the main theme, referring to the idea of depth of field and interchanging of foreground and background, and similarly, referring to the elasticity of melodic and textural scale; translation-rotation.

In terms of the process to achieve the work, a special set-up was designed for the Jazzmutant Lemur multi-touch control surface to affect several parameters simultaneously within the 3D-Composer environment (see Appendix F). The use of a two co-ordinate mouse as a user input was not sufficient to control the various aspects of the micro-composition. In particular, many of the more interesting musical effects are created by adjusting the playback speed, rotation angle, note length, pitch range and centre of rotation simultaneously. This is only achievable with access to several parameters at once such as with a multi-touch controller. This multi-parametric control surface in conjunction with 3D-Composer allowed effective generation of MIDI data through Core MIDI, and it was therefore possible to record the output into Apple's Logic Pro sequencer. The arrangement within Logic was set up to enable recording the MIDI events and save them as separate musical gestures on various tracks with different instruments assigned to them. For the purpose of this piece the following sounds were used: five instances of the Sculpture physical modelling synthesiser, two instances of the Ensemble Synthesiser ES1, five instances of the Ensemble Synthesiser ES2, two ESX Samplers, and a source of white noise. The white noise is triggered through a gate, activated by recurring note attacks from a rotating micro-composition to add a rhythmic dimension. The layers of instruments interact in two ways, thus creating polyphonic structures. The first treatment is the formation of texture through interweaving of the notes, similar to statistically generated data but with a geometric structure filtering some pitch material to extract a shape or form from the scattered data. The second treatment is the superimposition of micro-composition rotations and translations to create a relationship between the order of the notes played back. The resulting polyphonic elements create what could be labelled a geometric mode, organising both pitch and rhythmic material based on the interaction between different rotation speeds and angular positions.

4.3 System requirements

Instructions to open *3D-Composer* are included on CD No.1. Additional instructions to operate the software are found in Appendix E.

Minimal computer system requirements are as follows:

- Mac PPC G4 or G5 processor, or Intel´ processor
- Mac OS X version 10.3.9 or later (10.4 Recommended)
- 256 MB of System Memory RAM (512 MB recommended)
- 175 MB of available hard disk space
- 1024 x 768 screen resolution (1440 x 900 recommended)

3D-Composer was saved as a Max/MSP Application which incorporates MaxPlay Runtime 4.6. No installation of Max/MSP is necessary for the Application to run. All the required third party Max/MSP externals are included as well, such as the *pyext* external.

Python 2.5 must be installed to run *3D-Composer*, because the Application relies on specific Python modules which are only available for Python 2.5. If you do not have Python 2.5 installed on a computer, the MacPython 2.5 installation package is provided on CD No.1. The Python script called by the external object *pyext* within Max/MSP requires the following modules installed on the user's computer:

- numpy
- networkx
- sys
- random
- math
- colorsys

Only *numpy* and *networkx* modules need to be installed separately as they are not included in the basic Python installation. All other required modules are included (*sys, random, math, colorsys*) in the pre-installed version of Python. Instructions are provided to install additional modules, and a package is provided on CD No.1 to install all the necessary components automatically.

Depending on the computer system configuration, the efficiency and speed of the transformations being performed on the micro-compositions will be variable. This is caused by the large amount of calculations needed for the rotation of the matrices containing the coordinates of all the elements of the micro-composition. the complexity of the calculations is proportional to the number of nodes contained by the micro-composition. Table 4.3 lists the amount of central processing unit (CPU) required to display, and then rotate the micro-compositions. The 'Process' name indicates the micro-composition and the number of nodes, 'mc4' would therefore describe a micro-composition with four nodes. There are three states for this test. First, the display without any transformations. Second, a rotation performed by the user with the help of the rotation knob on the graphic user interface. Third, there is one instance of the auto-rotate function, to demonstrate how automated tasks take much of the CPU. Further study is required to determine if the CPU will be affected by: either a more powerful computer system, or a better algorithm to simulate the rotation of the micro-composition.

The test was performed on an Apple 2.16 GHz Intel Core Duo with 1GB SDRAM. Figure 4.1 shows the relationship between the number of nodes and the percentage of CPU required for transformations applied to a micro-composition. It is clear from this figure, that the processing required to transform micro-compositions increases with the complexity of the micro-composition.

TABLE 4.1: Computer processing for micro-compositions in Max/MSP/Jitter.

Process	CPU (%)	Threads	Real memory (MB)	Virtual Memory (MB)
open Max/MSP/Jitter	11.80	19	39.99	823.46
open3-DC	20.00	25	86.77	918.15
mc1	25.00	26	103.32	930.18
mc1 rot	32.90	26	104.21	929.43
mc2	26.20	26	103.33	930.18
mc2 rot	35.20	26	103.97	929.43
mc3	28.00	26	103.35	930.18
mc3 rot	37.90	26	103.68	929.43
mc4	30.50	26	103.37	930.18
mc4 rot	41.40	26	103.49	930.43
mc5	33.70	26	103.52	930.43
mc5 rot	50.10	26	103.66	930.43
mc6	35.00	26	104.18	929.43
mc6 rot	59.90	26	104.55	929.43
mc7	37.40	26	104.61	929.43
mc7 rot	63.20	26	105.43	930.71
mc8	39.30	26	104.84	929.43
mc8 rot	65.40	26	105.29	930.71
mc8 autorot	104.30	26	136.49	959.37

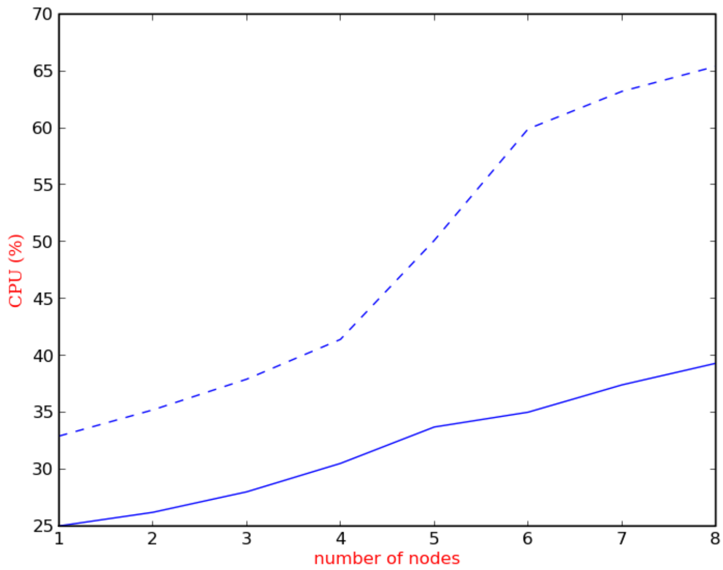


FIGURE 4.1: Processing a micro-composition in Max/MSP/Jitter.

CHAPTER 5

Conclusion

5.1 Future directions

This work represents only a few steps in the vast field of music visualisation and conceptualisation. Many more models will emerge to generate content and analyse musical structures, and much needs to be done in order to improve the proposed representation paradigm for a more integral use in composition. Here are some aspects of the current system which could be enhanced:

- This project only deals with discrete entities represented by MIDI values to generate evolving motivic structures. A direct application of this process to both acoustic and sound parameters could open new avenues in sound synthesis.

- Associating gestural control with every dimension of the micro-composition algorithm would enable interactive real-time performance situations.

- Adding a structured rhythmic dimension to micro-composition would diversify compositional use.

- Although the system works in real-time for individualised micro-compositions, a simulation of several micro-compositions interacting with one another would be useful to create polyphonic works.

- Associating individual nodes to sonic events would allow diffusion over a multi-channel loudspeaker set up.

- Analysing perceptual associations while transforming micro-compositions could help us understand creative activity from a cognitive perspective, and such a musical model can be a source for investigations into a mathematical theory of the phenomenology of the mind.

5.2 Concluding remarks

During the elaboration of this thesis I have demonstrated how a personal compositional approach could open interesting avenues towards unexplored musical territory through the application of concepts from other areas of study. As a starting point, the formalisation process was strongly influenced by early ideas of the avant-garde period. Certain fundamental questions revealed strategies for solving problems of musical order rather than strictly compositional ones. In particular, a scheme to function in the realm of computer-assisted-composition was established. The main elements characterising computer music systems as a manifestation of musical activity were delineated by : innovation, representation and communication. As a result, a software application was developed to transform visual representations of motivic elements to generate music in real-time. This technique enabled to establish a symbolic link between geometric and musical elements.

A definition of micro-composition was proposed and aspects of geometry were implemented in a three dimensional coordinate space. The visual representation of musical elements in Euclidean space has enabled a more accurate rendering of the original musical intent in a non-arbitrary way. At first, this was very difficult to implement due to limited graphical rendering capabilities. However, with the increased computational efficiency and programming techniques involved, it was possible to represent sophisticated musical structures in a three dimensional virtual environment. This could eventually lead to visualisation and transformation of multiple micro-compositions to generate polyphonic structures in three dimensions, and engender a new framework for compositional activity.

The technical challenges associated with innovation may sometimes exceed the capacity to produce integrated compositional systems, enabling several techniques to be combined within the same technological framework. Exploring the boundaries of creativity in a defined context may establish grounds for a more adaptable and ubiquitous solution to deal with complexity in the conceptual realm.

The respective roles of the composer and electronic music practitioner are essential for the development of a methodology aimed at furthering digital artistic expression. Interactions between composers and technology remain important aspects for the ramification of compositional techniques. As a result, it can be stated that beside the actual technology, it is the evolution rate of technology which has an unprecedented influence on the exploration of musical ideas. This project epitomises an original compositional and multimediatic approach within a dynamic creative context, reliant on a quickly evolving technological framework. *3D-Composer* exemplifies the extensibility of Max/MSP/Jitter, integrating lower-level object oriented programming environments such as Python and its related modules. Many other systems may be used to accomplish the same task, but Max/MSP/Jitter graphical programming environment provided efficient solutions for designing the graphical user interface and dealing with technicalities such as MIDI.

In addition to defining and analysing the role of a composer, this project required learning new programming skills, structuring formal aspects of an idiosyncratic compositional system suggestive of some new paths toward future musical developments. *Six Electroacoustic Studies* were derived from the use of *3D-Composer* software to illustrate different musical aspects of micro-composition. One question comes to mind when describing the intricacy and complexity involved to represent simple notes in three dimensions: why go to the extent of adding variables to represent such a trivial concept? I here argue that if traditional musical notation engenders a complex array of syntactical information, finding models to visualise musical phenomena in real-time from a conceptual and creative perspective could help composers organise musical information with other means than conventional timelines, piano-rolls, sequencers and staves found in the current computer-based composer's toolbox. This is therefore an attempt to create the 'spirit of the time' and enhance the creative experience while exploring new musical territory.

