Information Structures

for Organization of Sonic Events.

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0 Preface

> *"Art, and above all, music, has a fundamental function [..] It must aim [..] toward a total exaltation in which the individual mingles, loosing consciousness in a truth immediate, rare, enormous, and perfect. If a work of art succeeds in this undertaking, even for a single moment, it attains its goal. " [Xenakis, 1992]*

A composer is unique in his/her ways of organising sound. Even though the operations, tools and devices used are often very similar, the musical outcome of the composition process is excitingly diverse. This shows that, regardless of technical and procedural actions, in the end, the music and its originality arrives from different worlds, individual and personal, inaccessible to standardized interpretation. Still, the rational means act as constructive tools that serve to assign a material form to the music of thoughts and ideas.

Nonetheless, in our time of increasing significance of the technical aspects, we tend to be interested in the analysis of procedures that have been taken in the course of creation of a musical composition, at least within the circles of practitioners of this art. Perhaps, not as much of the interest in the actions themselves, but rather in the modes of their application, as a factor displaying a certain musical thought and a process that has supported its consolidation into musical formation.

Before starting my studies at the Institute of Sonology, I had only a distant intuition about the type of compositions I want to realise: exploration of sound masses, networks of musical relationships and morphological forms of these constructs. On a practical level, it led to the subject of organisation of a complex structure of microsonic events that require specific methods to be composed in the context of multiple timescales. During the study, I believe I have succeeded to come nearer to the realisation of these concepts in music. Thus, the thesis summarizes my research that has led to the proposal of particular approach to organisation of sonic events that involves concept of space and application of visualisation techniques to musical information. As a description of a compositional approach, it may or may not be useful for others, while it contributes to an important larger scale discussion of various ways of managing parametric data within electronic music.

1 Background

Within the rational western culture, one can observe an ongoing line that connects the technological developments and the advancement in creation of music (for example, acoustic - analogue - digital). With the progress of Information Technology, the processing capabilities of digital tools have increased exponentially. The great potential of the digital systems in formalizing musical material has given rise to new generation of musical expressiveness. Unsurprisingly, most of the innovative developments in the music today originate from the digital domain of creation. While the technology itself is not a part of the artistic motivation behind the creation, it permits an artist to explore the musical realms not known before, brining new sonorities and musical ideas to life.

Most recent developments can be described by increased capability of processing of large volumes of data at realtime speeds. For a musical application that enables creation and control of complex sound structures, allowing performer/composer to apply computationally intense processing while listening to the immediate results. These expansions of boundaries pose a challenge to explore musical concepts that were inaccessible before due to the technical limitations.

In the course of music history, one can observe an ongoing effort to access the continuum of music by way of subdividing it into smaller units that are easier to transform and control within the structure of a sound. Within the realm of electronic music, the idea of note, as the elementary particle, has subsequently transformed into notion of frequency, sonic grain, down to the subatomic level of a single sample. By this process of abstraction, the musical sound is described by the information necessary for its creation and the parametric structure becomes the genetic code of music. With the detailed information, increases the ability to organize sonic processes, at the price of increased amount and complexity of the data. At some degree of complexity, these structures become inconceivable due to the quantity of information that faces the nature of the human perception. Increasingly, in computer music field one can arrive at a situation where possibilities of organizing sounds are greater than our obvious capability to control these processes in an intuitive way (a trivial situation: too many faders of a controller). On the other hand, there are technical developments that increase the computational possibilities to create, synthesize, transform sound, and call for artistic exploration that might prove to be fruitful for creation of a novel musical content. Such is the case when we want to involve larger information structures as material for composition. With the introduction of microsound, it has become clear that the conscious construction and control of dynamic spectrums requires a high degree of automation and development of refined control algorithms. Though, the question that one quickly arrives at by following this path is: how do we humans can effectively conceive such large quantities of information (a pile of numbers in its raw form) that extend beyond capabilities of our perceptual system?

This task can be forwarded to intelligent models originating from rational sciences, physics mathematics and informatics in the first place, where notion of mass-structures consisting of large number of elements are combined with analytical view. Implying this knowledge, the musical processes are guided by rules of chaos, statistic, and analytic or other simulated models.

Modern digital sound synthesis environments are now at a solid state of development and in combination with computer and DSP hardware, offer the widest range of elaborate sound synthesis and processing possibilities at high precision in real-time. Large number of discrete synthesis processes and refined control can be performed simultaneously, resulting in complex sonic structures. Following these advantages, there's a challenge for composer to perform processing over large amount of data and maintain control over just about every aspect of the composition. This control range can be extended both, at micro- and macro-structural level, the first representing "grains" or sound-points, synthesis parameters or individual samples. The second – macro-structure represent organization and sequencing of sonic events in macro and Meso time scale, lasting from milliseconds to hours. At this degree of possibilities, a certain method is needed to actually have control over all parameters at once, envisioning notion a meta- structural view of parameters.

At the same time, the question of an adequate human control over these processes and human-computer interface in digital environment remains open, as the importance of interaction within the scope of compositional process increases. In this context Horacio Vaggione [2001] suggests a revision to definition of compositional process. He refers to the perception/action feedback loop, a "live" compositional process that involves regular revision of results by composer, possibly in realtime, in order to evaluate and make corrections and decisions. Composition can be compared to a performance-like situation, in which the sonic output of the system might be utterly dependent of the user input. Within this type of environment "The role of the composer here is not one of setting a mechanism and watching it run, but one of setting the conditions and that will allow him or her to perform musical actions" [Vaggione, 2001]. We arrive at the notion of a complex ecosystem where composer-computer interaction becomes a crucial element of compositional process. Following, the kind of composition environment evolves towards responsive environment, operating which, to some extent could be compared to playing a musical instrument.

On Musical Atoms

With the evolution of the music, the composers have attempted to access the continuous flow of music by way of subdividing it into ever-smaller units that would be easier to arrange in various musical forms. In the traditional music, this atomistic view is expressed in the note as the elementary particle of the building of music. In the realm of electronic music however, the idea of note has been subsequently morphed into different notions in regards to particular perspective on musical material and available tools for its construction. We can see in the practice of the "Elektronische Musik" founded at the Köln WDR radio in 1950s, how Helmholtz's theory of acoustics and waves has contributed to the musical ideas in works of composers as Karlheinz Stockhausen and Gottfried Michael Koenig. They were the first to arrange pure waveforms, discrete frequencies in order to achieve sounds that are more complex. With the introduction of the digital computers as tools for creating music, we can see the evolution of this idea in the reference to the technology being applied for the sound production. In computer domain, sound is produced by means of synthesis of electronic waveforms that are transferred to acoustic domain by the way of DA conversion and amplification. Also here we can follow the path that continues atomistic view on sinewaves to the implementation of Fourier analysis and synthesis by looking at complex spectra as addition of sinewaves of certain frequency amplitude and phase values.

In parallel, a complimentary view arriving from the scientific proposal of Dennis Gabor [1947] exists that sound can be constructed from even smaller units - acoustic quanta that is scattered across time.

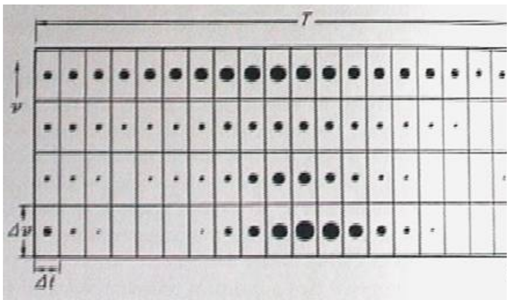

Fig. 1.1 Gabor matrix

The different models that represent different accounts on the sonic phenomenon all have in common the atomic view of sound as composed of smaller elements: frequencies, sonic grains, down to the subatomic level of a single sample. Similarly, when expressed as synthesis models, these views introduce separation between the specific synthesis processes themselves and their controls or input parameters.

> *"In electronic music, every technique of synthesis is controlled by a number of parameters. This invites a process of composition based on a parameter variation." [Roads, 2001]*

While the line connecting western instrumental music tradition and computer music is certainly more complex and varied than described here; we can observe how the compositional focus that was once on organization of notes has now shifted to organizing parameters in contemporary computer music. Both, the instrumental notation and parametric view have in common the possibility to manipulate compositional material "*separated from the production of sound in time*" *[Roads, 2001].*

The effect of this abstraction process is that two aspects can describe the musical sound: the production mechanism (instrument or synthesis model) and the parametric instruction of utilization of the model - control of its properties. These instructions, ordered in a temporal dimension become a score. In this light the evolving parametric structure can be seen as the DNA of music – an exact recipe containing the information necessary for its creation. This comparison to genetic information should not be understood literally but rather as an analogy of a principle. While the genetic information has strict grammar and optimal rules of "code", the rules of musical creation are freer. They permit a situation where different methods and "recipes" can achieve identical or very similar sonic results. The particular approach that implies separation of a sound production model (synthesis) and a timed structure of the control parameters (score) has found a wide acceptance and implementation in the current day computer music environments such as CSound [Fitch, Vercoe], ACToolbox [Berg, 2007], Supercollider3 [McCartney, 2001], where the score part can be described as explicit parametric values or as algorithms that generate the values, involving the element of (constrained) variance and chance.

On Parametric Information

There exists a history of the analytic view of music (note, frequency, spectra, sound particle etc), in parallel with methods to organize the musical material based on this analytical view. In this context, a stream of electronic music considers parameter as the elementary composition unit. These developments and the possibility to separate sound from its description has contributed to the emergence of parameter as the central material of music composition. The advancement of the analytic view has contributed to the increase of complexity and the amount of information involved to describe the creation of sound. Recent developments in computer music are concerned with the microsonic structure and texture of the particle field. With the granular synthesis technique a sound particle at its creation is described by number of synthesis parameters and adding the number of grains per time unit, the amount of this parametric information grows. Given that hundreds of particles occur every second, each of whom contains several parameters, the amount of parametric data increases dramatically. At this rate of the dataflow, it might be hard to realise the causal relation between parameter constellations and the resulting sonic structures, as the possibilities of combination are nearly infinite. These multidimensional relationships obviously exist but can be inconceivable due to the nature and capability of our cognitive system.

On the other hand, compositional practice implies adequate degree of the understanding of the structure of the material. To have control of creation and contents of the parametric field, a composer prefers to be aware of the processes at each possible level, in order to shape and provide constraints to the algorithmic operations. The necessary precondition of control is cognition of the structure that we want to influence, in compliance with the analytic model of process in question.

