Non Musical Time as a Point of Departure; Time as Inspiration and Theme in the Context of Electronic Music

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Each and every composition, choreography, or narrative writing expresses what its composer or writer regarded as an unfolding process which should not by that unfolding, pass.

(Fraser, J. T.)

Keywords: time and music, temporal art forms, time measurement, linear and nonlinear time in music, expressing time through sound, music and technolgy

Abstract:

Music is a temporal art form, it unfolds in time and without time we wouldn't be able to experience it. On the other hand, music has a unique ability to create and change time. There are many other intricate interrelations between time and music and my research aims to explore them. Surveying notions of time found in human history, culture and sciences, I try to derive interesting concepts. These ideas are then used to see, if they could inspire and stimulate creative process in the context of electronic and computer music. The key question I ask is about possibility of expressing time by means of sound.

My research has both theoretical and practical parts. In the first part of my thesis I focus on theoretical aspects of time. Chapters in this part will focus on time in relation to the human history, culture, philosophy, religion, science and music. The second part describes the four practical experiements in time, that I conducted, focusing on implementing theortical ideas into musical work. The outcome of the research will be a written work as well as a portfolio of musical pieces inspired by the ideas discussed in writing.

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Introductory remarks

Music is temporal: abstract sonorous shapes moving through yet simultaneously creating time. Time is both the essential component of musical meanings and the vehicle by which music makes its deepest contact with the human spirit.

(Kramer, 1988, p. 2)

Prolog - genesis, of the research idea

My artistic practice involves exploring sound through different media, styles and genres. Perhaps a more appropriate term would be a *sound explorer*. I like working with possibilities and limitations presented by various technologies, which give me a wide variety of tools but pose a risk (which I am willing to take) of not being stylistically coherent. There are motives in my work, however, that keep reappearing, one of them, which had led to this research, is that of time and its representation through sound, by looking at it from many angles. The practical part of my work very often (and perhaps always) involves making, designing and experimenting with custom-made objects, placing it in the context of DIY and makers' cultures. The esthetics and ethics of these movements are close to mine, with one little distinction, which is that they often place the medium at its center making it the main and only focus. I try to avoid doing it in my work. My approach is to make technology more '*transparent'* and unobtrusive in order to get the ideas behind it across.

I have been fascinated with the idea of time for quite long and, needless to say, my another great interest is sound. I find these two phenomena closely related. We can see this relation in everyday life, by a simple fact that in most places inhabited by humans time intervals are announced by sound of bells or other instruments (Kern, 2003). Looking from another angle, both of them are abstract, intangible, mysterious, escaping any verbal descriptions. These features make them a fertile ground for artistic work, which also deals with inexpressible but universal values. This fascination had also materialized in my work before. The pieces worth mentioning here are two audio-visual installations 'Cymatic Clock' and 'Around the Clock' . In these works, I tried to connect time and sound or to be more specific, I tried to *express time through sound*. As it often happens with audio-visual works, the visual aspect became dominant, even though the sound was the first part I worked on. In the end, I was satisfied with the results but at the same time, I could sense there was more to be discovered in this area, especially in terms of sounds. This feeling was one of the first reasons for me to start the research, the result of which is this thesis and a portfolio of practical works.

This part serves as an introduction to the research topic and lists factors that inspired me to undertake it, by first trying to place it in the context of my earlier works, then suggesting more general influences. Next, I introduce some important definitions and present my methodology, followed by the outline of the thesis structure and its aims and outcomes, with the list of experiments that comprise the practical aspect of this research. I start and end by giving some remarks about my approach to work and ideas about art and music in general, which gives this writing quite a personal and subjective character. This is intended to give the reader a wider context and help him/her understand my work better, as well as to avoid some ambiguities further on.

More inspirations

I should start by stressing, that music is primarily a temporal art form, (Hanoch-Roe, 2003) inseparable from time. It becomes evident when we look at the key aspects of music: the musical sound, the process of composing music and the nature of music. There are numerous sources I could quote, but let me refer to the founder of Institute of Sonology – Gottfried Michael Koenig. In regards to musical sound, he says that it might be described as a '*function of amplitude over time'* (Konig, 1967, p.1). When discussing the process of composing music, using his Project 1 system, he mentions that '"*Points" (in time) are the result of entry delays being distributed along the time-axis;*' (Konig, 1983, p.1) In another context, by comparing music to speech, he points out that '*Music occurs in time; its subject is therefore its temporality – the relationship, unambiguous at all times, between "before "and" after."*' (Konig, 1982, p.1) This then is the starting point of my research: the fact that music and time are inextricable. After having established that, I can proceed further by saying that my aim is to look at various concepts of time in different eras and areas of human culture, in search of concepts, that could be applied in my practice.
Time and sound intersect on many layers, this fact, hopefully, renders my work meaningful. For instance, it is a commonly known fact that our culture is dominated by visual stimuli and most of our sensory data comes from vision, but interestingly *'when it comes to rhythmic perception and temporal resolution, the auditory system tends to perform significantly better than the visual system.'* (Neuhoff, 2011, p.93) This characteristic of human auditory system suggests, among other things, that the domain of sound is better suited for working with complex rhythms and temporal patterns, then the visual one.