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APPENDIX A

A.1 Python script for 3D rotation of micro-composition

```
##########################################################################
# Geomatrix - python script for py/pyext object in MaxMSP
# Copyright (c) 2006-2007 Ivan Zavada i.zavada@usyd.edu.au
# For information on usage and redistribution, and for a DISCLAIMER OF ALL
# WARRANTIES, see the file, "license.txt," in the py/pyext distribution.
###########################################################################

try:
    import pyext
except:
    print "ERROR: This script must be loaded by the PD/Max pyext external"

from numpy import *
from networkx import *
import sys,random
import math, colorsys

#################################################################

#mydescriptor = [('ind', int8), ('x', float32), ('y', float32), ('z', float32)]

th_x=0.0
th_y=0.0
th_z=0.0
H=0.0
L=0.6
S=0.7
```

```
class ex1(pyext._class):

  """This class receives coordinates and rotates vertices around main axes"""

  # number of inlets and outlets
  _inlets=5
  _outlets=4

  # constructor
  def __init__(self):
      self.num_count = 4
      self.a = zeros((self.num_count,4),float32)
      #self.a = delete(self.a,self.a[0],axis=0)
      self.c = zeros((1,4),float32)
      self.c = delete(self.c,self.c[0],axis=0)
      self.d = zeros((self.num_count,4),float32)
      #self.d = delete(self.d,self.d[0],axis=0)
      self.counter = 0
      self.reset = 1
      self.cam = array([0,0,-1])
      self.origin = array([[0,0,0,0]])
      self.note = 0
      self.dir = 0
      self.ramp = 1
      self.rotate = 0
      self.transpose = 0.0
      if self.num_count >= 3: # condition for graph by Kuratowski's criterion
          self.edges = 3*self.num_count - 6
      else:
          self.edges=self.num_count
      self.G=networkx.gnm_random_graph(self.num_count,self.edges)

  # methods for inlets

  #method for inlet 1: setting matrix dimension;
  #input coordinates;recall matrix
  def int_1(self, f):
      self.num_count = f
      print "The matrix has dimension: ",f
      if self.num_count >= 3: # condition for graph by Kuratowski's criterion
```

```
        self.edges = 3*self.num_count - 6
    else:
        self.edges=self.num_count
    self.G=networkx.gnm_random_graph(self.num_count,self.edges)

def reset_1(self):
    self.reset = 1
    print self.reset
    self.counter = 0
    self.a = zeros((1,4),float32)
    self.a = delete(self.a,self.a[0],axis=0)

def bang_1(self):
    self._outlet(3,'clear')
    for i in range(self.num_count):
        mylist = self.c[i,1:]
        self._outlet(1,mylist)

def list_1(self, *s):
    if self.reset ==1:
        if self.counter < self.num_count:
            print "List",s,"into first inlet"
            b = append(self.a,[[self.counter, s[0], s[1], s[2]]], axis = 0)
            print b
            self.c = b
            self.a = b
            self.counter += 1
            print self.counter

        else:
            print 'the matrix is full'
            self.reset = 0

#method for inlet 2: setting rotation matrix and output results
def bang_2(self):
    self._outlet(3,'clear')
    self.d=add(self.d,self.origin)
    for i in range(self.num_count):
      mylist = self.d[i,1:]
      self._outlet(1,mylist)
      #configure for OpenGL
      if i == 0:
```

```
            gl_list='moveto %.3f %.3f %.3f' % (self.d[i,1],self.d[i,2],self.d[i,3])
            #gl_list=filter(lambda c: c not in "[]", str(gl_list))
            self._outlet(2,gl_list)

            H = ((self.d[i,2] * 0.2 + .5)*127.)%12/12.
            RGB=colorsys.hls_to_rgb(H,L,S)
            gl_colour='glcolor %s %s %s, sphere 0.05, bang' % (RGB[0],RGB[1],RGB[2])
            gl_colour=filter(lambda c: c not in "()", str(gl_colour))
            self._outlet(2,gl_colour)

          else:

            gl_list='lineto %.3f %.3f %.3f' % (self.d[i,1],self.d[i,2],self.d[i,3])
            #gl_list=filter(lambda c: c not in "[]", str(gl_list))
            self._outlet(2,gl_list)

            H = ((self.d[i,2] * 0.2 + .5)*127.)%12/12.
            RGB=colorsys.hls_to_rgb(H,L,S)
            gl_colour='glcolor %s %s %s, sphere 0.05, bang' % (RGB[0],RGB[1],RGB[2])
            gl_colour=filter(lambda c: c not in "()", str(gl_colour))
            self._outlet(2,gl_colour)

    def int_2(self, i):
        self.transpose = 5*i/127.

    def list_2(self,*s): #rotation coordinates
        self.counter = 0
        self.d = zeros((1,4),float32)
        self.d = delete(self.d,self.d[0],axis=0)
        th_x=s[0]*pi/180.
        th_y=s[1]*pi/180.
        th_z=s[2]*pi/180.
        matX = array([[1,0,0],[0,cos(-th_x),sin(-th_x)],[0,-sin(-th_x),cos(-th_x)]])
        matY = array([[cos(-th_y),0,sin(-th_y)],[0,1,0],[sin(-th_y),0,cos(-th_y)]])
        matZ = array([[cos(-th_z),sin(-th_z),0],[-sin(-th_z),cos(-th_z),0],[0,0,1]])

        direction=dot(matX,matY)
        direction=dot(direction,matZ)

        while self.counter < (self.num_count):
            relative_dir=subtract(self.a[self.counter,1:],self.cam[0])
            direction2=dot(direction,relative_dir)
```

```
        d = append(self.d,[[self.counter, direction2[0], \
            direction2[1]+self.transpose, direction2[2]]], axis = 0)
        self.counter +=1
        self.d = d

    self.rotate = 1

#method for inlet 3: adding notes mapped into matrix
def int_3(self,i):

    if self.reset ==1:
        if self.counter < (self.num_count):
            x_coord=self.counter*0.2
            b = append(self.a,[[self.counter, x_coord, \
                5*(i/127.-0.5), 0.]], axis = 0)
            print b
            self.c = b
            self.a = b
            self.counter += 1
            print self.counter

        else:
            print 'the matrix is full'
            self.reset = 0

def list_3(self,*s):
    index=int(s[0]/0.08)
    self.a[index,2]=s[1]*1.6
    self.d = self.a

def random_3(self):
    octv=60
    self.counter = 0
    self.a = zeros((1,4),float32)
    self.a = delete(self.a,self.a[0],axis=0)

    while self.counter < self.num_count:
        x_coord=self.counter*0.2
        b = append(self.a,[[self.counter, x_coord, \
            5*(((random.randint(0,23)+octv)/127.)-0.5), 0.]], axis = 0)
        print b
        self.c = b
```

```
            self.a = b
            self.counter += 1
            print self.counter

        print 'the matrix is full'

    #method for inlet 4: choosing playback order
    def bang_4(self):

        if self.rotate == 0:
            #e=add(self.a,self.origin)
            e=self.a
            e=sorted(e,key=lambda x:x[1])
            e=concatenate(e[0:],axis=0)
            e=e.reshape(self.num_count,4)

            noteout=e[self.note,2]
            noteout = (noteout/5.+0.5)*127
            self._outlet(4,noteout)
        else:
            #e=add(self.d,self.origin)
            e=self.d
            e=sorted(e,key=lambda x:x[1])
            e=concatenate(e[0:],axis=0)
            e=e.reshape(self.num_count,4)

            noteout=e[self.note,2]
            print 'noteout',noteout
            noteout = (noteout/5.+0.5)*127
            self._outlet(4,noteout)

        if self.dir == 0: #up

            if self.note < (self.num_count-1):
                    self.note += 1
            else:
                    self.note=0

        elif self.dir == 1: #down

            if self.note <= 0:
                    self.note=self.num_count-1
```

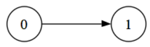
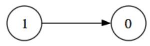
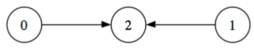
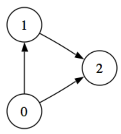
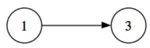
```
        else:
                self.note += -1

    elif self.dir == 2: #updown
        self.note += self.ramp
        if self.note >= (self.num_count-1):
                self.ramp=-1
        elif self.note <= 0:
                self.ramp=1

    elif self.dir == 3: #random
        self.note=random.randint(0,self.num_count-1)

    elif self.dir == 4: #graph
        #G=networkx.gnm_random_graph(self.num_count,self.edges)
        graph=self.G.edges()
        print graph
        graph=filter(lambda c: c not in "[],()", str(graph))
        graph = str(graph).split()
        print 'GRAPH', graph

        if self.counter < (self.edges*2-1):
                self.note = int(graph[self.counter])
                print 'note',self.note

                print 'counter',self.counter
        else:
                self.counter = 0
                self.note = int(graph[self.counter])
        self.counter += 1

def up_4(self):
    self.dir=0
    self.note=0
    print 'direction: UP'

def down_4(self):
    self.dir=1
    self.note=self.num_count-1
    print 'direction: DOWN'

def updown_4(self):
```

```
        self.dir=2
        self.note=0
        print 'direction: UP-DOWN'

    def random_4(self):
        self.dir=3
        self.note=0
        print 'direction: RANDOM'

    def graph_4(self):
        self.dir=4
        self.note=0
        self.counter=0
        print 'direction: GRAPH'

    def newgraph_4(self):
        self.G=networkx.gnm_random_graph(self.num_count,self.edges)

    def edges_4(self,f):
        self.edges=f

    #method for inlet 5: camera position in OpenGL environment
    def list_5(self,*s):
        if s[0] ==0:
            self.origin = array([[0,s[1]*1.6,s[2]*1.6,0]])
            self.t=add(self.a,self.origin)
            print self.t
            print self.origin
        if s[0] ==1:
            self.cam = array([s[1],s[2],s[3]])
    def bang_5(self):
        self.a=self.t
        self.origin = array([[0,0,0,0]])

##################################################################EOF
```

APPENDIX B

B.1 Listing of possible configurations for selected directed graphs.

Table B.1: Listing of possible configurations for selected directed graphs.

Order	Vertices	Edges	Graph
1	V=0	E=nil	empty graph
2	V=0, 1	E=(0, 1)	
2	V=0, 1	E=(0, 1)	
3	V=0, 1, 2	E=(0, 2)	
3	V=0, 1, 2	E=(0, 2), (1, 2)	
3	V=0, 1, 2	E=(0, 1), (0, 2), (1, 2)	
4	V=0, 1, 2, 3	E=(1, 3)	

Continued on Next Page...

Table B.1 – Continued

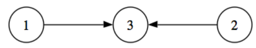
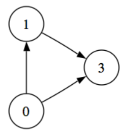
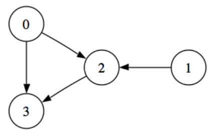
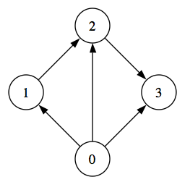
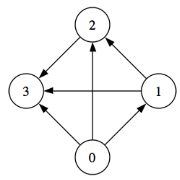
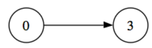
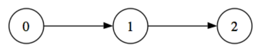
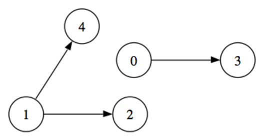
Order	**Vertices**	**Edges**	**Graph**
4	V=0, 1, 2, 3	E=(1, 3), (2, 3)	
4	V=0, 1, 2, 3	E=(0, 1), (0, 3), (1, 3)	
4	V=0, 1, 2, 3	E=(0, 2), (0, 3), (1, 2), (2, 3)	
4	V=0, 1, 2, 3	E=(0, 1), (0, 2), (0, 3), (1, 2), (2, 3)	
4	V=0, 1, 2, 3	E=(0, 1), (0, 2), (0, 3), (1, 2), (1, 3), (2, 3)	
5	V=0, 1, 2, 3, 4	E=(0, 3)	
5	V=0, 1, 2, 3, 4	E=(0, 1), (1, 2)	
5	V=0, 1, 2, 3, 4	E=(1, 2), (1, 4), (0, 3)	