The factor of steep increase in data rate is a unique situation in the context of musical composition and poses new challenges as well as new problems that require special methods to address them. In my view, the complex parametric structure can be compared to a genetic code of music: a description of a constitution that originates the existence of a particular sonic event. Therefore I find it appropriate to consider these various types of parameters that serve to construct music, to be categorized under the general term of information.

Most of the contemporary electronic music can’t be imagined without the use of digital computers, where the information is the mater that computers process and produce. Once we use a device that is built around this concept as our main tool for music production, it is logical to conclude that the music shares close ontological relation with information. Furthermore, one might as well argue that within this process at least some part of the music has to be or to contain information or even data, as we will see in further analysis.

As the composition of electronic music largely takes place within the formal environment of a computer system, it is plausible to be aware of the compositional process in the terms of this context. When dealing with this type of materiality within a musical context, we can employ the knowledge and methodology that these disciplines have accumulated for effective treatment of information.

An immediate benefit that arrives from the justification of the parametric layer of music as information is the wide arsenal of methodology of working with information that becomes available for the assistance of composition. An array of disciplines of information science and technology address the various aspects of the very concept of information. By way of refined adaptation of this knowledge, the operations with parametric information can be improved in several aspects:

Providing an analytical view and aid to cognition of parametric structures, by application of appropriate methods of information design, information visualisation, information architecture and cognitive science.

Morphologies of parametric structures can be discovered by way analyzing and establishing multidimensional similarity patterns with aid of knowledge originating from disciplines such as statistics, data mining and mapping algorithms.

Modes of interaction with compositional material by means of improved interaction strategies, Human-Computer Interfaces and physical interfaces.

Of course the knowledge of these disciplines can cot be transferred directly and carelessly, as Vaggione warns us, *"Music cannot be confused with [..] a formalized discipline: even if music actually uses knowledge and tools coming from formalized disciplines, formalization doesn't play a foundational role in regard to musical processes."* [Vaggione, 1999]

Consequently, we cannot remain immune to the implications that this process involve, as the specific setting of working with information in computer environment imposes specific uses, possibilities, interaction scenarios and so on. Even more, I think that we have to be very conscious of this fact and, while recognising and keeping track of its consequences, also be aware of the transformations and corrections that this change brings into process of music production itself. While the general idea of musical composition remains intact, the tools that we use to create it do have impact on the outcome to a certain extent. A part of this effect can be attributed to the available modes of operation and the way in which we approach the process that has a great impact on how we write and listen to music. In other words, the tools and ideas that we use, inevitable shape our modes of action, our perception of the process, and our behaviour in this setting, while the available arsenal of operations, define the modes by which we use the tool.

2 *Information*

Before continuing the discussion of the musical information, I would like to discuss more general concept of the information itself.

Information is such an omnipresent category that it would be hard to imagine our world without it; to the extent that since 1960s researchers agree on the term “Information Society” when referring to our social organisation *“... where the majority of employees work in information jobs, i.e. they have to deal more with information, signals, symbols, and images than with energy and matter.”* [Otto, Sonntag, 1985] In distinction from the Industrial Society,

> *“An information society is a society in which the creation, distribution, diffusion, use, and manipulation of information is a significant economic, political, and cultural activity. The knowledge economy is its economic counterpart whereby wealth is created through the economic exploitation of understanding.”* [Wikipedia, 2007]

But what is the matter that takes increasingly central role in many aspects of activities of our civilization? What is the content and structure of this substance? However, finding the definition of the answer is not an easy task. While the semantic jungle of this term is too wild to be described here in detail, there is a general agreement among researchers of fields from information philosophy to information theory that the term itself is quite ambiguous. As Claude Shannon, one of founders of the information theory, notes:

Fig. 2.1 Information?

"The word 'information' has been given different meanings by various writers in the general field of information theory. It is likely that at least a number of these will prove sufficiently useful in certain applications to deserve further study and permanent recognition. It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this general field." [Shannon, 1993]

Due to the polymorphic nature and polysemantic content of this ever-present phenomenon, its definition is largely dependant on the context in which it is observed, as well as from position of the observer and the discipline that envelops the discussion. Still, regardless of these ontological uncertainties we can arrive at more or less usable functional definition:

"Information is the result of processing, manipulating and organizing data in a way that adds to the knowledge of the receiver. [..] the concept of information is closely related to notions of constraint, communication, control, data, form, instruction, knowledge, meaning, mental stimulus, pattern, perception, and representation." [Wikipedia, 2007]

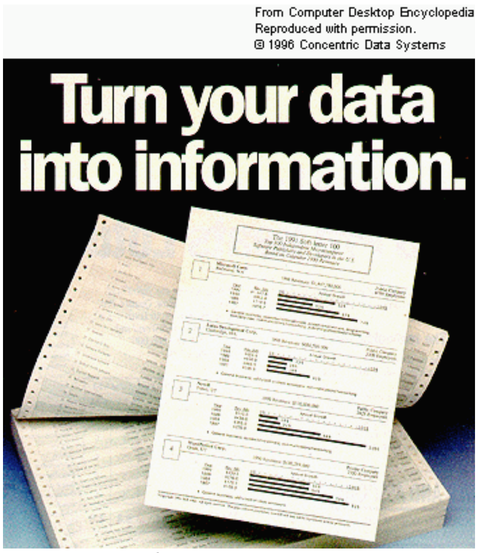

Fig. 2.2 Information vs. Data.

In addition to that, in the scope of this thesis I'll provide an definition that seems satisfying in a musical domain, comprised of several aspects:

- Information is a message or description that is encoded and carried by a physical property of matter (substance or field).

- Information implies a certain structure and organization that uses the code familiar to the receiver, though its forms can vary (can be expressed in different ways and carriers). Otherwise, we can arrive at a situation, described in the story of Jorge Luis Borges "The Library of Babel", where the wealth of all the information in the world is rendered absurdly meaningless by the absence of reading instructions of its code.

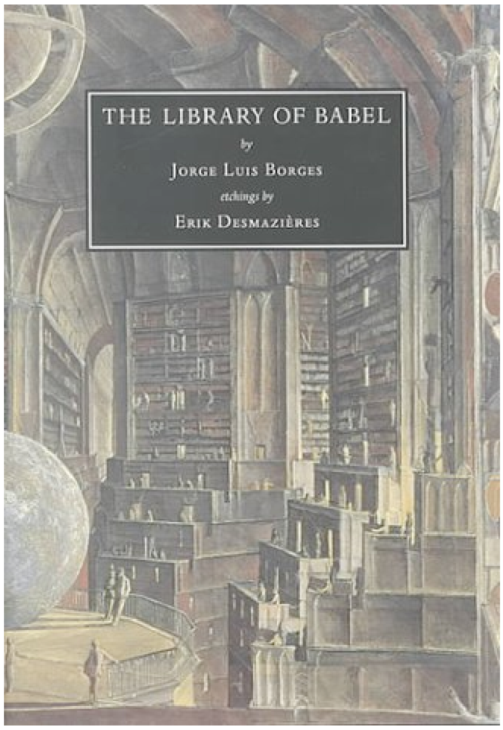

Fig. 2.3 "The Library of Babel" by Jorge Luis Borges (1941)

- The data becomes meaningful information from the position of receiver, if it is transferring some knowledge that is also relevant to him/her. In this respect, I would like to discriminate between info and data, although they are often used as synonyms, they are actually not. The term comes from Latin (*datum*) and can be approximated as "given". Data is raw material, whereas information implies organization and meaning, in reference to subject that acquires knowledge from information. Though data has a potential to become information.

Aesthetics of Information Society

Inevitably, a change of the size of transition from the industrial to information society couldn't pass without causing an impact on the culture and the arts. It is evident that since the second half of the 20th century a stream of artistic practice has emerged that utilizes knowledge – as the product of information society - of most diverse disciplines for creation of novel artforms that no longer can be addressed from the modernist perspective. Since the forms are as diverse as the knowledge heritage of our civilization, it makes it particularly difficult to classify them.

The discourse of information and its use is certainly of great importance here and in this context it's interesting to look how different authors comment on these aesthetic developments. One of attempts to give an account of these creative practices is Stephen Wilson's book titled "Information Arts: Intersections of Art, Science, and Technology" [Wilson, 2002] that provides an extensive survey on the artistic practice dealing with scientific ideas and tools. His definition of the information art could be summarized as art that is makes use of knowledge, the key product of information society, and tools and methods based on this knowledge. He continues with categorization of the most diverse examples of these practices from virtual reality to genetic engineering and on, based on the scientific/technical medium that they relate to. As the combinations of mediums, technologies and knowledge are infinite, by following this scheme, we could arrive at situation where nearly each of the works would call for its own category. Lev Manovich in the article "Post-media Aesthetics" from the manuscript of the book "Info-Aesthetics" criticizes the categorization as unable to keep up with the multiplicity of the forms of new art practices:

> *".. cultural and technological developments have together rendered meaningless one of the key concepts of modern art – that of a medium. The assumption that artistic practice can be neatly organized into a small set of distinct mediums has*

> *continued to structure the organization of museums, art schools, funding agencies and other cultural institutions -- even though this assumption no longer reflected the actual functioning of culture"* [Manovich, forthcoming]

Further on he calls for a devise of a new topology that would be apt for artistic practice within the society, whose central product and consumption is information.

Materiality of information: Bits and Atoms

While the means and for obtaining processing, storing and transmitting information have their material appearance, the information itself is a rather a semi-immaterial category. Information is linked to reality by the need for a material carrier or media to be expressed. While the means and for obtaining processing, storing and transmitting information have their material appearance; the information itself is a category that exists as middle layer between "hard" reality and the immateriality. It reflects upon reality in two ways, as instruction that can describe something that exists or has existed, or something that has a potential to become existent. To the later case, we can relate such examples as architectural design, genetically modified DNA structure, musical score and so on; something that has a potential to acquire a physical form.

The particular structure of information represents a certain tension of material duality between information and its manifestation physical form. A part of this discussion has been addressed as opposition of "Bits and Atoms" by Nicholas Negroponte in his book "Being Digital" [1995].