Electronic music seems particularly well equipped for the task of time manipulations, having at its disposals tools such as modern computer, allowing sound manipulations at an atomic (sample) level. As stated by Horazzio Vaggione: *Machines give us greater control over any parameter of music, especially time*. (Vaggione, 1993, p.14), With its perfect time-keeping abilities, computers also introduce an interesting distinction between human and machine time. No matter how hard we try, we cannot compete with the accuracy of computers in time keeping. I do not say that this perfectly quantised time is interesting on its own (techno fans would disagree here), rather, that the juxtaposition of human and computer time can yield interesting effects.

Moving from technological to more personal reasons, I would like to mention an important area of inspiration, which has to do with the obsession of our culture with time keeping. Throughout the human history, time was divided into smaller and smaller pieces (Conrad, 2004) and was getting more standardized yet, at the same time dehumanized. This perfect punctuality and precision of clocks had negative effects on people and had already been noticed after introduction of the 'standard time' in the 19th century. (Kern, 2003). In the following centuries, time has been speeding up putting more and more pressure on people's lives, who can try to keep up with the pace or fall behind. As Jonathan Kramer puts it: *'The society seems to demand that we either accept absolute time, with all its limitations and contradictions, or else that we remove ourselves from the social conventions we call reality and enter a schizophrenic world with its own time'.* (Kramer, 1988, p 165) I found numerous statements about this condition of our culture; let me just give one example: *'One of the deepest errors of the modern world is its obsessive passion for time.'* (Neville, 1993, ch.2) I list this as a personal inspiration because I often suffer from the stress resulting from it. With this research, I am hoping to get a deeper understanding of time and look for a possible remedy for the obsession.

Definitions and Research Methods,

Initially, my research topic did not contain the 'non-musical' abverb to characterize time. However, when I started my research, I realized that I would never be able to talk about all the topics I had intended to. I had to limit myself somehow. I looked at the areas of research and noticed that the ones I found the most inspiring and intriguing were the ones from outside the realm of musical time. What I mean by non-musical, is that these ideas have been derived from non-musical disciplines, such as time – measurement, biology, physics, technology etc. Another important characterization in regards to the meaning of the word non-musical, is that time values used in practical works are not derived from musical meter, but for example from physical pendulums, clocks, biological oscillators or technological manipulations. Let me make one more thing clear: it does not mean that I am not aiming at achieving interesting musical time structures as outcomes of my practice, on the contrary, this is one of my key goals, but the way I get to achieve them is not through exploration of musical values of timing and metro but through ideas of time derived from other disciplines (or alternative approaches to musical time).

As stated above, this research is about non-musical time and the ways it can be applied to the electronic music practice. My research method was to look at time in various areas of human activity and see if I could find something inspiring there. The amount of literature on this topic is overwhelming and so I had to narrow the work down to some specific subjects. There were two criteria that affected my choice. The first one was somewhat intuitive and had to do with the ideas I had for the practical part of my work (clocks, calendars, time-shaped by music). The second one was to choose these areas of human culture, which are naturally more involved in time. I decided on the following subjects: horology, philosophy, religion, biology, physics and music. As a result, the theoretical part of this research is divided into sections corresponding to the above subjects and views on their relation to time, trying to distil the most 'musically' interesting and relevant ideas from each of them. There is still a lot to cover and many volumes could be written on any of these topics. I do not claim to have covered all of them in details, but I picked the most relevant ideas from each. Even though I have a (Ba) degree in cultural studies, I do not see this as a scientific research. I merely put together ideas about time, gathered from various disciplines and use them as an inspiration for my work. My approach is more that of a naive child that has discovered something new about the world, or that of an artist looking for inspiration for his works. An interesting thing to mention here is that I have found similar ideas in areas that seem to be very far apart. For example, the idea of plurality of times can be found in psychology, physics, religion and philosophy. This leads me to another remark: I had a lot of difficulties trying to decide how to structure the theoretical part of the thesis. A lot of ideas discussed here overlap and appear in many sources. As a result, they get mentioned more than once in different chapters. This reflects the non-linear nature of our subject and I hope it will not be considered a stylistic flaw.

Structure of the Thesis

The body of the thesis is divided into two parts: theoretical and practical. The first one focuses on the results of the theoretical research, where each subsection talks about a specific discipline in relation to time and outlines the ideas derived from there, which I found inspirational. The last and biggest section is dedicated to time and music. I decided to keep it for the end, for it builds on previously introduced ideas.