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Table B.1 – Continued

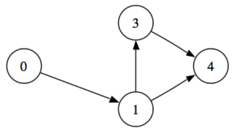
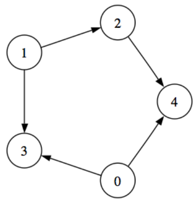
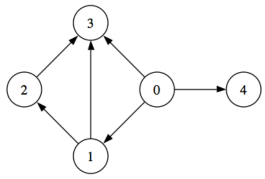
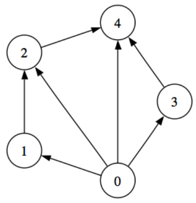
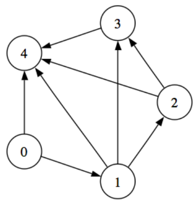
Order	Vertices	Edges	Graph
5	V=0, 1, 2, 3, 4	E=(0, 1), (1, 3), (1, 4), (3, 4)	
5	V=0, 1, 2, 3, 4	E=(0, 3), (0, 4), (1, 2), (1, 3), (2, 4)	
5	V=0, 1, 2, 3, 4	E=(0, 1), (0, 3), (0, 4), (1, 2), (1, 3), (2, 3)	
5	V=0, 1, 2, 3, 4	E=(0, 1), (0, 2), (0, 3), (0, 4), (1, 2), (2, 4), (3, 4)	
5	V=0, 1, 2, 3, 4	E=(0, 1), (0, 4), (1, 2), (1, 3), (1, 4), (2, 3), (2, 4), (3, 4)	

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Table B.1 – Continued

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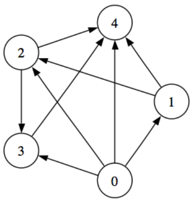
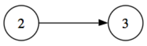
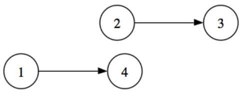
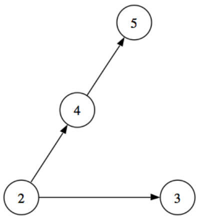
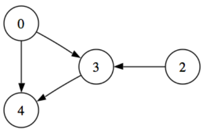
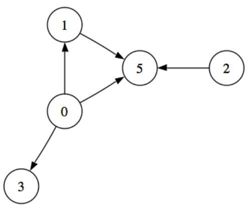
5	V=0, 1, 2, 3, 4	E=(0, 1), (0, 2), (0, 3), (0, 4), (1, 2), (1, 4), (2, 3), (2, 4), (3, 4)	
6	V=0, 1, 2, 3, 4, 5	E=(2, 3)	
6	V=0, 1, 2, 3, 4, 5	E=(1, 4), (2, 3)	
6	V=0, 1, 2, 3, 4, 5	E=(2, 4), (4, 5), (2, 3)	
6	V=0, 1, 2, 3, 4, 5	E=(0, 3), (0, 4), (2, 3), (3, 4)	
6	V=0, 1, 2, 3, 4, 5	E=(0, 1), (0, 3), (0, 5), (1, 5), (2, 5)	

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Table B.1 – Continued

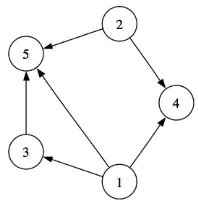
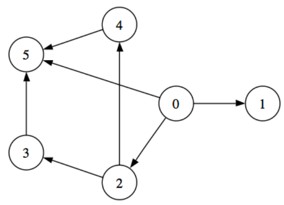
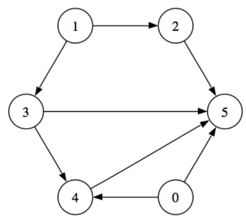
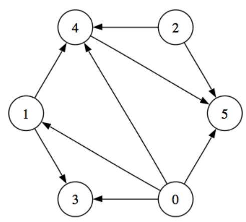
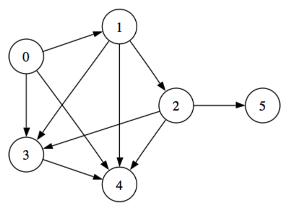
Order	Vertices	Edges	Graph
6	V=0, 1, 2, 3, 4, 5	E=(1, 3), (1, 4), (1, 5), (2, 4), (2, 5), (3, 5)	
6	V=0, 1, 2, 3, 4, 5	E=(0, 1), (0, 2), (0, 5), (2, 3), (2, 4), (3, 5), (4, 5)	
6	V=0, 1, 2, 3, 4, 5	E=(0, 4), (0, 5), (1, 2), (1, 3), (2, 5), (3, 4), (3, 5), (4, 5)	
6	V=0, 1, 2, 3, 4, 5	E=(0, 1), (0, 3), (0, 4), (0, 5), (1, 3), (1, 4), (2, 4), (2, 5), (4, 5)	
6	V=0, 1, 2, 3, 4, 5	E=(0, 1), (0, 3), (0, 4), (1, 2), (1, 3), (1, 4), (2, 3), (2, 4), (2, 5), (3, 4)	

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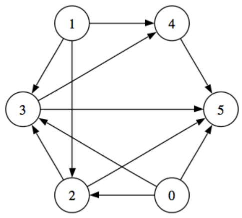
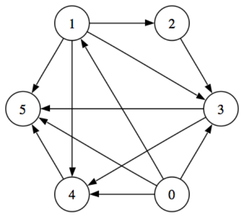
Table B.1 – Continued

Order	Vertices	Edges	Graph
6	V=0, 1, 2, 3, 4, 5	E=(0, 2), (0, 3), (0, 5), (1, 2), (1, 3), (1, 4), (2, 3), (2, 5), (3, 4), (3, 5), (4, 5)	
6	V=0, 1, 2, 3, 4, 5	E=(0, 1), (0, 3), (0, 4), (0, 5), (1, 2), (1, 3), (1, 4), (1, 5), (2, 3), (3, 4), (3, 5), (4, 5)	

APPENDIX C

C.1 A topography of the interdisciplinary nature of music technology.

Music Technology

A topography of the interdisciplinary nature of music technology...

Technology definition: the application of scientific knowledge for practical purposes (Oxford)
from Greek: *techne* - technique of bringing something forth, creating

Music - some definitions

1. language of sounds which permits the musician to express himself (Larousse Encl. 1975)
2. form of art 'Tonkunst' (Wiesbaden 1971)
3. art form based on the ordering of sound phenomena (Grote Winkler Prins Encl. 1971)
4. the temporal organisation of sounds
5. is an art, entertainment, or other human activity which involves organized and audible sound (Wiki)
6. structured sound events preformed by a musician or singer

PHYSICAL PHENOMENA (above)

PERCEPTION external physical phenomena which is interpreted by humans

SOCIAL CONTEXT subjective listening experience of an acoustic phenomena, governed by a social and cultural context

PHILOSOPHICAL VALUE platonic experience which is not governed by physical laws or psychoacoustic properties

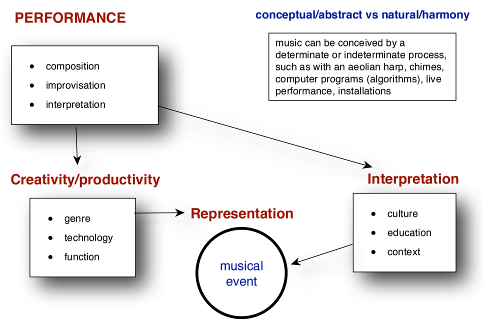
TRADITION vs INNOVATION

John Cage: "There is no noise, only sound" *1952*

Jean-Jacques Nattiez: "The border between music and noise is always culturally defined--which implies that, even within a single society, this border does not always pass through the same place; in short, there is rarely a consensus.... " *1990*

Edgar Varèse: "I long for instruments obedient to my thought and whim, with their contribution of a whole new world of unsuspected sounds, which will lend themselves to the exigencies of my inner rhythm." *1917*

Luigi Russolo: "Nowadays musical art aims at the shrillest, strangest and most dissonant amalgams of sound. Thus we are approaching noise-sound. The revolution of music is paralleled by the increasing proliferation of machinery sharing in human labour... Our ears, far from satisfied, keep asking for bigger acoustic sensations...." *The Art of Noise - Manifesto 1913*



conceptual/abstract vs natural/harmony

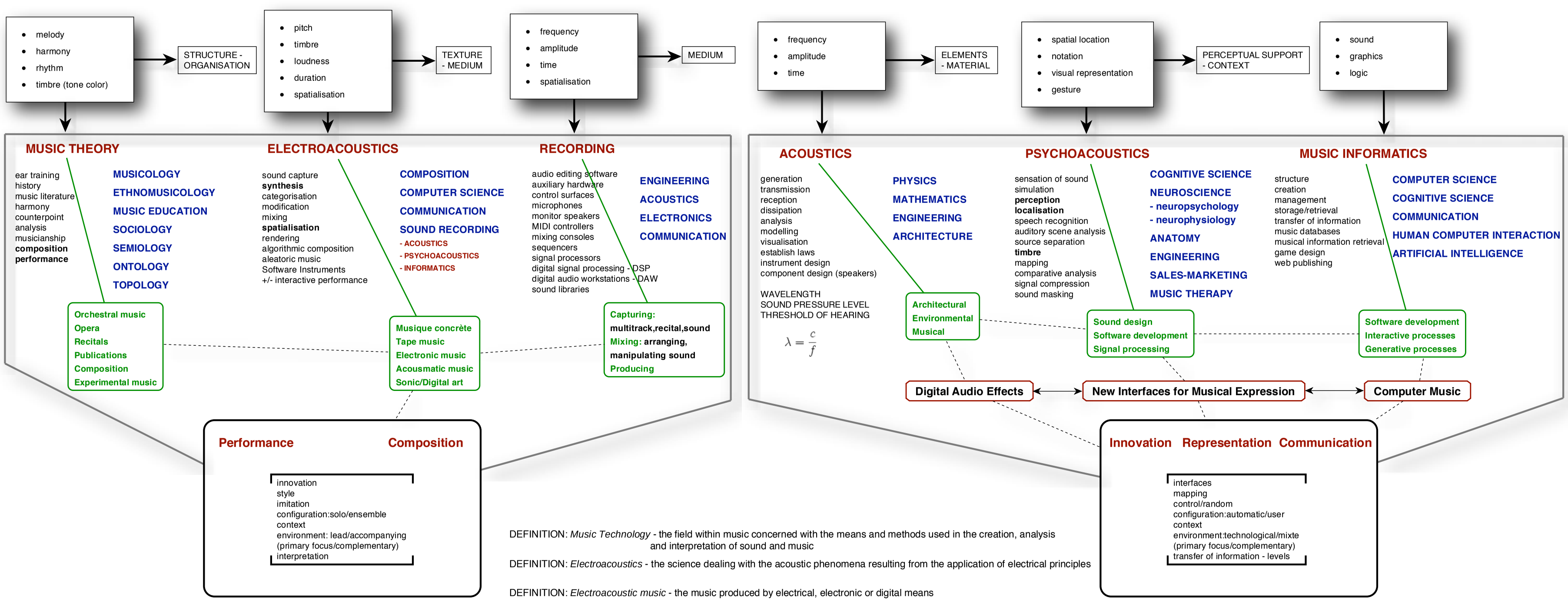
music can be conceived by a determinate or indeterminate process, such as with an aeolian harp, chimes, computer programs (algorithms), live performance, installations

MEDIUM

- live performance
- radio, television, internet, games
- recording
- film,video
- mobile communication

COMMUNICATION
creating, analysing, sharing and transforming musical information

ASPECTS OF MUSIC



DEFINITION: *Music Technology* - the field within music concerned with the means and methods used in the creation, analysis and interpretation of sound and music

DEFINITION: *Electroacoustics* - the science dealing with the acoustic phenomena resulting from the application of electrical principles

DEFINITION: *Electroacoustic music* - the music produced by electrical, electronic or digital means

APPENDIX D

D.1 Development of electronic music in Ukraine: emergence of a research methodology

Development of electronic music in Ukraine: emergence of a research methodology

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In this article the authors will present an overview of the current situation in Ukraine, with regards to the question of analytical terminology applied to new methods of creation in electronic music composition. The article will establish the differences and the similarities between the analyses of instrumental and electronic music structures, while considering the role of technology in the creation of new electronic music works. This paper will also establish a link between the origin of current analytical processes and electronic music practice in Ukraine, taking into account the function of a given terminology and its characteristic elements relating to a local geographical and cultural context. We will underline the importance of integrating new music forms in academic circles and discuss external influences in the development of new musical systems. This will be demonstrated by exposing selected musical materials, which can be considered representative of the creative and theoretical processes found in the field of electronic music in Ukraine.