While bits need atoms for their existence, but in many aspects bits are superior to atoms in terms of easer transportation, ecology, but above all, bits are much more easier to manipulate shape and create. We can look at this situation in the following way: analyzing the stages of how information links its material appearance to manifestation as knowledge in the consciousness:

Layer	/ Domain
Medium	(Physical, material)
Encoding	(Field, Analogue)
Data	(Digital)
Information	(Construction of data)
Message	(Interface)
Knowledge	(Understanding)

Ultimately, due to this property of material mobility, human have realized that the ability to create, manipulate things at information level gives incredible capability and increase of productivity and precision, provided that there are ways to transfer the information structures to reality. This capability is successfully developed at production of sound and image, perhaps because they themselves can be seen as signs that have closer relation to information. This transfer to reality or time, is obviously more complicated with hard material things, but there are developments in this direction as well - things like 3d printer, smell-printer and similar that actually turn information in something tangible.

Musical Information

> *"In this music, the role of the composer is to create a pattern of acoustic sensations in the form of a code that organizes them into a meaningful structure.[..] The intellectual challenges and emotions experienced by the composer in creating the structure may be very profound and intense (or not). In any case, they are independent from those experienced by the listener. " [Roads, 2001]*

As any work of art, music as well, takes place as individual experience in the space between the author and the listener. From the composer's side this plateau is described by his/her musical intentions, projected via his/her cultural experience. Whereas the listener, absorbs the musical content via the prism of his/her expectations that are formed of cultural, emotional, personal, collective experiences. Both contexts, the listener's and the composer's, do not necessary coincide, as the piece of music thus happens somewhere on the vector between these two poles. Yet, the apparent separation doesn't distract the musical enjoyment, but rather witnesses the broadness of interpretation of a musical content and suggests the existence of universals that resonate across diverse cultural backgrounds. This phenomenon is particularly characteristic to the music as being probably the most abstract of the arts, since in distinction from the literature and visual art, almost no explicit signs and symbols are communicated, rather the sounds create vocabulary of their own.

Regardless of this blurred communication situation within music, from a compositional point of view there is a content of musical information that we can analyze from rational disciplines. In this respect, I would like to propose a distinction between at least three conceptual layers of information of music:

I The musical information that is rendered to the physical reality of acoustic domain, and comprised of technical (such as frequency, amplitude, phase, spectral content) and perceptual (such as pitch, loudness, timbre) qualities that can be either perceived by listening or analyzed by quantitative approaches and technical means and thus considered to be objective to certain extent in the sense that same analysis would always provide the same results.

II The structural information that is not necessarily (although it might be) transferred acoustically, but rather constitutes the framework for the acoustic information to be created. In other words, this layer refers to the intelligent structure that was used to arrange elements into continuum of musical composition and the set of instructions that were used to create the physical sound.

III The higher semantic and artistic content of the music that communicates the meaning and the composer's intentions.

Luckily, one cannot draw a sharp line between these three, as in a practical case of music composition they are interlinked. Inevitably, a strong correlation between all layers information exists, as together they constitute a musical composition, yet for the purpose of analytic approach they can be observed separately. While not underestimating the importance of the other two, this thesis mainly focuses on the layer of organizational information that represents the composers' perspective, within the realms of electronic music.

Musical Intelligence and Quantitative Information

The perspective on music that employs the concept of information is not a new idea. In the 1960s, the circles of new music were inspired by the Mathematical Theory of Communication (MTC) [Shannon, 1948] that regarded information as a technically quantifiable, measurable entity for determining the transmission capacity of a channel and the technical redundancy of data. On these grounds Meyer-Eppler, with whom Stockhausen studied information at the Bonn University, described Gabor matrix in the context of measuring the information content of audio signals. Latter, it was suggested to apply Shannon's theory to aesthetic problems in music [Moles, 1968]. The Serialist proposal, based on the information theory was to segment music into small units to measure information content and expressed the view on music as a stream of single elements, comparable to a signal of encoded data.

While the quantitative approach could be useful to describe an acoustic signal, as the actual sound of music is expressed by amplitude fluctuation of the acoustic wave (one-dimensional at any given instant); except the physical properties of the carrier signal, little it says about the music itself and the compositional ideas behind it's creation. In the light of the catalogue provided above, this approach refers to I layer of musical information, the acoustic reality. In the context of musical information, I would argue that the music is probably not the signal itself, but rather something (meaning) that is carried by that signal that is decoded by our aesthetical, cultural and acoustic expectations.

On the other hand, Xenakis expresses *".. the overriding need to consider sound and music as a vast potential reservoir in which a knowledge of the laws of thought and the structured creations of thought may find a completely new medium of materialization."* [Xenakis, 1991] And suggests the intelligence that is semantically linked to knowledge, as a measure for *"validity of a particular music"* [ibid.]. If combined, both of these quantitative and qualitative approaches provide us with a full picture on the phenomenon of musical information.

Architecture of the Musical Information

In a rational composition situation, we can recognize ontological levels that constitute music: of musical idea that exists as intention of the composer, musical information that as formalization of idea, and the actual formalization of the two above as physical sound. The musical information in this regard can be seen as certain type of in-between state of music, the one that functions as interface between the musical ideas and intuitions (immaterial) and their fixation in a finite form of physical sound (as property of a material / field). While the material properties of the information itself opens up a wider discussion, the "physical" existence of information is manifested as values transmitted by encoding of data into a physical medium such as Compact Disc and can be transferred electronically as digital signals.

In the course of my study, I'm mainly concerned with the 2nd layer, the compositional information that is used to organize the vertical (structural) and horizontal (temporal) aspects of a musical piece.

The information layer can thus be seen as a formalization of general higher-level musical thoughts; the formal interface is the necessary bridge that that leads to the consolidation of the musical thought as sound. Here I'm suggesting that these considerations should take place also on a compositional realm where information can be seen as a general construction that gives birth to the physical appearance of the sound. In this light the setting the composition process can therefore be approached as the design of compositional information, architecture of data structures and objects into continuum that describes the process necessary to execute a musical piece. By this way, I feel that various subjects and issues of composition can be effectively accessed from the perspective of information.

Sources of Musical Information

In a compositional setting where "process results in structure" [Roads, 2005], the computer music is concerned with a creation of a coherent information structure that can be arranged in many diverse ways. In fact, the various generative strategies can be seen as meta-information: instructions that create instructions of how to generate functions to be written to DA converter of a computer. The origins of this meta-information can be seen as arriving from two general sources:

Sampling

A group of work takes a path that can be related to the sampling approach, when transferred to information domain. Here, information is derived by sampling of data source that describes a real event (not necessarily acoustic) such as seismological activity or meteorological records or stock market data and so on. The information is acquired by recording or reading data and stored for processing.

Generated (abstract)

We deal with the abstract information on a higher level of organization, when the material we work with is not in it is final form, but rather describes the possible rules for its creation. Xenakis [1992] refers to this compositional situation as creation from nothing (ex nihilis), but this is not a plain nothing as it usually derives from some previous knowledge of cultural or scientific background.

In electronic music there has been a lot of interest in adopting concepts from scientific disciplines, mathematics, physics, biology and others. There are numerous examples of the use of these algorithms in composition: Chaotic attractors, algorithms of population growth, cellular automata, Lindenmayer-Systems, particle physics and so on, all kinds of things.

Both of these information sources can quickly yield to a large amount of data. At one point of working with these data sets, the amounts become too large to be understood, either due to dimension or number structural complexity. At the same time, the interest to use the sophistically created data is the hope that they reflect some sort of structure that is musically meaningful, as opposed to plain randomness. It is also true that in order to effectively manipulate and organize information, we need to gain substantial level of understanding of its structure. This aspect becomes increasingly important when we depart from the processing where we deal with formalized information for example editing a picture or sound; In other words, in processes where information is not yet in the form of interface and ultimately, the result as it is the case with generative parametric data.

Here, the recognition of the parametric field as information can be beneficial to music composition, as we can employ strategies from the disciplines of Information Technology that has aggregated significant amount of knowledge just about every aspect of this notion of handling information, from its creation to delivering this knowledge to human consciousness.

Interface to Understanding

In order for data to provide knowledge and become informative to someone attempting to understand the underlying process that the data describes, we need an appropriate interface that bridges the numerical output of the digital machines to our cognition. With the advent of computer technology and information systems, the amount of data available for exploration has increased exponentially. Immediately specific ways and rules are required to design and organize information and effectively represent large structures of data.

A number is one type of symbolic representation that is efficient up to a certain threshold. It has been observed that our perception has certain cognitive numeric limits, a number of elements that it can effectively process (count, memorize, understand etc) at an instant. Hypothesis states that the optimal numerical limit might be 7±2 elements [Miller, 1956]; and is followed in design practice when creating information layouts. While this is probably not the actual limit in the case of musical parameters, the finding demonstrates that some limit exists. When it comes to larger structures in order of hundreds or thousands of elements as, the amount of processed information dramatically increases with the rise in power of computation, we are rather interested to perceive the organisation and distribution of units and relations than the exact values themselves.

To communicate information and the meaning it represents, it is often more efficient to employ senses than to use symbolic operators as words or numbers. While a page of text or a spreadsheet full of numbers can be very informative if studied carefully, these types of representation become less usable in a realtime scenario, when we are rather interested in the overview and the general constellation than the local values of information volumes. It is by the way of an interface that a seemingly complex and senseless data can acquire meaning and inform the mind. And the only human interface we have through which anything can enter a human mind is our five senses (six if we include intuition).

Out of our senses, hearing and seeing are the two most capable of decoding information. Each of these are sensitive to different tasks and types of information, organisation: we can hear what we can't see and vice versa. Each of these senses has its specialties due to which it's more appropriate to use one or another.

Information and representation: Sonification & Visualisation

To address this particular question of data representation, information science has long been concerned with question of human cognition of large and/or complex data structures. Several approaches have been proposed to address the various stages of cognition process. A group of these practices addresses the understanding of information itself, while the other concerns the transmission of information to human cognitive channels. Undoubtedly the ones which have the most capability of receiving information are the visual and auditory channels. Both of these perceptual categories function differently and are capable of handling different stimuli, and are capable of delivering differently formatted information and different amounts of it. In essence, they function complimentary: to deliver us full picture of the environment we are in. While the sonic perceptual channel is certainly best capable of specific tasks and perception of specifically encoded information, these practices often emphasise the capability visual system of perceiving structures and organisations as well as large amounts of data.