1. INTRODUCTION

Electronic music locates itself in a very specific area of contemporary music systems in terms of the function and nature of the creative process. On the one hand, its appearance in music history is a direct and logical consequence of the development of twentieth-century avant-garde movements, and to some extent embodies the combined experiences of contemporary music thinking.

On the other hand, from its inception in the twentieth century, electronic music operated within different parametric structures and acoustic materials, within a redefined artistic model – the world of synthesis, relying on new aesthetic realities derived from the integration of technology in the process of creating experimental art music. Electronic music usually evolved '*ad marginum*', outside conventional contexts and has found itself at the crossroads of two different artistic philosophies, mainly, contemporary academic art music as an extension to more traditional compositional approaches, and synthesised media art forms mostly reliant on technology and non-conventional use of source materials. Electronic music has thus progressively become an independent sphere of musical activity, where the constant transformation of the methods used to compose such music has created the need to reflect upon, question and redefine the fundamental notions of music theory and practice. These notions include aspects of musical production, performance, analysis and perception.

A number of questions arise when attempting to characterise the underlying structures of a formal school of thought in a locally defined geographic, political, cultural and social context. How do the formal structures of 'electronic music schools' emerge? Which genres and stylistic preferences take precedence within these structures? How is the knowledge of previous electronic music pioneers integrated and assimilated – how is electronic music culture valued and regarded in academic music environments? What are the overall influences of the electronic music period on music studies in general and, more specifically, music analysis methods? We will try to establish a link between these questions with a brief comparative overview of selected musical works from the repertoire of algorithmic and electronic music in Ukraine.

1.1. Context

The eclectic nature of electronic music has conditioned the area of analytical research where, in particular, conventional music analysis coexists with a wide range of disciplines such as computer music, musical acoustics, psychoacoustics, cognitive psychology and music sociology. Naturally, most theoretical works in the field of electronic music are concerned with technical aspects of the creative work (modification and implementation of various synthesis techniques, theory of algorithmic composition, sound spatialisation and localisation, integration of virtual instruments, etc. …), but theoretical notions about the process of creating and the aesthetics of electronic music remain relatively incipient.

In the larger scale of music history, the current 'electronic music period' occupies a relatively small portion of time; however, this small timeframe is not representational of the florescence and significance of electronic music innovations. Notably, early electronic music experiments in Russia coincided with a period of

Organised Sound **12**(2): 153–166 © 2007 Cambridge University Press. Printed in the United Kingdom. doi: 10.1017/S1355771807001811

experimentation with electricity and noise elsewhere in Europe and North America, and it is therefore possible to retrace the early stages of experimentation with non-conventional instruments back to the first uses of a new '*instrumentarium*' derived from non-musical applications at odds with traditional artistic intents. The creation of instruments relying on a different paradigm of sound production (electricity and magnetism) has had a great influence on the conceptualisation of new methods of musical creation. From this perspective, Eastern European countries have also joined the quest for compositional innovation, but with various levels of adaptation and implementation. In some cases, research was even conducted independently of the limitations imposed by existing institutional frameworks. This has unavoidably caused a considerable time-shift in the adaptation of new techniques for the creation of electronic music works.

Analysis methods have therefore integrated new types of musical thinking and the ensuing need for substantial new musical creations supported by larger educational and cultural bodies. Is the assimilation of new independent research methods possible in the larger scope of music theory? Regardless of the globalisation process currently in motion, electronic music today contains distinct identifiable qualities inherited from the geographic context, which exhibit national characteristics influenced by the historical context, stylistic and cultural elements offering a wide palette of aesthetic genres from within. More specifically, electronic music represents an independent sphere within the larger scope of contemporary music, and has its own *raison d'être* in a defined cultural environment.

1.2. Historical overview of the development of electronic music in Ukraine

The development process of electronic music lacked homogeneity and sometimes one could even qualify the situation as being somewhat dramatic because of the marginal circumstances in which it appeared. Nevertheless, there was always a strong will to increase the local knowledgebase.

To various degrees, the musical repertoire was always acclimatised to conceptual influences from the west. This gradually led to the popularisation of new technologies (MIDI synthesizers, computers and such), which had tremendous implications in algorithmic music of the 1960–1970s and experimental music of the 1980–1990s. However, it is indisputable that these conceptual adjustments were difficult to implement in a context strongly anchored in tradition within a hierarchical socio-cultural and political system. Here, the role of electronic music was very important because it integrated a neutral element in the compositional equation – technology, which contains inherent knowledge about the universal properties of sound.

During this adaptation process, one can establish certain historical phases, correlated to the overall cultural situation in the country, either weakened or possibly strengthened by ideological tensions caused by changes in political climate, and nourished by global trends of information dissemination. Let us propose some historical phases in the development of electronic music in Ukraine.

1.2.1. Emergence of 'musique concrète' and algorithmic composition – the 1960s

At the dawn of political change in soviet society during the democratisation era (1956–1965) when Khrushchev came to power in USSR, Ukrainian composers were actively engaged with the discovery of post-war musical avant-garde. To a certain extent, this was enabled by the Warsaw Spring Festival, which occurred in 1956, in the neighbouring socialist Poland. The music of Varese, Webern, Boulez and Xenakis exposed new ideas to Ukrainian composers, which subsequently led to the formation of groups dedicating their efforts to elaborate new compositional techniques. The main forerunners were Leonid Hrabovsky (b. 1935), Valentyn Sylvestrov (b. 1937), Vitaly Godziatsky (b. 1936) and Volodymyr Zahorcev (b. 1944). In its contrasting opposition to ideological aesthetics of 'socialist realism', any electronic music movement would be far from official government or institutional support. The sporadic attempts of integrating new techniques relying on non-conventional systems of artistic creativity were only possible for composers working in film, radio and recording studios.

In 1964–1965, Vitaly Godziatsky created the work *4 Scherzi domestiki* which is mainly based on the common sounds of everyday life. This was the first composed work in the style of '*musique concrète*' in Ukraine. At the same time, the composer Leonid Hrabovsky actively worked on his own compositional method of algorithmic composition, in collaboration with scientists from the Ukrainian Cybernetic Institute, which resulted in the creation of new works such as *Homeomorphie I–III* for piano (No. 3 for two pianos) in 1968–1969; *Ornaments* (for oboe, viola and harp or guitar) in 1969; and *Concerto Misterioso* for nine instruments (flute, clarinet, bassoon, antique cymbals, harpsichord, harp, violin, viola, cello) in 1977.

1.2.2. Presence of electronic instruments in non-academic environments – the 1970–1980s

Whereas alternative musical approaches were not recognised by official academic music institutions, electronic musical instruments gained much respect among independent composers' circles. An extraordinary palette of sounds created with new technological means made its presence in film music, new genres of popular and improvisational music. The nature and complexity of the subjects treated in films offered a new setting to integrate previously unexplored sonic textures. Ukrainian composers had many opportunities to join their counterparts in Moscow for important studio projects. This allowed direct access to the latest hardware developments and a well-established methodology based on a long musical tradition.

One such example was access to the ANS synthesizer, a photoelectronic musical instrument created by Russian engineer Evgeny Murzin in the years 1938 to 1951. The ANS synthesizer produced photo-optic sound recordings by obtaining a visible image of a waveform, and conversely synthesising sounds from optically drawn images. The first electronic music studio in the USSR was established on the basis of this instrument, and from 1967 onwards it was located at the Scriabin Museum in Moscow. Access to such advanced technology considerably changed the attitude toward the development of new sound production processes. Edward Artemiev, a pioneer of Russian electronic music, is best known for having composed soundtracks for Tarkovsky, Mikhalkov and Konchalovsky, and his influence was felt during the numerous collaborations in studios, particularly related to the use of the ANS synthesizer.

During this time, Ihor Steciuk, then a young composer, was actively engaged in learning sound synthesis techniques and was increasingly using synthesizers in his music. He was among many Ukrainian musicians interested in this new form of musical expression and had been influenced by Artemiev's ideas. Steciuk is currently docent at the department of Music Informatics and Technology of the National Academy of Music in Kyiv.

Improvisational music based on electronic synthesis and modulation techniques was another area of development during this phase. Here, we mention Oleksandr Nesterov (1954–2005), who made use of his instrument, the bass guitar, to create textural material generated from extensive manipulations of signal processors. In a way, this self-reliant tendency was indicative of the experimental attitude and desire to dissociate from conservatism. At a later stage, Nesterov combined MIDI guitars in his performance systems with samplers and synthesizers for improvisational concerts.

1.2.3. Appearance of electroacoustic compositions – the 1990–2000s

Gaining independence and a shift towards democracy in Ukraine[1] were most crucial events affecting the development of electronic music in Ukraine. Thereafter, scientific, educational and cultural exchanges with the international community became reality. Public access to global information networks created a favourable situation for overall scientific advancement and artistic emancipation. But a detailed account of this transitional period in history, and its effects on the artistic community is beyond the scope of this article. Here are the main lines confined to the field of electroacoustic music.

In 1992, composers from the GRM (France) organised electroacoustic music concerts and masterclasses in Ukraine. This and other similar events prompted a favourable environment for a gradual increase of electroacoustic performance series involving Ukrainian and foreign composers. Festivals and concert series now include *Kyiv Music Fest*, Forum for Young Musicians – Kyiv, *Two Days and Two Nights*, New Music Festival – Odessa, and *Kontrasty*, International Festival for New Music– Lviv.

During the mid-1990s we can clearly identify the recognition and establishment of academic electronic music in Ukraine. The first electronic music studio and department of music informatics and technology at the National Academy of Music in Kyiv was organised with the assistance of the Soros Foundation. This was a major impetus for students and young composers to study electroacoustic music. Ukrainian art music of the 1990s was composed of a wide range of styles and configurations: mixed music for tape and solo instrument (or ensemble), performances for musicians and live electronics, video installations, multimedia performances and such. Among the first works integrating electroacoustic techniques, we might include the following compositions:

- *Quartet* (1991) for string quartet and electroacoustic recording by Maxym Abakumov (b. 1976)
- *Dialog with my reflection* (1993) by Ivan Nebesny (b. 1971)
- *Implicatio* (1993) for clarinet, string trio and tape, by Ivan Nebesny (b. 1971)
- *Andrij Bulba* (2000), interactive multimedia piece for soloists, instruments, orchestra and electronics, by Ivan Nebesny (b. 1971)
- *Cosi fan tutte* (2000), audio-visual installation by Oksana Plisiuk (b. 1966) (video) / Alla Zagaykevych (b. 1966) (audio)
- *Virginalia* (2003), multimedia opera in 7 acts, by Danylo Pertsov (b. 1976)
- *Melancholy* (2005), video installation, by Sviatoslav Luniov (b. 1964)

Other contributors using electroacoustic means to compose their works are the following:

- Karmela Tsepkolenko (b. 1955)
- Ludmyla Yuryna (b. 1962)

[1]After Ukraine gained its independence in 1991, international cultural organisations established their offices and institutes in the major cities. Funds were at last available to support young artists for study abroad in Institutes of international standing.

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The Charlesworth Group, Wakefield +44(0)1924 369598 - Rev 7.51n/W (Jan 20 2003)

Figure 1. Transcription from ethnographic recordings.

- Ivan Taranenko (b. 1963)
- Sergiy Pilutykov (b. 1965)

In the latter part of the 1990s a new wave of worldwide trends has changed the conformist *modus operandi*, and composers quickly adopted new methods of sound manipulation found abroad and have even integrated real-time image rendering technology with live sound manipulation. Sound Art experiments (in the sense of early avant-garde movements) re-emerged in a digital domain and it was then possible to convey similar aesthetics found in other regions of the world due to the ubiquitous functionality of the equipment used to create musical material. The label Nexsound is a perfect example demonstrating the emergence of experimental electronic music in Ukraine. The array of available titles displays a blend of abstract electronic music with elements of national character, and has heightened the potential of electronic music to new levels of expression. The exponential ascent of original material produced by such labels is driven by the natural tendency toward competition and collective valorisation. However, local infrastructures must be available for this to happen effectively.

During an epoch where diversity is truly blurred with uniformity, distinct elements and cultural symbols may easily fade through the use of technology. Conversely, the capacity to store and reorganise information can also enhance the value and significance of the musical intention. Perhaps examining the inherent mechanisms of composing electronic music in contrasting circumstances and contexts would emphasise the universal characteristics of creativity in the larger sphere of musical development in its natural tendency toward perpetuation.

2. CREATIVE PROCESS

Let us take a closer look at some algorithmic and electronic music works found in Ukraine.

2.1. Algorithmic composition

Leonid Hrabovsky[2] composed *Concerto Misterioso* (flute, clarinet, bassoon, antique cymbals, harpsichord, harp, violin, viola and cello) in 1977 (see Audio Track List). This piece illustrates the composer's versatile approach to algorithmic composition using independent combinatory systems to generate rhythmic and melodic motifs – *mikromotyvy*. Almost all the musical material originated from folkloric and ethnographic sources. In the pre-compositional phase, Hrabovsky used a collection of folkloric songs and recordings from 1965, mainly interpretations by E. Zuikhy recorded by H. Tancury. This rare song collection was unique in its authentic flavour of vocal interpretations, and the repertoire exhibited a large array of vocal mannerisms found in rural areas. This gave forth to the systematic categorisation of melodic and rhythmic patterns construed within different folkloric genres (see Figure 1).

The idea of the composition relies on a system linking smaller portions of transcribed melodic cells or *mikromotyvy*, used in the configuration of larger architectonic structures. Pitch and rhythm would be linked by the algorithm and in the building blocks of the form-structure. By algorithmically treating the embedded melodic cells, the composer would generate new pitch material. The same would apply to rhythmic patterns derived from the categorised and subdivided ethnographic recordings (see Figure 2).

This resulted in a vast collection of transcribed figures, and was a good indicator that folkloric source material embodied a rich informational complex useful for the creation of substantial (algorithmic) compositions. Here, some examples of rhythmic series based on the combination of numeric proportions derived from segments of authentic material are presented (see Figure 3).

[2]Leonid Hrabovsky was born in 1935 in Kyiv. He studied economics at the Kyiv University (1951–1956) and concurrently took piano and theory lessons. He then entered the Tchaikovsky Conservatorium in Kyiv to study composition with Lev Revutsky (1954–1956) and Boris Lyatoshynsky (1956–1962). Hrabovsky obtained a graduate diploma in 1962 and taught at the Conservatorium from 1966 to 1969. Later, he became associated with a group called the 'Kyiv Music Avant-garde' where a circle of Ukrainian composers got together to study works by Stravinsky, Bartok, the composers of the second Viennese school, as well as works by Varèse, Cage, Xenakis and Berio. He then moved to Moscow where he became editor of the journal *Sovetskaya Muzyka* for some years until he left for the United States in 1989. He now resides in New York where he holds a position as composer-in-residence at the Ukrainian Institute of America. His works include instrumental, symphonic, choral, theatre and film music.

Figure 2. Rhythmic series based on authentic material.

Figure 3. Derived series from categorised patterns.

Not only does the algorithmic system bridge the melodic and rhythmic elements together with the structure, but it also determines the timbral qualities of the sections generating the form, based on the universal concept of a functional foreground–background interplay, where the melodic lines become the foreground and the accompanying polyphonic harmony, the background.

Hrabovsky used five types of backgrounds emanating sonorous textures, which do not suggest defined motifs, but create a link between the various algorithms and the melodic interventions in the foreground (see Figure 4).

All the sections of the *Concerto Misterioso* (from shortest to longest, 4–89 measures) are linked by a common timbral idea. Every section has its own instrumentation associated with a numerical system based on number series (including Fibonacci series). The 'tectonic' structure of the work delineates the different sections characterised by the instrumentation used (see Figure 5). The structural arrangements expose a three-part canon varying polyphonically over the background.

As a result, we obtain thirty timbral variations. The original score by Hrabovsky indicates all the sections with double markings symbolising the transition from one texture to the other making up the background.

The originality of the algorithmic system used in *Concerto Misterioso* lies in the combination of a constructive approach to form, with the composer's subtle intuition with regard to the use of ethnic/folkloric source materials, and the integration of ancient polyphonic forms in a contemporary context. This unified approach toward different stylistic media is regarded as a major influence for many composers of the younger generation (1990 until present) in their methods and attitudes toward composition in general (Luniov, Pertsov, Voitenko).

2.2. Musique concrète in Ukraine

The appearance of *musique concrète* in Ukraine launched the development of electronic music in this region. Then, composers only had access to recording facilities and sound editing equipment through the flourishing film industry, which made it possible to modify sound sources and create diverse sound effects and montages. A well-known initiator of *musique concrète* in Ukraine was Vitaly Godziatsky. From 1956 to 1961, Godziatsky studied composition and orchestration with Boris Lyatoshynsky (1895–1968) at the Tchaikovsky Conservatorium of Music in Kyiv. During his studies at the Conservatorium,

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Figure 4. Musical textures for creating the background.

Godziatsky spent his time studying new directions and compositional techniques which came from Western Europe (serial composition, sound synthesis, *musique concrète*). His music was soon performed in the West (*Autograph* and *Rupture*). The music of Godziatsky and other composers of the Soviet avant-garde have generated considerable interest from abroad, while at the same time they were ironically considered dissidents in the USSR for their non-conformist views.

The original idea of *objet sonore* was openly accepted in the socio-cultural climate of Ukraine of that time. Somehow idealised and interpreted as a liberation of sound in the sense of Varèse (*liberation du son*), this concept of *objet sonore* coincided with the ideas of Ukrainian-Russian Futurists of the 1920s. These include Davyd Burluk (painting, litterature), Artur Lurje (music) and Mykhail Semenko (poetry).

The first *concrète* piece by Godziatsky is considered to be *4 Scherzi Domestiki: Poltergeist amusing oneself, Emancipated suitcase, Realization, Anti-World in a box* (see Audio Track List). It was first available on tape and was simply named *Four studies for tape recorder*. Later the composer created a score, which allowed the work to be performed in concerts. The sounds are taken from objects found in everyday life, such as domestic appliances and kitchen utensils (cups, pots, sieve, grater, spoons, glassware, metallic pans, bowls, plastic containers) with the mechanical sounds of the piano (strings, resonating soundboard, hammers, pedals) and percussion mallets. All these sounding objects were used by the composer with the purpose of obtaining a colourful blend of clashing textures, extracting the timbral and pitch qualities of these materials. The surprisingly lively sound of kitchen utensils and domestic appliances came in extraordinary contrast with the conformist choral

Figure 5. Example of a section defining the tectonic structure.

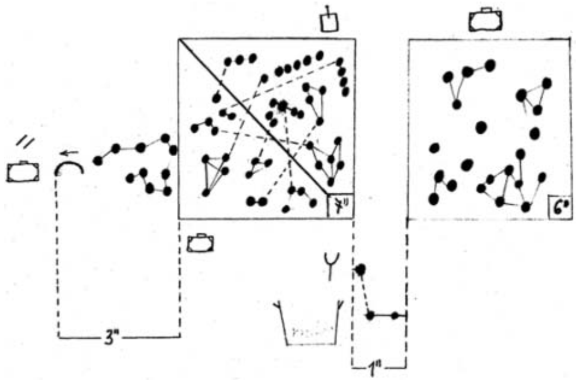

Figure 6. Excerpt from the graphic score of *Realization* by V. Godziatsky.

and symphonic works in the Soviet spirit – *For Honour and for Glory* (see Figure 6).

Whilst the composition did not display elements of montage typically found in *musique concrète*, which allowed the composer to separate the phenomenological value of the sound from its origin, the unconventional sound orchestration had a splendid and disproportionate effect of discordance. The work contained about three groups of sonic textures composed of individual unified timbral elements organised sequentially, thus creating a succession of varying timbre shapes (*klangfarbenmelodie*). The structural syntax of the timbral elements consisted of irregular rhythmic figures (smaller portions of micro-motifs made of 2–3 sounds) broken up by pauses or lines of tremolo-like textures combined with dynamic envelopes (see Audio Track List).

In 1968, while working on the music for a cartoon series called *The Career*, Godziatsky created a *musique concrète* piece in the real sense. He applied a montage technique on pre-recorded sounds of different textures. The following sounds were used: vibration of a saw after striking it, the sound of a plastic ashtray, wooden board, suitcase, rubber tyre, prepared piano, vibraphone, human screen, crowd noise, water falling in a metal bowl and excerpts of a tutti orchestra. The sounds were then manipulated with the following methods: use of several reel-to-reel tape machines at different recording and playback speeds (constant), gradual speeding or slowing down of the playback reels, reverse playback of the tapes. Such techniques widened the possibilities of working with predominantly non-instrumental sound sources such as noise and sound objects, and revealed subtle intonation changes not possible otherwise. However, these preoccupations remained embedded in a more traditional framework when concerned with intonation, pitch and rhythmic elements. During the editing and montage of the sounds, the composer also paid particular attention to building a flexible musical syntax based on the modulation of similar timbral structures, or different timbres combined and modified by the same dynamically evolving shapes within the structure itself (see Figure 7 and also excerpt from *The Career* in Audio Track List).