The two most often applied methods of data representation are visualisation and sonification, where the visual and auditory senses act as interface that translates the data to the human consciousness. While the sonification would be redundant in the case of musical composition, the visualisation can greatly enhance our understanding of information structures. This idea is expressed very clearly

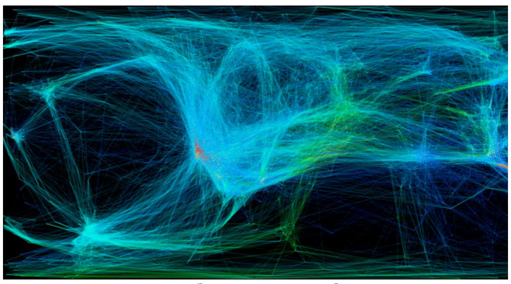

Fig. 2.4 Visualization of Music Relationships & Social Network

information structures. This idea is expressed very clearly in a paper by Colin Ware, an expert in the psychology of perception:

> *"Why should we be interested in visualization? Because the human visual system is a pattern seeker of enormous power and subtlety. The eye and the visual cortex of the brain form a massively parallel processor that provides the highest-bandwidth channel into human cognitive centres. At higher levels of processing, perception and cognition are closely interrelated, which is the reason why the words "understanding" and "seeing" are synonymous. " [Ware, 2000]*

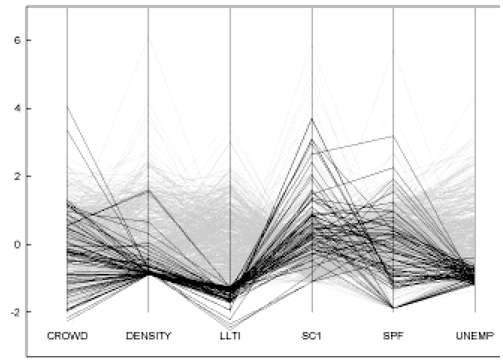

Fig. 2.5 Visualization of relationship in six dimensions (in Parallel Coordinates)

Due to the complimentary nature of our perception, the addition of the visual channel to a especially realtime composition setting helps to conceive and memorize the sonic structures in relation to visual organisations and thus contribute to the learning process and improve the ability to recognize the causal understanding between parameters and sonic results.

Another group of information science that deal with cognition addresses the issue of data itself. As the amounts of data increase, the harder to find pattern and meaningful information, in other words, to provide us with knowledge and understanding from the data that describes the process in question. This task has been examined by disciplines such as Data Mining, Information architecture, Information design. The last is the most complete concept, as it concerns the whole process from data to understanding [Fry, 2004].

3 *Space as an Interface*

As soon as we enter the visual domain, the notion of space is inevitable, as we know that the natural environments are spatial and have three dimensions that we mainly experience by the visual means. As is the case with all of the general notions, there is not a single definition of space. The world of human habitat is experienced as multi-sensory environment, where different sensory stimuli are combined and weighted in order to obtain knowledge about the spatial environment of our location. An important aspect that envelops out our understanding of separate events and elements is space. Objects, sounds, images, smells are attached certain locality information, and placed in a dimensional environment, that combined establishes our perspective of reality. Thus, concept of space functions as essential framework for understanding.

Our understanding of space is a construct that to envelops the cognition of reality, and since we are living inside of this notion, we are incapable of looking outside of it. Nevertheless, the concept of space is deeply rooted in our consciousness, to the extent that it is one of the main categories of cognition of reality: we cannot imagine anything that is not in space, though we can think of objects separately [Kant, 1988, originally 1787].

Otto Rössler, a physicist famous for his work in chaos research suggests the discipline of Endophysics that explains our world of space-time as an operational interface [Rössler, 1998] to a larger reality beyond the capability of our consciousness existence of which might explain the fundamental problems of physics and quantum mechanics.

Many fields though use an operational definition, in which the units of measurement are defined, but not space itself. Hence our analytic understanding of space originates from Euclidean geometry (ca. 300BC), as described by five postulates in his writing “Elements”. Over time, with the advancement of exact sciences, the notion of space evolved as well. The Euclidean principles were further formalized in the idea of Cartesian space, proposed by the French philosopher and scientist Rene Descartes (1559-1650), who developed the use of coordinate system to locate a point in two or three dimensions, which we still use today. In part two of his “Discourse on Method” Descartes introduces the system of specifying the position of a point or object on a surface, using two intersecting axes as measuring guides. In “La Géométrie”, he further explores the above-mentioned concepts. Space became discrete, linear and normalized with the invention of the meter. Other kinds of geometry (non-Euclidean) were proposed in 19th century; and notion of spaces with higher (larger than three) number of dimensions were suggested.

Fig. 3.1 Dimensions of freedom (0...4)

More recent research searches for description of the space not in a geometrically hierarchical sense but rather as a network of relations and intensities. Besides, different approaches to degrees of dimensionality and definition of space co-exist, describing those are beyond the scope of this thesis.

For the practical application, I am considering space, as we know it from the natural environment, as having three objective dimensions that can be measured with linearly units.

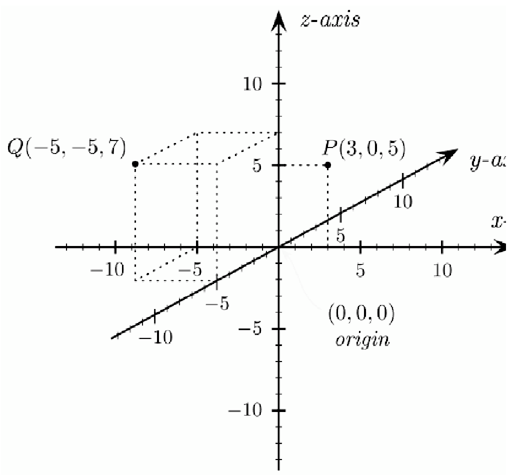

Fig. 3.2 Coordinates in Cartesian space

Encoding and Memory

Through the history, the concept of space has been considered to be an effective aid to encode, represent and store information; largely, due to familiarity of this concept to our perception and its dimensionality. An early application of this property is used in Abacus, a primitive calculation device, where numbers are represented by spatially positioned keys.

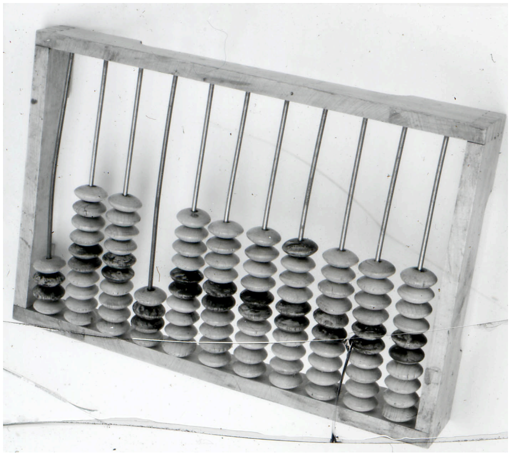

Fig. 3.3 Abacus.

More recent application example is Punch card, used in early days of computer technology; the presence or absence of a hole denotes the bit state in respective locations.

Needless to say, that spatial principle of representation of information has found a wide use in input and output devices of computer systems - mouse, keyboards, screens and others.

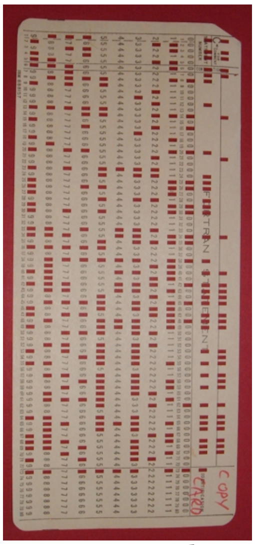

Fig. 3.4 Punch card in the binary format containing a self-loading IBM 1130 program.

In addition, spatial understanding seems to be linked to memory. We tend to remember things and thoughts in the context where they are occurring. The spatial context functions as the perceptual framework for the events to happen. Method of loci or *Ars memoriae* has been practiced since Classical times, when before Gutenberg's invention of production of books, human employed the mind's ability to memorize at much larger capacity.

In 1520 Dominican monk Johannes Romberch published "Congestorium artificiose memoriae", a book on various memorizing techniques, using spaces and images. Monks of medieval orders used these memory techniques to remember long passages of text, by placing words of a long text or speech in rooms of an imaginary building and associating with objects. The reading of this information then becomes a journey through the space that forms context and contains links to the memorized objects. To recall a writing, one made a walk through the chambers of an abbey, as reading a book, page after page.

Fig. 3.5 Mnemotic system with abbey
(Johannes Romberch: Congestoriu
Artificiose Memorie, Venice 1533).

Musical Space

Our concept of space in the natural environment is such a powerful metaphor to aid understanding that it has been found to be beneficial to describe various aspects of music as well. As one might argue, there probably is no “Musical space”, and indeed, we cannot prove existence of such thing as well as we cannot prove the opposite. Instead, the concept of space in music functions as an idea and a mental construct that helps to arrange and realise relationships within musical material, by analogy to organization of a matter within a physical space. We can speak of a space in relation to music, as indeed, a sound wave needs matter of certain density and volume to be transferred, and time to facilitate velocity of particle motion. Organization of sonic objects and fragments, arrangement into the continuum of musical composition resembles operations of architectural design. Thus, in musical context the notion of space can mean at least few things: a compositional plateau, waves of sound travelling in space by aid of spatialization techniques, control space of musical parameters, acoustics of music halls, etc. In this ambiguous situation, I would propose that the application of space in music fall in three general categories:

- Acoustic space - the spatial aspects of sound as interaction with the environment where it is produced – an architectural aspect of sound. There is of course a rich tradition concerning sound and space in the sense of acoustic aspects of placing sounds in context of physicality of an actual room. With the appearance of amplification techniques, this aspect of music is also composed, as the use of multiple loudspeakers allows for spatial distribution of sounds within a room.

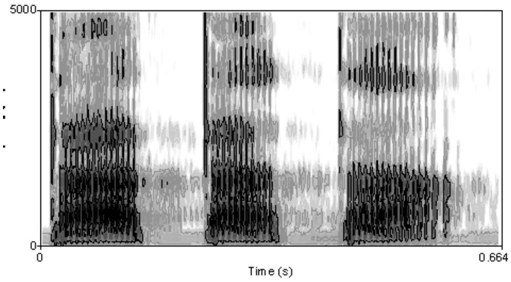

Fig. 3.6 Sonogram of a voice.

- Representation Space – the concept of space is used as an interface for representation of a musical (sonic) information. Here, the display of information is facilitated mainly in two-dimensional interfaces. (i.e. oscilloscope, vectroscope, waveform display, sonogram etc).