2.3. Integrating electronic sound synthesis in mixed music

There was a gradually increasing interest in sound synthesis techniques during the late 1970s and 1980s in

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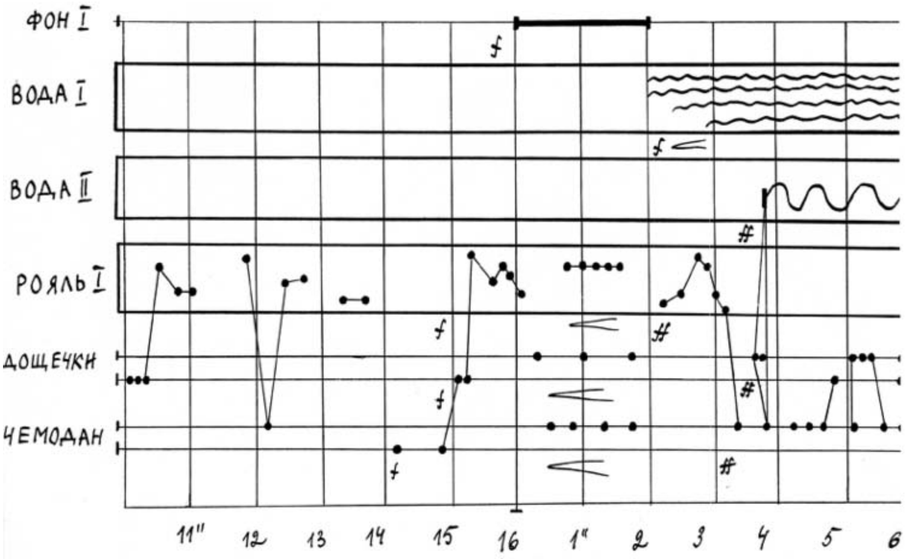

Figure 7. Excerpt from the graphic score of *The Career* by V. Godziatsky.

relation to the omnipresence of commercial synthesizers in young musicians' circles in Ukraine; the artistic potential of such hardware devices was yet to be explored. The use of electronic sound synthesis in musical works was well adapted in Ihor Steciuk's compositions. Born in 1958, Steciuk graduated from the Tchaikovsky Conservatorium of Music in Kyiv in 1987. He writes symphonic, chamber, jazz and popular music, and has created more than twenty film and television soundtracks for European, American and Ukrainian productions. The aesthetic foundations of his work rely on the combination of contrasting and even totally opposing musical elements and styles: symphonic genre with respect to harmony and polyphony, jazz collectives, ancient Ukrainian folklore and modern electronic instruments. Like his contemporaries in the 1970s, Steciuk was fond of electronic resonances, particularly after hearing originally arranged pieces such as Isao Tomita's electronic version of Mussorgsky's *Pictures at an Exhibition*, which uncovered a new palette of sounds and more importantly, the creative possibilities generated by such instruments. Understanding the potential of what was achievable with new technology was strengthened by the music of Wendy Carlos, Keith Emerson's incorporation of modular synthesizers in popular music, and the futuristic soundtracks by Edward Artemiev. It is worth mentioning that this cocktail of synthesised music was only available sporadically during an epoch when information access was very limited, and at times even difficult to obtain. Musicians were particularly eager to discover anything that fell outside conservative views.

Steciuk had encountered FM synthesis with the polyphonic versatility of the Yamaha DX7 synthesizer. A new vocabulary describing synthesis techniques needed to be deciphered and applied to a cycle of compositions created in the spirit of his predecessors. The young composer devoted much time to re-create world repertoire classics and explore new timbres and textures generated electronically. The problem arose in terms of spontaneity and fluidity of expression when using solely pre-determined synthesis interfaces and functional algorithms to generate sound. A comparable system to acoustic instruments in its performance accuracy was desired. This is why, later in the early 1990s, Steciuk turned toward other means of sound generation such as the Yamaha VL1 and the Korg OASYS PCI based on *Virtual Acoustic Synthesis*, or more precisely, physical modelling techniques implemented by hardware and software devices. Here, the possibilities extended beyond the colouristic approach of modifying timbre, and allowed a better control of all synthesis parameters involved in the production of sound (see Audio Track List).

The introduction of sophisticated sampling techniques provided a new quality in the rendering of acoustic instruments, and also introduced a new functionality: the ability of reproducing pseudo-traditional intonation, originating from unexpected and usually non-tempered sampling material, sometimes complex and other times relating to noise. The miniature entitled *Urbo* (1994) demonstrates the use of sampling in parallel with FM Synthesis. It underlines the urbanisation process and a syntax yielded by non-pitched or non-rhythmic material; in essence, a new functional organisation of form, based on noise structures.

Sound synthesis, as a systematic form of improvisation, was adopted by Kyiv based musician Oleksandr

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Nesterov (1954–2005). He studied electronic means of producing music with signal processing techniques applied solely to a bass guitar, and created an album entitled *Mirror* in 1989. The principal aim of this exploration was to utilise electronic signal processing to optimally modify the sound of the bass guitar, in its extreme dynamic range and timbral possibilities. He used a flexible technique to affect all stages of the dynamic envelope (attack, decay, sustain, release). Often the resulting sounds were reminiscent of vocal qualities, which allowed him to seamlessly integrate his electronic processes with wind instrument ensembles. The album *Claustrophobia* (1991) exposed the achievability of applying MIDI control to sound synthesis, thus adding a dynamic aspect to music created by non-acoustic instruments. For example, Nesterov used the multi-channel capabilities to produce poly-timbral textures with various techniques of sound generation, such as in the bass solo of *Coloured Fluography* (see Audio Track List).

An intense interweaving of sound manipulation techniques was accomplished in the recording *Contaminated Sound* (1998), in dedication to the Chernobyl nuclear disaster in 1986. This electroacoustic project combined fifteen traditional songs and several recordings of instrumental music taken near or within the remaining villages of the Chernobyl zone of exclusion, and performed by traditional voice ensemble Drevo. Indeed, the most important aspect of the creative process was the rich quality of authentic voices and varying overtones, which became the sonic model for the accompanying electronic instrumen-tarium (MIDI guitar, synthesizers, samplers, electronic percussion).

In general, we can distinguish two types of electronic music projects integrating authentic genres in recent decades. The first type is the structured integration of electronic and authentic sounds, where complex electronic sounds usually created from samples or synthesised sounds (generated from FM synthesis, for example) are directly correlated to the authentic material, either live or sampled. The resulting texture created resembles a strange rural–urban blend, a sort of *heterophonic tutti* which is hard to grasp in its eclectic anachronism.

The second type is perhaps a sonically disintegrated form of electroacoustic exploration, where the segmented and transformed authentic material generally results in a repetitive rhythmic background to which layers are added, sometimes non-periodic lines of a lead variation with unexpected punctuations, but not necessarily tightly related to the original form. Layers of variable periodicity inherent to the structures of authentic voices or instruments may generate macro-rhythms and if syncopated by the variance of multiple layering, create a general sense of timelessness, such as in *ambient music* or *world music*.

2.4. Electroacoustic music

The first electroacoustic compositions of young composer Maksym Abakumov (b. 1976) are based on the aesthetic and technological fundaments of *musique concrète* and sampling synthesis (*Quintet* in 1992 and *Quartet* in 2001). In the first composition, brass sounds, small cymbals, guitar strings and two voices are mixed onto tape, and identical copies of the same recording are used for playback on several magnetophones. The main idea lies in the gradual widening of space, caused by a progressive de-phasing of all the tracks leading to the final de-synchronisation of all the pre-recorded material. The latter piece *Quartet* stands on small fragments of instrument samples (piano, guitar, bass, and elevator) and their variations. This programmatic composition resides in the juxtaposition of various elevator noises with the sounds of acoustic instruments. The emphasis, however, remains with the noisy aspects of the elevator.

Electroacoustic works by Alla Zagaykevich coincide with the idea of attaching transcendental meaning to spectral qualities of sound, extended by the metaphoric representation of the playing techniques of instrumental parts of the works applied to timbre. Usually, mixed electroacoustic compositions make use of sampling synthesis, with its accompanying signal processing techniques such as filtering, cross-synthesis and granulation. FM synthesis acts as a counterpoint to the generation of various noise-type sounds by chance algorithms.

Pagode for recorders, tape and live electronics, is a characteristic example of the timbral integration of electronic and instrumental parts. The pitch structure and playing techniques of the recorder parts are more or less traditional. The key aspect is hidden in the already rich textures produced by the entwining of the three recorder parts. The spectral qualities of the instruments vary with the natural built-in inflections produced by the sound of recorders. This builds up with the complexity of the dialogue between the three parts, by use of 2 to 7-tuplets with differently accentuated notes and pauses generating a certain thematic texture (see Figure 8).

Another aspect is the addition of registers creating the impression of several independent voices. Acoustic properties of the instruments are accentuated during the solo part, and natural noises of the recorder arise when amplified through a microphone. This represents the double quality of the instrument, as its musical and noise components emerge simultaneously. The electroacoustic and instrumental aspects of *Pagode* are texturally binded by melodic interplay. Samples of recorder sounds are modified using cross-synthesis techniques with small metallic and percussive sounds. Live electronic effects are also used during a performance, such as reverberation, harmonizer, flanger, distortion, delay and filtering, acting as a binding force

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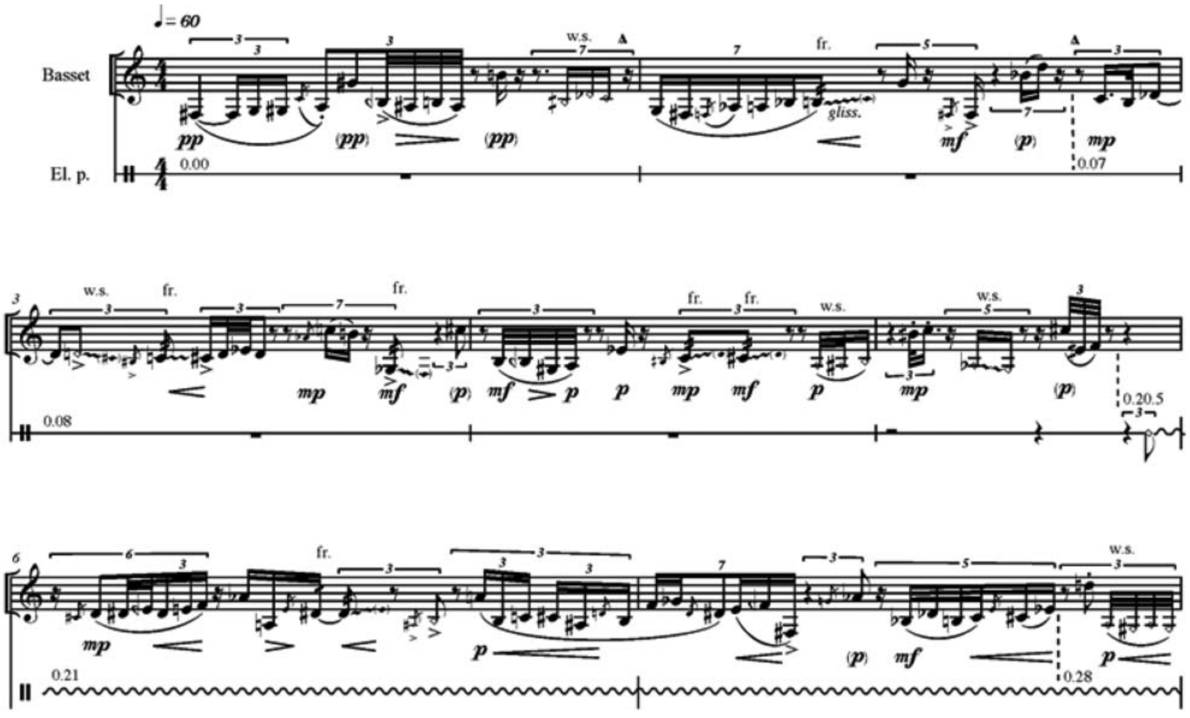

Figure 8. Excerpt from the score of *Pagode* by Alla Zagaykevych.

in the integration of acoustic and electronic instruments (Rakunova 2005).

3. THEORETICAL PROCESS IN THE FIELD OF ELECTRONIC MUSIC AND MUSIC INFORMATICS

Academic reflection in the realm of electronic music and music informatics evolved rather independently from the generic attitude towards creative processes and the practical implementation of compositional techniques. This specifically concerns theoretical considerations about Ukrainian electronic music and algorithmic composition, which unfortunately only reached the milieu of musicological experts in the early 1990s. However, the theoretical questions concerning music informatics, musical acoustics, statistical research methods applied to music, and computer modelling of creative processes, were never a forbidden topic for music experts and academics. Moreover, the Institute of Cybernetics of the National Academy of Science in Ukraine was established in 1962 in Kyiv under the direction of V. Glushkov, founder of information technology in the former USSR. He was most influential in the topics of global computerisation of society and artificial intelligence embedded in computer technologies and networking systems.

Alongside active research in information technology during the 1970s, several branches relating to information theory were starting to develop a formal approach toward musical analysis methods, quantification of musical style and the processes of musical creativity through mathematical modelling. Concurrent developments in the field of acoustics were used to investigate new ways to analyse music, based on the harmonic and spectral contents of a musical score performance. The mid-1990s finally brought a restrained circle of music experts to study contemporary usage of computer technologies applied to composition. At last, there seemed to be some sort of consensus on which direction analysis of electronic music might take in the future, depending on the elaboration of adequate analytical terminology. The following sections will elucidate some aspects relative to theoretical processes.

3.1. Application of information theory to musical analysis

The 1960–1970s opened a new awareness to earlier studies on the properties of information, communication and organisation systems, mainly the *General Systems Theory* (L. V. Bertalanffy), *Information Theory* (C. E. Shannon) and *Cybernetics* (R. Ashby, N. Wiener). These theories added a multi-disciplinary angle to the study of music and revitalised attitudes toward musical thinking in academia. Notably, the publication of *Cybernetics and Music* by R. Zarypov (1963, 1971), and the Russian translation of *A Framework for Representing Knowledge* by M. Minsky in 1979, both had an impact on the conceptualisation of the musical phenomenon.

Igor Pyaskovsky, one of the most active music theorists at the time, developed statistical methods to analyse musical works of various stylistic characteristics. In collaboration with Volodymyr Hoshovsky (who initially used empirical methods to study archived ethnographic materials), Pyaskovsky applied statistical methods to Ukrainian folkloric music in the hope of establishing a link with larger formalised compositions. In the 1980–1990s he made use of the concept of frame models to analyse polyphonic structures of vocal music and later published the article 'Frame models for polyphonic styles' (Pyaskovsky 2004), where he described a method of devising semantic networks to analyse musical works. By way of recognising and quantifying specific structural anchor points in the analysed music, Pyaskovsky proposed a method of reconstituting a frame model from a particular musical style. A style was therefore defined by the characteristics of the frame model, which was the starting point for further statistical analysis, thus creating a more objective perspective eliminating any possible stereotypes.

3.2. Acoustic analysis methods applied to musicology

In the late 1970s, Leonid Dys elaborated the theory on the *leading horizontal* as an acoustic model, which presupposes the acoustic value of musicological analysis. Keeping in mind the oscillograph of a complex waveform originating from one or more leading voices always results in a continuous representation of the sum of all parts, by extrapolating information from a complex waveform system passed through an oscilloscope, Dys's experiment proved it was possible to obtain the acoustic model or shape of a melody by analysing the overall shape of the evolving waveform. The acoustic model would provide information on pitch, loudness and timbre. These experiments relied on acoustic measuring equipment (oscilloscopes, spectral analysers, frequency detectors, etc. …) to analyse pieces of different styles and configurations (monophonic, homophonic, poly-phonic). Dys arrived at the conclusion that when applied to musical excerpts of homophonic style (such as in Beethoven or Mozart Sonatas), the *leading horizontal* model almost invariably coincided with the thematic structure of the notes in the score, and it was therefore possible to apply the concept of *leading horizontal* to musical structures of various complexity in order to obtain a complete acoustic model of a scored composition. 'Aside from providing the *'leading horizontal'* model, the analysis of musical works by electroacoustic means allows us to assume the existence of the acoustic reality in some theoretical and musicological categorisations' (Dys 1980).

Other investigations relating to the acoustic properties of sound are included in the article 'Acoustic phenomena as events' by Gennady Kohut. The author presents an analysis of the composition *Pression* by Helmut Lachenmann, written for cello in 1969–1970. Foremost, Kohut analyses the composition as a sequence of musical events, seen as fully integrated acoustic entities. Again, Kohut used an oscillogram to determine the spectral content of the independent sonorous entities. By analysing the spectral quality of events, Kohut obtained the following categorisation of events and applied them to the analysis of *Pression*:

- Noise categories (white, pink, brown)
- Harmonic spectrum
- Non-harmonic spectrum
- Periodic modulations
- Non-periodic modulations
- Filtered spectrum
- Impulse signals
- Complex spectrum

Rhythmic organisation (time) and dynamic scale (amplitude) were used as indicators for a complete analysis of sequential acoustic events. In trying to grasp the intrinsic notions of instrumental compositional techniques, analysis would be incomplete or even impossible without the additional use of a systematic acoustic analysis methodology (Kohut 2005). According to Kohut, this is also true for electronic music works.

3.3. Computer modelling of musical creativity

With the active development of cybernetics in Ukraine, music theorists started to look at artificial intelligence to solve problems in general musical theory, and more specifically in understanding the mechanisms of musical creativity. The article by Leonid Dys, 'Investigating the question of musical creativity: potential of computer modelling' (Dys 1988) describes the modelling of artistic and musical processes by computerised means. One of the aims of the article was to answer the following question concerning the transition from acoustic reality, sounding, to musical imagination; how is acoustic reality interrelated with musical thought? In essence, the aim is to understand how sound can help transform abstract musical ideas into artistic reality with the use of structure, order and sequence of musical events. In another article by I. Pyaskovsky, 'Toward computer modelling of the creative process' (Pyaskovsky 2002), a heuristic approach is used to present computer methods to model musical creativity as a solution to analyse works of different styles. The author proposes the following methods:

- stochastic experiments on notes and structure,
- probability analysis of sequential data (notes), and

- application of Markov chains to form and structure.

3.4. Computer technology and compositional practice

The propagation of computer technology in the late 1990s prompted musicians and composers to upraise the techniques used in the creation of new works. New music technologies included MIDI-based equipment, score typesetting, arranging, sequencing, hard-disk recording and other means to enhance the functionality of the composer's studio setting in many ways (Haydeiko 2002, 2005). Viktor Kaminsky collated detailed information on the history of the development of Western electronic music techniques in the book *Electronic and Computer Music* (Kaminsky 2001), but the focus was mainly on arranging, sequencing and publishing. However, the main advantage of this work was access to information written in the Ukrainian language, which historically proved difficult in the past. With the mutli-disciplinary tendency of current research in electronic music and music technology, the processes became increasingly sophisticated, and that dimension has not yet reached the analytical phase of research development in Ukraine. The questions about the aesthetic, poetic and stylistic aspects of technological integration remain unsolved. The uncertainty arises when weighing the importance of technology versus musical and theoretical aspects, but this does not hinder experimenting with various compositional techniques encompassing morphological and syntactic algorithms borrowed from other disciplines (Shyp 2005).

3.5. Electronic music analysis

Theoretical research about electronic music was integrated rather late in the realm of musicology in Ukraine. It was perhaps within circles of musicology students that deep analytical reflections on electroacoustic and algorithmic music (notably Xenakis, Nono) first appeared. Ukrainian electronic music was analysed through the aesthetic and historic prism, on the background of national artistic and musical traditions. Analysing electroacoustic compositions by Ivan Nebesny, Kateryna Maryniak focused on the imagery conveyed by his works and the individual voice of the composer. Here, Maryniak assumes the existence of a national school of electronic music, which benefited from the national heritage of traditional instrumental music, and continues and expands the determinant ingredients of national character with the use of electronic sounds (Maryniak 2002).

A good illustration of the current situation regarding the analysis of Ukrainian electronic music is Inessa Rakunova's research on the role and functional aspects of sound synthesis in composition. The author conceives a structural semantic analysis of electroacoustic works by Alla Zagaykevych, and studies the interrelationship between instrumental and electronic parts. Furthermore, she introduces new technical terminology to describe the practice of sound synthesis and creation of electronic music.

Current Ukrainian publications about music technologies in both academic and vernacular cultures appropriate mostly borrowed terminology from the English language, or simply transliterated into Ukrainian. This applies to digital signal processing, sound synthesis, and MIDI hardware devices. The type of analysis proposed by Rakunova with the optic of expanding terminology is essential to preserve the intrinsic values and significance of the works analysed.

4. CONCLUSION

Creative and theoretical processes in the field of electronic music in Ukraine exist as independent phenomena and are only starting to find their place in the scope of recognised scientific and artistic contexts. Despite the rather fragmented infrastructure of electronic music studies in Ukraine, arising questions deal with a wide range of fundamental notions of musicology, acoustics and computer music applications. Actually, the rather unsynchronised evolutive processes which lead to scientific reflections were unavoidable and occurred naturally as a consequence of the delayed introduction of electroacoustic methods in the realm of the higher layers of academically aligned art music projects.

In our view, the cumulated locally determined experience of musicologists, and systems of musical thinking, relative to the integration of information theory in musical analysis, acoustic research, together with fundamental analytical knowledge about the functional aspects of musical form, structure and timbre, will be 'synthesised' in the light of a new perspective on the analysis of electronic music processes and their derived compositions. With the emergence of new music technologies, it is perhaps necessary to adopt a new aesthetic discourse to minimise the setbacks, which may have existed in the 1970–1980s in Ukraine.

Today, in a relatively sophisticated communication environment, contemporary compositional techniques and methodologies undergo important influences, which no longer uniquely depend on existing institutional or local infrastructures. Traditional musical systems are omnipresent in the transmission of cultural values associated with the preservation of a certain identity: either musical, philosophical, social or cultural. Introduction of new media technologies may have the effect of destabilising and modifying traditional musical practice. Analysing this particular phenomenon could be determinant in thoroughly understanding the cultural significance and intrinsic meaning of musical creations relying on new technologies.

In this regard, the present article epitomises the process by which artistic and theoretical concepts may emerge through the various combinations of elements from different spheres of influence and domains, sometimes even hemispheres. In fact, it is interesting to note that this collaborative work occurred entirely via the Internet, and demonstrates the vast creative potential available through new mediums of communication, drastically affecting the concept of continuous time and geographic space.

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Urbo, an excerpt from the ballet *WE*; *The Breakthrough*, an excerpt from the *Triptych* (based on the music score to the motion picture *The Breakthrough*; *This Is Ukraine*, an exerpt from the suite *This Is Ukraine*; and *Visions Fugitives 2*, electronically created with the participation of A. Matar on a theme by Sergei Prokofiev; reproduced by kind permission of Igor Stetsyuk.

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AUDIO TRACK LIST

Included on this Volume's *Organised Sound* DVD

1. Hrabovsky, Leonid. *Concerto Misterioso*, for 9 instruments (fragment). Duration: 02′19″.
2. Godziatsky, Vitaly. *4 Scherdzi domestiki*. Duration: 02′45″.
3. Godziatsky, Vitaly. *The Career*. Duration: 02′12″.
4. Steciuk, Ihor. *Shvydkoplynnosti No. 2 Prokofieva* (Vision No.2 Prokofiev). Electronic interpretation. Duration: 01′32″.
5. Steciuk, Ihor. *Urbo*. Duration: 01′20″.
6. Nesterov, Oleksandr. *Coloured Fluorography* (fragment). Duration: 02′43″.
7. Abakumov, Maksym. *Quartet* (fragment). Duration: 02′52″.
8. Zagaykevych, Alla. *Pagode* for tape and live electronics, J. Isaac on recorder (fragment). Duration: 03′24″.