- Space as compositional approach. A compositional space where spatial ideas are applied on a more metaphorical level, space functions as a compositional tool to organize structures of musical information. The notion of space is used to facilitate the architecture of musical thought in composition of various elements that constitute music (sounds, parameters, etc).

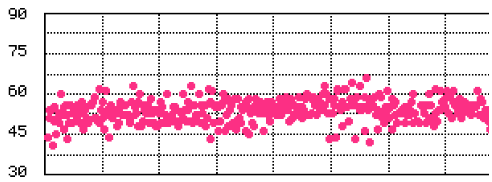

Fig. 3.7 Two-dimensional space displaying parametric information as a result of an algorithmic process in the ACToolbox software environment [Berg, 2007]

Evidently, there is a close link between the category of information display and the respective compositional approach. One of the most common examples is the musical score, where pitch heights are placed across time. The score not only to represents pitch and duration information, but also a certain compositional milieu, where the composition takes place as organization of notes within the given grid-space of the score. In the course of this thesis, my focus is primarily on the notion of space that is used to facilitate organisation of musical parameters and their dynamics over time (motion), at the same time providing display interface, to support intelligibility and causal link between parametric constructions and resulting sonic events.

As is the case with an architectural space, musical space as well has degrees of dimensionality. We know of examples that have one degree of freedom such as pitch space or scale or, a single parameter of certain range. Musically more interesting in this respect are two-dimensional applications, known as parametric space and used to structure information for sound generation. Traditionally, the horizontal axis is used to represent time as it is inherited from the graphical image of score. Similar approach is expressed in interfaces that hold parameter values such as tendency masks and screens [Xenakis, 1991].

In the book “Cahier <M>” [2000] Dick Raaijmakers describes a compositional technique for arrangement of microtime events in making of his piece “Canon I” (1964). The diagram below illustrates rotation of vertically aligned *“sound-points”*. The different rotation angles result in phase shift (time delay) between occurrences of the events, when projected on the time axis. It is interesting how in this example Raaijmakers introduces spatial thinking in composition by employing of purely geometrical (spatial) operation, as is rotation, to arrangement of abstract sound material that traditionally is not conceived as dimensional. But without the notion of dimensionality this operation would become impossible to perform.

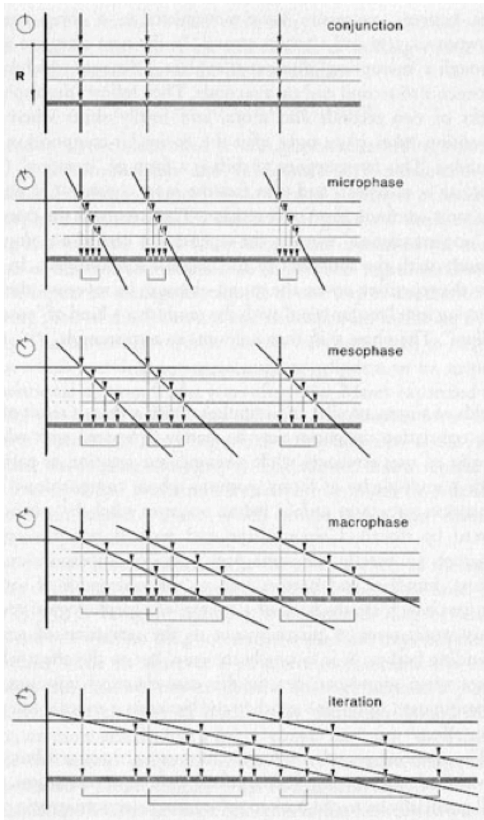

Fig. 3.8 Five categories of translation:
conjunction, microphase, mesophase,
macrophase and iteration

It is also characteristic that composition employs certain interpretations of notion of space in the arrangement of musical elements by using explicit visio-spatial metaphors.

musical elements by using explicit visio-spatial metaphors. One of such examples is the famous UPIC system envisioned by Iannis Xenakis that allows the composer literally to draw the elements of the score using an electromagnetic pen.

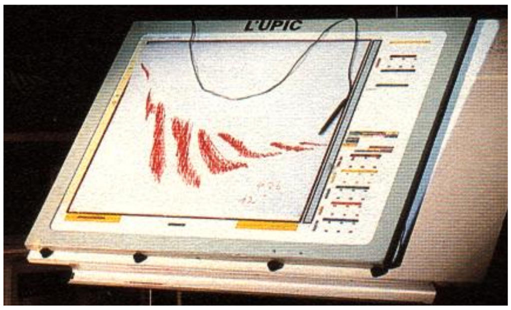

Fig. 3.9 The UPIC interface

> *"... the first version of UPIC was built by Xenakis' research centre, the CEMAMu, in the late 1970s. Instead of a keyboard to perform the music, the UPIC's performance device is a mouse and/or a digital drawing board. These are used to trace the composer's graphic score into the UPIC computer program, which then interprets the drawings as real time instructions for sound synthesis - the composition/performance of a graphic musical score and real-time sound synthesis are unified by the UPIC's approach."* [Mode, 2001]

The first work composed for the new system was Xenakis' "Mycenae Alpha" (1978), based on a two-dimensional graphical score was translated to spectral content.


Fig. 3.10 Graphic UPIC score from "Mycènes Alpha" (1978)

From the compositional point of view, other works of Xenakis are probably more interesting for a spatial analysis. In Metastasis (1953/54), the space where composition takes place is three-dimensional, therefore allowing for more refined spatial operations and transformations. In the dimensional setting where the particular piece takes place, a curved surface is described by use of straight lines (string glissandi). Clearly, Xenakis' technical and architectural background has strong corelation to this music, as few years later he uses similar folded surfaces in the design for the structure of Philips' pavilion in Brussels (1958).

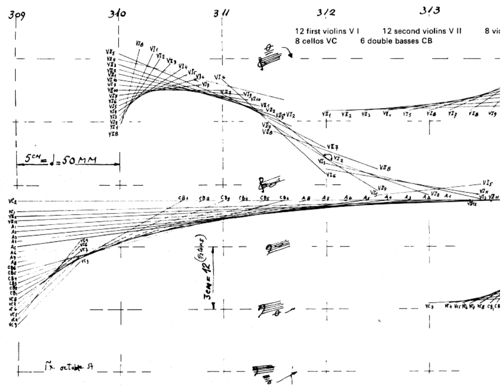

Fig. 3.11 String Glissandi, bars 309-314
of "Metastasis" (1953/54)

Another composition employing spatial thinking of organization of musical material is the "Nomos Alpha" for cello. Here, besides sophisticated arrangements in Outside-Time structures, the organization in-time are determined by rotational transformations of a cube. The provided kinetic diagrams illustrate the development of temporal transition.

As we can see, the notion of space has been applied in the work of composers in the past. In the recent years, at least few of my colleagues, students at the Institute of Sonology [Trützschler, 2005; Woltsovitch, 2006] have suggested the use of spatial metaphor as an approach to music composition.

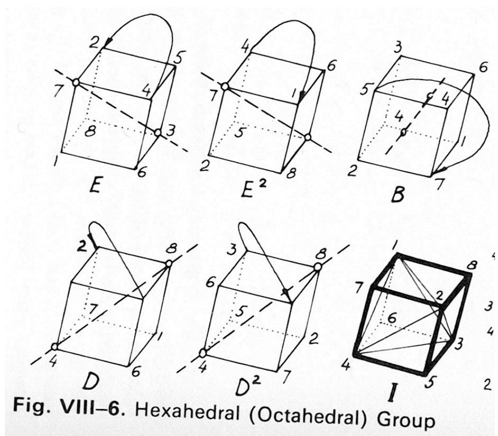

Fig. 3.12 "Nomos Alpha"
Organization in-time

4 Towards the Environment for Spatial Composition

The combination of concepts of information and space in the context of musical composition led me to the notion of a composition process based on design of multidimensional information that is encoded spatially and represented visually. While there are numerous possible realisations of such an approach in a software environment, the following description reports on my research in the implementation and practical utilization of the particular software environment that I have designed as a practical examination of these ideas.

The QuantaSonic environment (title refers to the quantum approach to sonic events) addresses the issue of organisation of complex volumes of parametric information that control synthesis processes within a parameter-based music composition process. The environment is a compositional tool that produces sound in realtime and can be used in studio as well as in performance situation.

In the context of the system, the information provides for compositional material in a space that functions as a facility to organize and shape the information to form a musical structure. The parametric structures within the environment are encoded into a spatial form (a three-dimensional shape) according to a geometrical grammar.

The spatial information describing these forms is linked to the sound production mechanism in such a way that the spatial modulation results in change of the control parameter values of the given synthesis model. The application of the algorithmic processing applied on the structures of parametric information renders to immediate sonic results. Added to that, the spatial structures are displayed graphically in a way that contributes to the causal understanding of the link between multidimensional parametric organisation and the resulting sonic event, thus allowing for visual feedback of the control structure.

General principles

Following the idea that the space can represent information, the spatial interface extends in three dimensions. Spatially encoded information here is the central object of the system. By application of various space-related transformations and algorithms, the design of information is realised.

This organisation of information determines the parameters for the synthesis processes and resulting sonic events, while the organization is simultaneously reflected via system's visual output that is responsible for cognition and monitoring of underlying information structures. The realtime properties of the environment forms the perception-action feedback loop [Vaggione, 2001] as crucial element of composition process, enriched by visual information channel as addition to the sonic.

Within this system I define a few principles:

- The information is the central object of processing and compositional manipulation. The outcome of this manipulation is translated to two different perceptual domains, acoustical and optical.

- Due to this specific installation, neither the visual output is derived from the acoustic, nor vice verse. Both of the perceptual outputs of the system are interpretations of the compositional information (object), thus the discussion of “which was the first” is rendered useless.

- The both perceptual elements are related and to certain extent synchronous because they both share the same origin: information object.

- The translation here is made in such a way, that it contributes to cognition of information organization and understanding of causal relation to musical output produced.

Description of the Environment

Within the scope the environment, few definitions need to be introduced. The core concept of this system is the

information-object, a body of data that exists as outside-time structure. An object from a perspective of information no longer necessary possesses physical properties but rather is an entity with specific structural unity and dimensional properties that constitutes its form that can be altered by means of processing. While the object is approached as holistic unity, it is composed of arbitrary number of ***information-particles*** – symbolic points that represent potential synthesis units. A single particle is a point in n-dimensional space, a collection of values that represent information necessary to describe the location of the point on the coordinate axes. The position information in Cartesian and Polar coordinate systems and derivatives such as statistical information provide the values that are linked to the controls of the parameters of the respective synthesis units. Thus the spatial manipulation of particles results in control over synthesis structures. The basic concept of the system is to link these control units to discreet sonic events and allow organization of complex sound structures, allowing for effective monitoring of parametric content of the *information*-object.