Organised Sound jos118731.3d 4/5/07 09:26:08
The Charlesworth Group, Wakefield +44(0)1924 369598 - Rev 7.51n/W (Jan 20 2003)

APPENDIX E

E.1 3D-Composer Software Instructions - *Read Me* file

Welcome to 3D-Composer Software Prototype!

3D-Composer is a standalone application built in Max/MSP/Jitter.
It contains externals relying on Python 2.5 and external Python modules.

Installation Instructions:

For Mac OS X 10.5 Leopard:

OS X 10.5 Leopard ships with Python version 2.5, you only need to run **3D-Composer Package Installer** which automatically installs two additional Python modules:*

1. You are now ready to install *3D-Composer* and additional Python modules to allow the application to run properly. Double-click the **3D-Composer Package Installer** icon and follow instructions. This should install the *numpy* module** to run the pyext max/msp external and the *networkx* module*** to implement Graph Theory, and *3D-Composer* software prototype.

You will need to enter an administrator password to install on your computer.

2. Double-click the **3D-Composer** application to start up the software.

*please see note at the bottom of the page if the command does not execute.
NOTE: If the modules and extensions do not load properly, you may need to restart the computer.

For Mac OS X 10.4 Tiger:

OS X Tiger ships with Python 2.3.5, please follow instructions to upgrade to Python 2.5* and install additional modules:

1. Double-click on the **Python-2.5.1-macosx.dmg** disk image to install MacPython 2.5 on your computer.

2. Once MacPython 2.5 is installed, double-click **verify_python.term** and in the terminal window, type in the word 'python', you should see the following appear as a result:

Python 2.5.1 (r251:54869, Apr 18 2007, 22:08:04)
[GCC 4.0.1 (Apple Computer, Inc. build 5367)] on darwin
Type "help", "copyright", "credits" or "license" for more information.

3. You are now ready to install *3D-Composer* and additional Python modules to allow the application to run properly. Double-click the **3D-Composer Package Installer** icon and follow instructions. This should install the *numpy* module** to run the pyext max/msp external and the *networkx* module*** to implement Graph Theory, and *3D-Composer* software prototype.

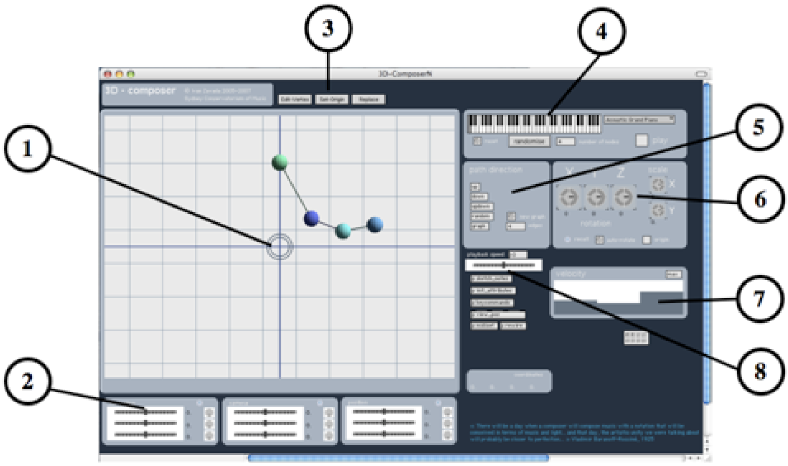
You will need to enter an administrator password to install on your computer.

4. Double-click the **3D-Composer** application to start up the software.

IMPORTANT: If **3D-Composer** does not quit properly, it might not start on the next run, simply double-click again and it should start properly the second time.

NOTE: If the modules and extensions do not load properly, you may need to restart the computer.

User Interface:



1. Display: interactive viewing pane for the micro-composition. The user can rotate and transform data by clicking on the nodes in the display.
2. Navigation panel: sliders determine viewer's position relative to the micro-composition and the scale at which the micro-composition is displayed.
3. Cursor options: there are three options to click-adjust the micro-composition in the viewer. Edit mode allows to modify the co-ordinates of one node, Set Origin allows the entire micro-composition to be adjusted and Replace allows updating the memory with most recent co-ordinates.
4. MIDI panel: the MIDI panel contains a user definable node input via note keyboard, additionally the choice f the MIDI instrument and number of nodes in the micro-composition are determined prior to playback.
5. Path direction: determines the playback order for the micro-composition. The four choices are forward, backward, random and graph.
6. 3D coordinates: allows the user to rotate the micro-composition in the x,y,z directions as well as auto-rotate in the z direction to generate MIDI notes.
7. Velocity panel sets individual velocity values for the nodes in the micro-composition.
8. Playback speed adjusts the rate at which the MIDI notes are played back with millisecond time intervals.

Operating Instructions:

1. Once 3D-Composer is open, the Jitter components should be running and the OpenGL engine as well. This means that if you click the orange randomise button, a micro-composition should appear in the display window. The initial micro-composition contains 4 nodes. You may interrupt the graphic update process by toggling Jitter On/Off.
2. To hear the result, toggle the play micro-composition button, or hit the spacebar on the computer keyboard. Choose a MIDI instrument from the drop-down menu next to the piano keyboard.
3. Use the X-Y-Z rotation knobs to transform the micro-composition

in three dimensions. Z rotation is the preferred transformation axis.
4. Choose a path direction for a more specific micro-composition playback, explore the difference with Up, Down, Up/Down, Random and Graph.
5. Adjust the relative playback speed, it goes from very fast to slower towards the right.
6. The navigation, camera and position sliders can be changed for a different perspective. To reset, click any of the small 'r' buttons.
7. Use the sliders on the lower right corner to modify individual velocities for the micro-composition.

Window Edit:

It is possible to edit and transform the micro-composition directly on the display window. To edit individual nodes select 'Edit-Vertex', this will edit nodes relative to the display window origin (0,0). To change and transpose the entire micro-composition, select 'Set-Origin' which allows real-time manipulation of the micro-composition. To replace the current values in the application memory click 'Replace'.

System requirements

Make sure that your computer system meets the minimum requirements to run Max/MSP Runtime and Jitter:

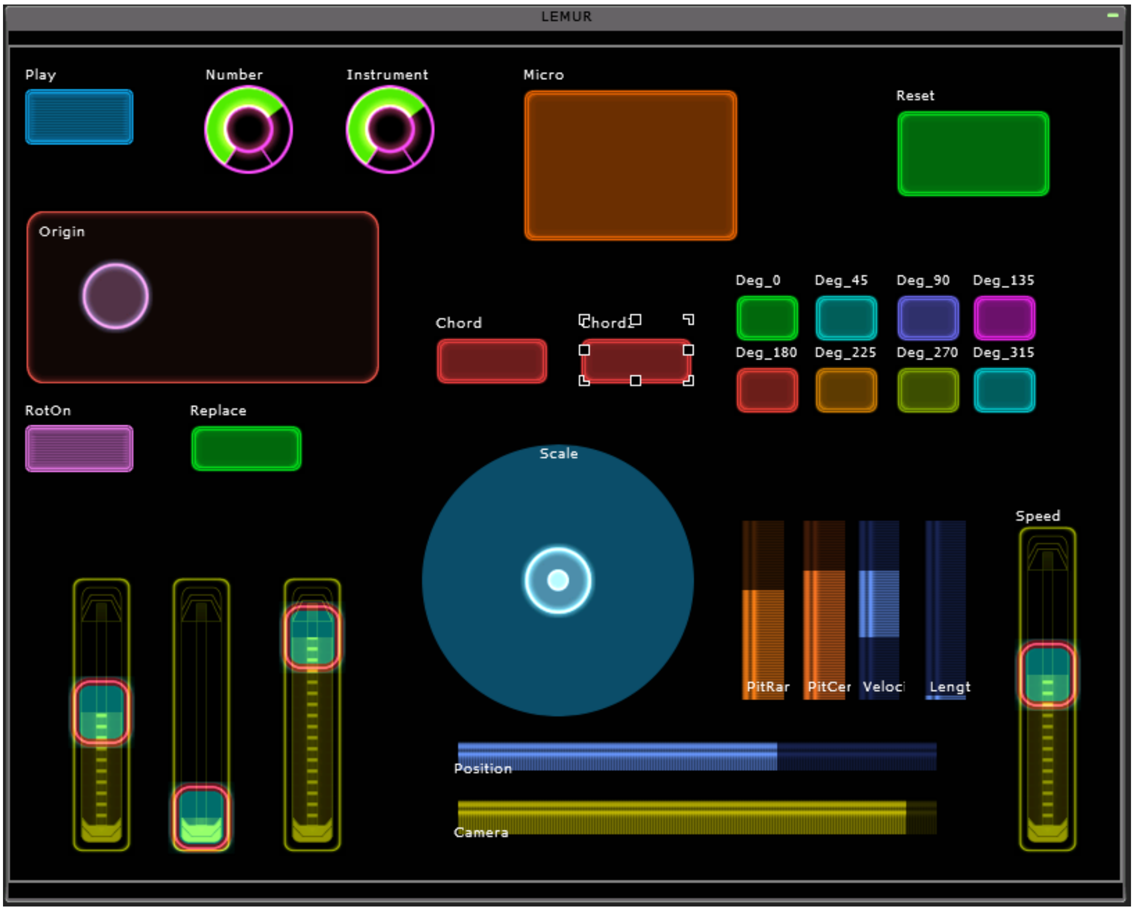
- Mac PPC G4 or G5 processor, or Intel® processor
- Mac OS X version 10.3.9 or later (10.4 Recommended)
- 256 MB of System Memory RAM (512 MB recommended)
- 175 MB of available hard disk space
- 1024 x 768 screen resolution (1440 x 900 recommended)
- Python 2.5

January 31, 2008

* Pre-built Python packages are available from PythonMac
http://www.pythonmac.org/packages/
** for more information on the Numpy module please visit
http://numpy.scipy.org/
*** for more information on the NetworkX module please visit
https://networkx.lanl.gov/wiki/Installing

APPENDIX F

F.1 JazzMutant Lemur multi-touch control set up



JazzEditor set up window for multi-parametric control of the micro-composition in *3D-Composer*.

APPENDIX G

G.1 Installer CD: 3D-Composer Software Installer - CD No. 1

G.1.1 3D-Composer Installer.dmg

G.1.2 Python-2.5-macosx.dmg

G.1.3 ReadMe.pdf

Installation instructions are found in the *Read Me* document located on the 3D-Composer Software Installation CD No. 1.

It is important to note, that Mac OS X 10.5 Leopard ships with Python version 2.5, you only need to run the 3D-Composer Package Installer which automatically installs two additional Python modules and the 3D-Composer software prototype.

However, Mac OS X 10.4 Tiger ships with Python 2.3.5, please follow instructions in the *Read Me* file to upgrade to Python 2.5, and then open 3D-Composer Package Installer which automatically installs two additional Python modules and the 3D-Composer software prototype.

APPENDIX H

H.1 Audio CD Tracks: Composition Portfolio - CD No.2

H.1.1 Six Electroacoustic Studies

Track 1: Study No. 1   4:50 min

Track 2: Study No. 2   5:15 min

Track 3: Study No. 3   5:25 min

Track 4: Study No. 4   5:15 min

Track 5: Study No. 5   4:44 min

Track 6: Study No. 6   5:08 min

H.1.2 Electroacoustic Composition

Track 7 : Dada 2009   9:00 min

Total playing time: 39 minutes and 37 seconds