An advantage of this approach is that the *information-object* is processed as a whole, and processes are applied to all values with the same gesture, achieving close homogeneous relationship of the material. For it's impossible to change state of a single particle without changing that of others.

Operative Stages of the System

I. Acquiring the Input Data

The processing chain begins with the generation of input data. At the initial stage some set of data needs to be acquired, using two general sources of information: generation and sampling. Bearing in mind the modular considerations, the origin of this data is not essentially important, since transformation, modulation and mapping is what gives it a shape and defines sonic interpretation of this data. Of course, the data needs to be formatted accordingly, to mach the input standard and dimensions of matrix, used in the system. In the course of development, the following strategies of input data generation has been considered:

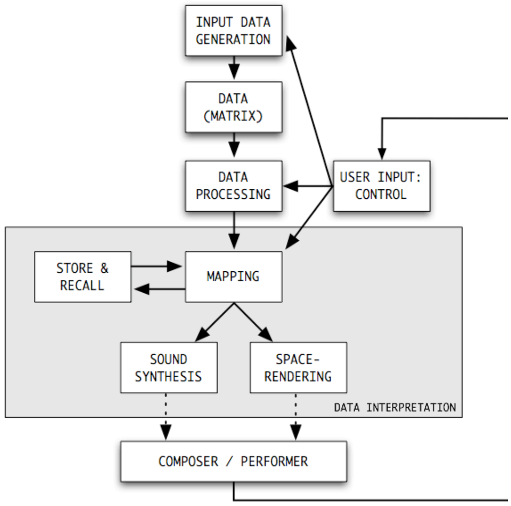

Fig. 4.1 Processing chain (schematic of the *QuantaSonic* environment

Algorithmic

An important method of input data generation is that of use of iteration process of various algorithms and functions, analytic models and simulations of processes.

As examples of this method, there exists wide range of possibilities, originating from different scientific backgrounds: Chaotic functions, random, noise functions, and cellular automata, to name just few. I will not describe these in detail, since that exceed the scope of this discussion.

Geometric

Since we're following the concept of space at the core of the environment, it is instinctive to investigate basic geometric (spatial) patterns: shapes and objects. While cube or pyramid is a very simple construction, complex results can be acquired modulating these simple shapes by applying mathematical operators. The objects can be added together or multiplied, their value planes – recombined, and values changed with trigonometric expressions.

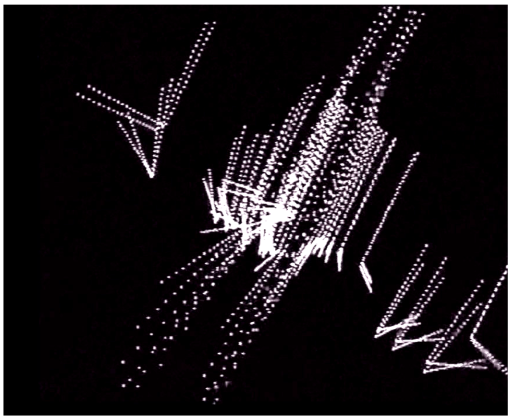

Fig. 4.2 Geometrically composed Structure.

Sampling / monitoring

The data is collected from some already existing data source, a database, wave table. Such data can be acquired by monitoring some physical process or event of reality, not necessarily related to music: seismic activity, oceanographic, astronomic observations.

Since information acquired with this method is usually represented as linear stream of values, an algorithmic method needs to be applied in order to organize it adequately for storage in matrix form. This algorithm can take advantage of sampling rate difference, or time dimension, to fill the matrix cells.

At this staged we have created a coherent data material, an information structure with certain internal relationship of organisation that determines the identity of data object. After generation of input data, the next step in processing is storage of this data. For the purpose, use of multidimensional matrixes has been proven most useful.

The Processing Matrix

An Array is a list of numbers and has one dimension. Matrix can be seen as two-dimensional array or grid of cells as chessboard. Each position is a storage and has an assigned value, that is accessible via it's x and y addresses. In the environment, a matrix of three planes is used. These planes are used to store the values of points related to number of dimensions: x, y and z. In theory, matrix can contain as many dimensions as needed, but since the model is linked to perception, we use only three. If more dimensions are used, those can be presented via projections in three-dimensional space.

II. Organization operations (sculpting)

The next logical stage, design of information allows for most diverse organizational practice. The core element of the environment, the information object, refers to the practice of modulating some unity of stored data; this process can be regarded as "sculpting". For practical reasons in a compositional setting, the process of dealing with such information can be reduced to notion of temporal and spatial design of information.

The stored the set of information values are applied various transformations that modulate the initial set of values. We utilize here the mathematical notion of a matrix as general storing and processing unit, thus the mathematical operations are applied on all information at once, preserving the coherent quality of relationship between values. In the course of the study, I have examined number of ways of modulation the set of initial data.

Navigation - the concept of navigation the parametric space is similar to action of transposition common in composition practice. Transposition of the location of information particles in three dimensions results in change of parametric values that the respective dimensions are linked to. The scaling of the object expands or contracts the parametric range that the values occupy.

Rotation – rotation around three axes change the spatial relationship between different information particles.

Deformation – non-linear transformation of an object changes the overall shape of particle structure.

Application of formulae – various iterative functions that process the values of matrix cells and positions of particles according to an algorithm.

III. Interpretation

Depending on the way the compositional technique, there exist several ways of interpreting this information to sound. The interpretation stage consists of various algorithms that determine the temporal and vertical design by which information contained by data-object is read and related to sonic processes occurring within musical time. These strategies determine the timescales that the resulting sonic structure will occupy.

IV. Mapping

In the mapping stage the output data of transformation operations is linked to the parameters of synthesis process. The location data of individual particles such as x, y, z and Polar coordinates is scaled to the numerical range to match the desired input range of the parameters for the synthesis units. The importance of tuning the mapping process is discussed in numerous research papers, and the general rules of this process also apply here.

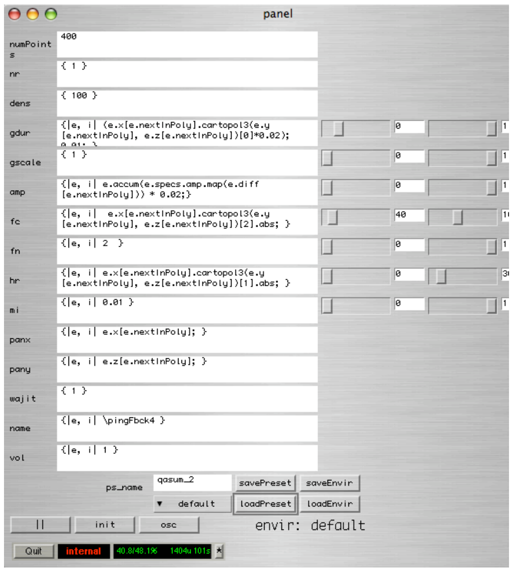

Fig. 4.3 The mapping and interpretation
Interface in *QuantaSonic* environment.

V. Sound Synthesis

The approach taken in the environment is that sound is composed by simple identical synthesis units (agents) that each has few parameters of control, and the sonic complexity arises from combinations of these units in mass-structures.

The synthesis units themselves can be replicable according to the synthesis model utilized in the composition. The most interesting task in the control of this process is determining the most relevant relationship between coordinate information and inputs of the synthesis patch. These choices, however, are arbitrary, i.e. and based on practical decision which spatial dimension is most suitable to encode parametric information to facilitate intelligibility of its structure. The general rule here is that within a context of information object the same input-output strategy is used for all particles of the object, for example the radius value is connected to duration parameter.

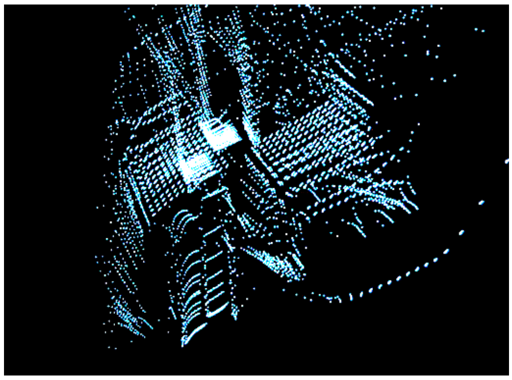

Fig 4.4 Iterative transformation of an
information-object (screenshot).

5 Composition of Information Objects

In compositional context, the concept of the object is used not in the meaning of material thing but rather in a philosophical sense, as a thing external to the thinking mind. The identity of the object is defined by the unique combination of its properties across several dimensions. This object is an entity that has certain volume properties, and structural identity allowing for processing (in the computer software sense of the term). Vaggione [in Budón, 2000] provides a very precise definition of an object in regards to composition:

> *“an object [..] is a complex unit that may simultaneously contain different representations, or codes, related to as many procedures (specific actions) as there are data elements (sounds and time structures) covering many scales or operating levels. [..] that is, a technical concept developed to realize a given musical action, capable of incorporating (encapsulating) different time levels into a complex entity which nevertheless has defined boundaries, and thus can be manipulated within a network.”* [Budón, 2000]

Although Vaggione doesn’t use explicit visual representations other than micro-montage of sound events, the spatial aspect is present in his musical work. Besides working at multiple temporal dimensions, the vertical structure of sonic content is designed from “objects” that form "networks", [Vaggione, 1991] thus emphasizing the complex multidimensional relationship.

The object itself is not yet a musical situation. Rather it provides a catalogue of the possible sonic events that are materialized by choices of the interpretation. Thus, the sonic properties are determined by application of translation processes that define both, the sonic/spectral qualities of the event and the time structure as it is presented to the listener, as well as the temporal scale on which it occurs.

Since the information-object itself is free from a time definition, as such it can be regarded as out-of-time compositional structure. Xenakis speaks of composition of music as comprised of three elements, composition *outside-time*, *in-time*, and *temporal:*

> *"... I propose to make a distinction in musical architectures or categories between outside-time, in-time, and temporal. A given pitch scale, for example, is an outside-time architecture, for no horizontal or vertical combination of its elements can alter it. The event itself, that is, its actual occurrence, belongs to the temporal category. Finally, a melody or a chord on a given scale is produced by relating the outside-time category to the temporal category. Both are realizations in-time of outside-time constructions."* [Xenakis, 1991]

The information-object refers to the organization outside of time, as it doesn't contain a time reference, but rather represents a catalogue of the probable value situations within the context of the object. It is largely defined by interpretation, in which order and on which time-scale the information structure is laid out and translated into a musical one within time. At first, a decision regarding the timescale(s) that the information-object will occupy must be considered. According to the explicit catalogue proposed in "Microsound" [Roads, 2002], a musical process can take place on several temporal scales:

- Macro, denotes time measured in minutes and hours;

- Meso, measure in minutes and seconds, sound objects form groups here and phrases and gestures are at play;

- Sound Object, a sound occurrence, a note in the traditional sense;

- Micro, sound particle, measured in milliseconds;

- Sample, smallest element in digital sound synthesis.

Due to the information capacity of the information-object in question (consisting of 200 to 400 units or more), it can be presented on a number of these scales, perhaps in parallel. In the framework of this study, a number of approaches of addressing the question have been examined.

Application examples

Additive / Sine model

An obvious translation that first comes to a mind would be to find an instantaneous link between the data object and that what is referred to as “sound object” on a Meso scale. A straight-forward way of achieving this would be a construction of a bank of identical synthesis units corresponding in number to the cells of the data object, and linking the values of data matrix to the control parameters of synthesizers. As a consequence of the additive synthesis, this approach creates a static sound event/stream, with all of the synthesis units being synchronous in time. The very first experiment that followed this approach was realised with an array of 200 sine-wave oscillators. The frequency, phase and amplitude parameters of the synthesis units where mapped to the spatial properties of data units. As a proof of concept, this setting provided immediate relationship between the deformation applied on the information structure and the reflection in sonic domain that allowed for gestural control over the resulting sound event. Although this prototype setup confirmed the general thesis and provided interface for parameter organisation that, suggested causal relationship with resulting sound, it also exposed several disadvantages of the particular interpretation model:

- The interpretation strategy was useful for composition of the harmonic/spectral structure of the sonic output, but due to lack of the time description of the particular synthesis model, it required for additional control of the temporal structure of musical organisation. For production of interesting musical situation, an effective mechanism for control of execution and duration of the sonic events should be added.

- Another problematic aspect was the lack of control over dynamics within the sound event; while the amplitude envelope of individual sound units varied across time, the overall sum envelope was smoothed out rather evenly due to the nature of the additive synthesis model.

Granular / Frequency Modulation model

The above issues where partially addressed in the next of the development stage by implementation of a granular synthesis model that proved to provide more flexibility over choices of timescale and temporal organization of the resulting sound.

The greatest advantage of the definition of model arrives from the fact that it contains time description, allowing for a wide range of possibilities of rational control of this parameter. By control of the time factor of executions of singular units, (the onset and duration) it is possible to vary between the times of execution and duration of the events. At one extreme of the temporal scale, the events of dense temporal relationship are produced. There, we achieve the same result on a dense "sound object" comprised of close to simultaneous synthesis grains. At this level, we can conceive that the individual parameters affect the inner micro-sonic structure of the composed object and create sonic texture as the result of interplay between multiplicities of grains.

On the other extreme of the timescale, the temporal differences between occurrences of synthesis instances become sparse (> 20 ms), so that they are conceived as individual the sonic events. This opens up compositional possibilities of organizing temporal execution of the events and enter the domain of rhythm. Various choices in between those two ends of timescales as well as simultaneous merged forms can be applied. Depending on the combination, the musical discourse varies between texture, micro-rhythms, and rhythm, providing distinct sonic results.

A number of extensive resources on various aspects of the granular synthesis model are available [Roads, 2001]; therefore I will not go into detailed description of the impact of various parameters. The general rules of the model are valid here as well, while the prototype provides precise interface for organization of the parameters, therefore allowing for more conscious organisation of sound, leading to causal understanding of the effects of control gestures.

By the use of the system I observed that interesting sonic results could be achieved by choices of refined mapping schemes. As the complexity increases in the mapping strategies, the relationship between sonic output and the graphical plot also grows in complexity. This facilitates a certain learning process within the system, and is an effect of the fact that we are visualizing a parametric structure rather than displaying results of sound analysis.

6 Conclusion

Music composition as well as many other productive human activities in the Information Age can be approached from the perspective of information design, if performed with a help of computational tools and methods. In the composition of electronic music in particular there is a category of organization activity that deals not with the sound itself, but rather the arrangement of the numerical material that is translated to sound by diverse processing and computational means. This parametric field clearly corresponds with the operational description of information, as a particular category of existence that functions as a matrix, recipe or description for something that has a potential to become materialized as a substance or field.

In the case of parameter-based composition, I have found it effective to employ the operational concept of space as a method to formalize the arrangement of values within the parametric field both because the potential of it's mathematical description and even more due to it's strength as a concept in human cognition. The formalization of the initial data material in information-objects permits the discovery of organizational and sonic morphology and multidimensional properties within the otherwise shapeless cluster of parameters. As the volume of parametric information increases, the spatially encoded objects are represented visually and added to the immediate sonic representation, provide a visual feedback, facilitating better understanding of complex structures of parametric organization in relation to the resulting sound.

The QuantaSonic environment developed as part of this study, explores these concepts in practice. Although still in an early stage, it proved to be an effective tool and interface to facilitate parameter organization and provided with more coherent and interesting sonic results than achieved with other methods of organization. Doubtlessly the performance of the environment offers a space for improvement by way of implementing more refined computational methods of data organization and analysis stemming from disciplines such as data mining and information design.

Nevertheless, the practical experience leads me to a conclusion that the use of space as a concept of musical thinking is a powerful metaphor for organisation of parameters for sound synthesis that can contribute to the compositional process of music by providing control of and establishing the multidimensional relationship between categories of various parameters. At the same time, as is the case with every new concept, I feel that the research in this area can be extended and the whole field of the particular approach to musical information and space yet offers a vast room for exploration and discoveries.

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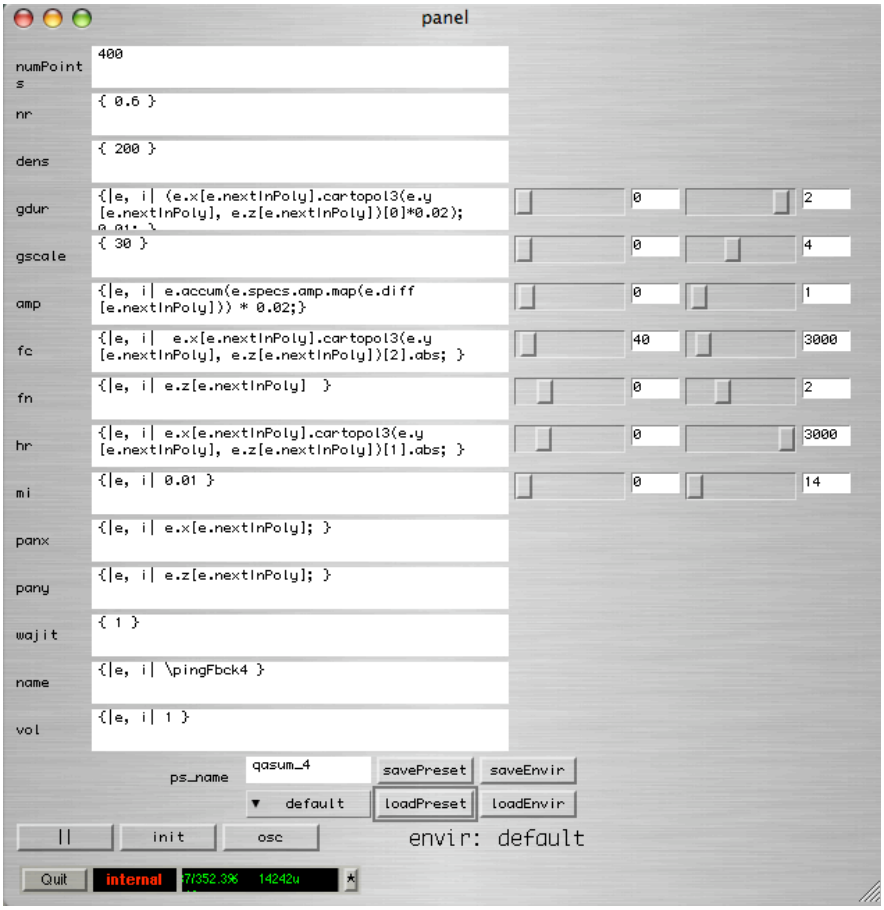
List of Illustrations

* The sources on the Internet were accessed during the month of May, 2007

List of Appendixes

Mapping example #1:

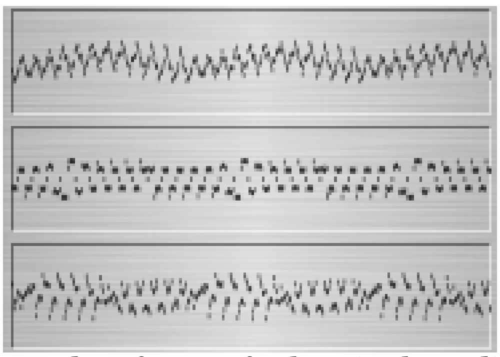


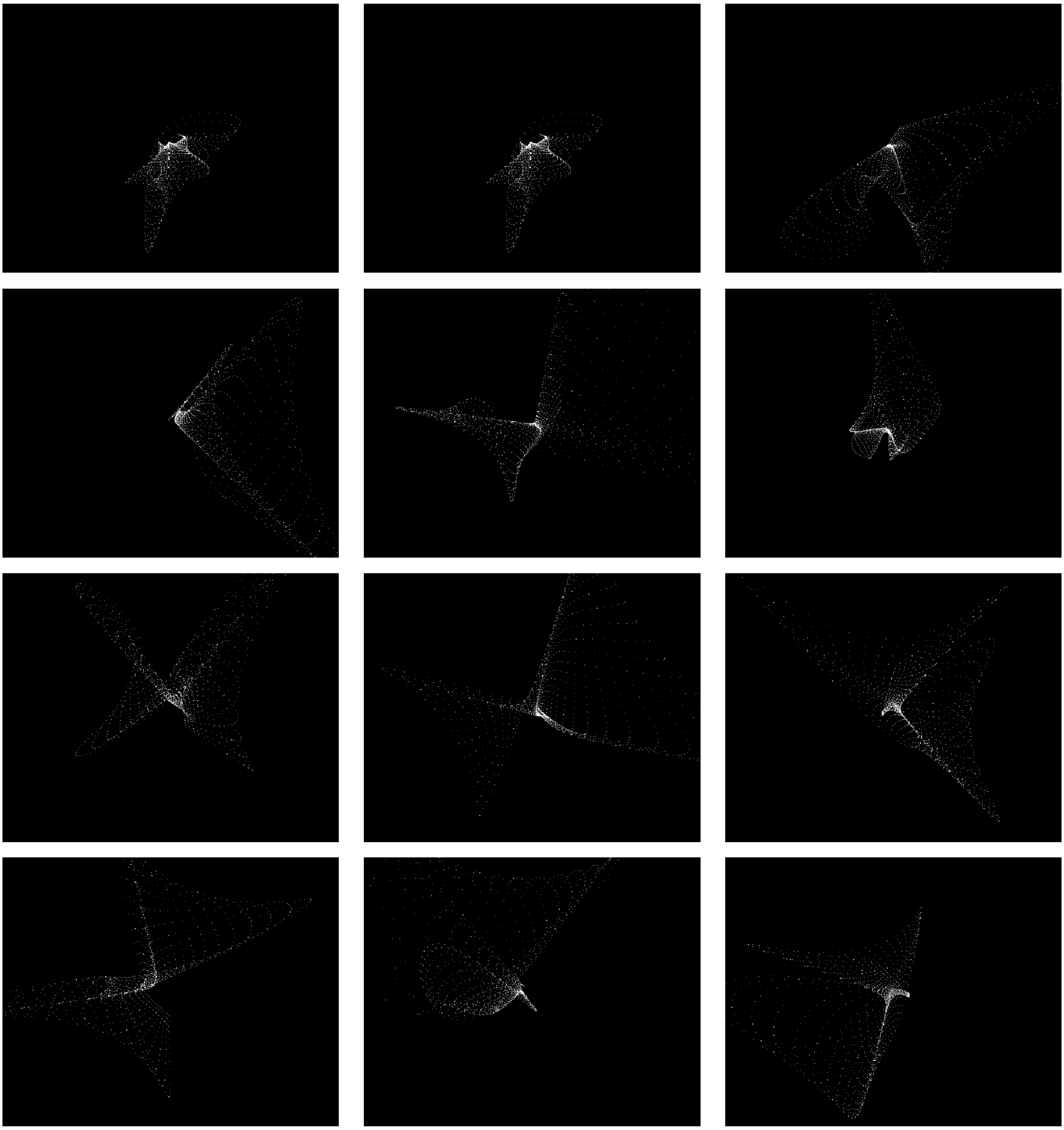
This simple example uses granular synthesis model with grains produced by Frequency modulation with high grain-density. The grain duration (gDur) is determined by the radiuses (distance from the centre) of the information-particles.

Amplitude (amp) is determined by the amount of motion of individual particles (difference in position from the previous position).

The centre frequency (fc) in the range of 40 – 200 Hz is coupled to the second angle in Polar coordinate system.

The Harmonic Ration (hr) in the range of 500 – 300 is determined by the first angle in Polar coordinate system. Modulation index (mi) is static.

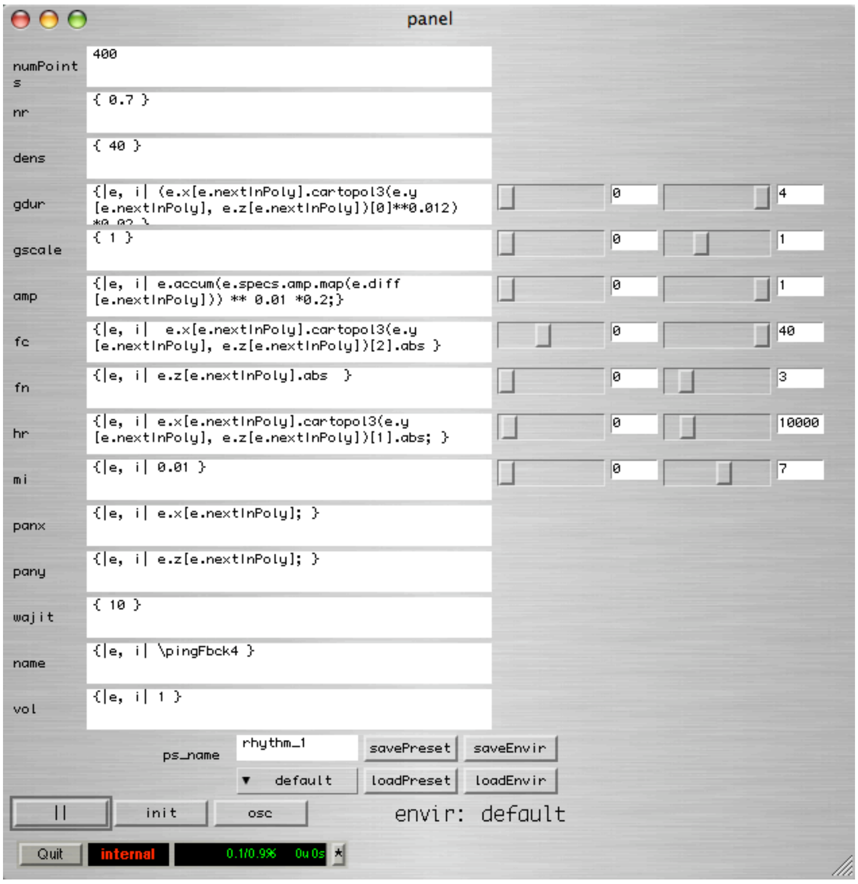

one data frame of values in three dimensions



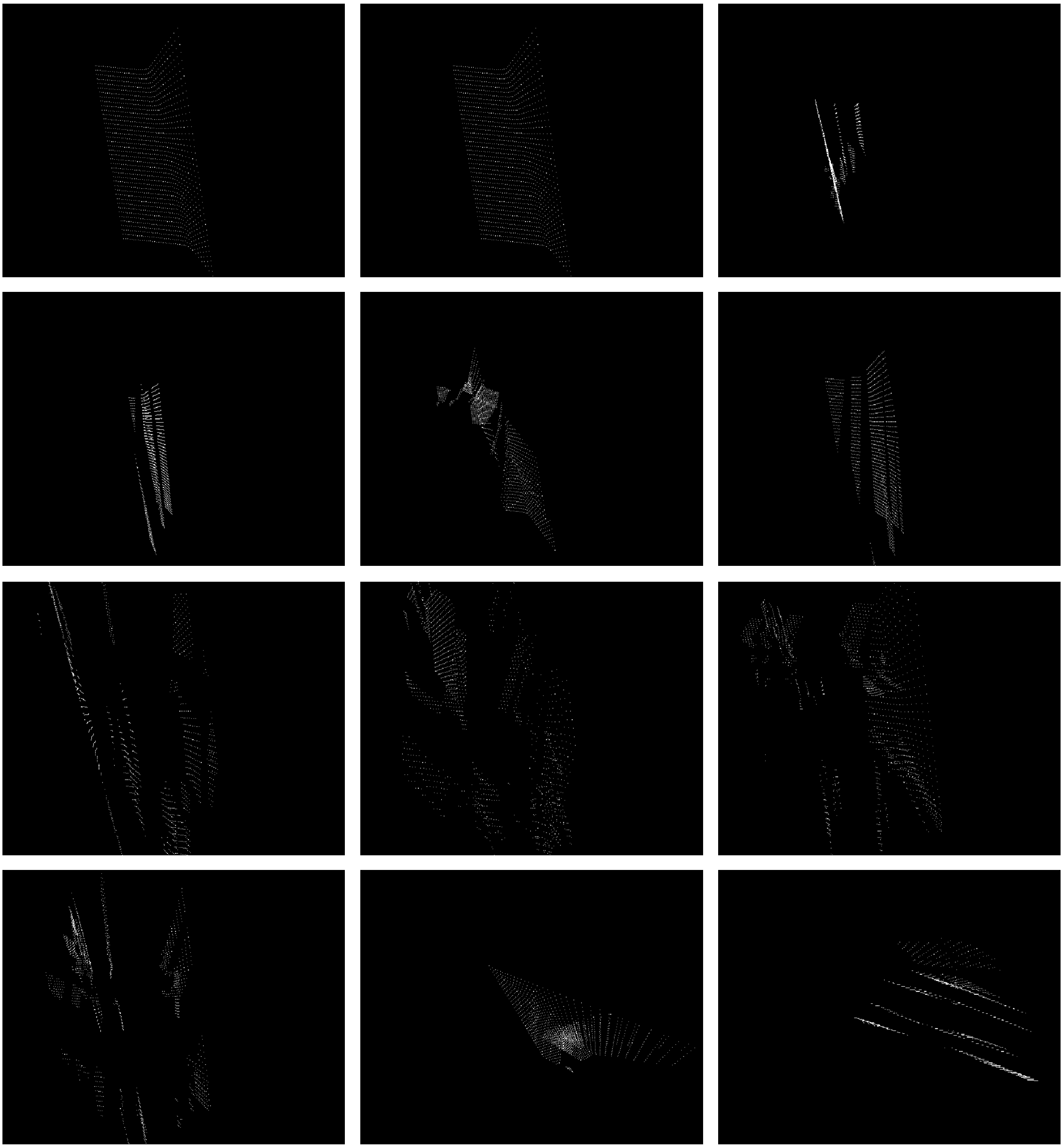
Processing: modulation of a round shape + rotation

sound file: mapping_1.aiff

Mapping example #2:



This simple example uses granular synthesis model with grains produced by Frequency modulation with low grain-density. The grain duration (gDur) is determined by the radiuses (distance from the centre) of the information-particles.
Amplitude (amp) is determined by the amount of motion of individual particles (difference in position from the previous position).
The centre frequency (fc) in the range of 20 - 40 Hz is coupled to the second angle in Polar coordinate system.
The Harmonic Ration (hr) in the range of 0 – 1500 is determined by the first angle in Polar coordinate system. Modulation index (mi) is static.



Processing: algorithmic cut-up of a plane in three dimensions

sound file: mapping_2.aiff