The second part deals with a practical aspect of my research and tries to describe how the ideas derived from the first section have been applied to my work. I start by listing all of them and describing their possible implementations. In the final parts of this section, I describe all the projects and experiments that I have undertaken and how they have evolved. This includes any changes and development of initial ideas and comments on how successful the final result is in my opinion. I believe that a little bit of healthy self-criticism is a good thing.

Outcomes

The practical part of my research is to create a portfolio of works, which will be presented at the final concert and that would reflect the ideas discussed in writing. All the pieces have the same genesis i.e. non-musical time, but are quite different in their character and realization. As mentioned, this reflects the way in which I work, exploring possibilities available from various technologies. The works have a strong DIY character, which is close to my esthetical and ethical choice.

The main four pieces comprising the practical part of my work are:

1. A generative piece in which all parameters of the composition are driven by the data received from the computer calendar. It could also take a form of a sound installation. (Untitled at the moment)
2. ‘A dialog of Three’, ‘Timing Issues’, ‘Synchronicity’. A series of pieces consisting of custom-made hardware and software where different types of times are juxtaposed. This work has gone through several intermediate realizations, which I will also describe.
3. 'ChaOSCync' - exploring time in chaotic systems and their synchronization implemented purely in the analog domain.
4. ‘Soundlapse’ – a project where a short sample is recorded periodically over a long period of time in the same location and then put together in order to create a time-lapse by means of sound.

Other Remarks

It is also important to notice that the ideas I derived from the theory are many times loosely related to the practical work; they are not direct implementations or mappings of the theory, but rather sources of inspiration. I believe that vast majority of artworks cannot be explained by means of language. That is the very essence of art: to express the inexpressible. That is why I discuss a lot of references and research areas that I have done, even though it might not seem to be directly related to the work presented (but I hope my thesis will help to understand this connection). These ideas have surely inspired me, possibly on more subconscious level, which again can reflect the non-linearity of mental processes.

I am not a very technically oriented person, my approach to technology is that of spontaneous improvisation, I like to be surprised by the things I make and design. For that reason this thesis is not full of technical descriptions, but they appear in some places, where necessary.

The final remark that I would like to make in this section is that my goal was to create works inspired by the ideas of time, which would, at the same time, evoke and express these ideas in the minds of listeners. This is probably the most difficult task, as due to everyone's different personal experience and mental state I cannot expect it to happen. I have no guarantee that while listening to my pieces people would associate them with time, unless they read the program notes or this thesis. It is an important aspect of my work that it is self-explanatory, it is simple to understand, intuitive, and does not require high level of knowledge. I am not an enthusiast of conceptual or overly intellectualized art, for it often results in too abstract works, in which the ideas become more important than the artwork itself.

Part A - Theoretical background;

Time in Human Culture, History and Sciences

Introduction

With a risk of being unoriginal, I open this part of research about time with the quote of St. Augustine: *‘”What, then, is time?" "If no one asks me, I know what it is. If I wish to explain it to him who asks me, I do not know."* (Augustine, 2002, p.224)

More than fifteen hundred years have passed and the question still remains unanswered and time has to be ultimately taken as indefinable. (Kramer, 1988). At first, this might seem as if this statement rendered my whole research pointless, why do I then make time the topic of my research? Because it is as (or perhaps even more) important for me to ask questions as it is to answer them. This is also, in my opinion, the role of art: questioning the reality that we have found ourselves living in. That is why in the following part of my thesis I will look at the concepts of time from various perspectives and I will try to derive from them some ideas that could be inspiring and useful for my practice of working with sound. By looking at different areas of human culture I will be able to look at different ideas of time, because nowadays the question: *‚What is time?‘* (Fraser, 2007,p.109) cannot be answered in a general way that would satisfy everyone. The answer is very much dependent on who asks the question. As Jonathan Frazer puts it: *‚For physics, it is generally an undefined t, for biology the cyclic and aging orders of life, for geology the eons of the earth’s evolution, for psychology a mode of perception, for sociology a convention of the group’*(ibid.).

I have decided to limit myself to the most important and fertile areas. Some of them had already been familiar to me and I only needed a confirmation of my earlier ideas or intuitions. However, some were very surprising and gave me new perspectives and insights. The order in which I present them seemed natural: starting with the history of ideas about time and changes it has undergone and how it affects our understanding of time, then focusing on the most important aspects of human culture and science and, finally, music. All these topics are interconnected and complement each other and for that reason, I might mention some of them more then once in various places.

A 1 - Time Measurement, Time‘s Revolutions, Time‘s Tyranny

Both time and one's experience of it, in pre-industrial agrarian societies, had most to do with the quotidian cycle of sleeping, rising, eating, and working. More complex social structures resulted in an extended imposition of temporality.

(Conrad, 2004,p.1)

A1.1 History of Horology – Antiquity to Modernism

If we look at the history of time measurement in the history of human culture we notice that it has been gradually divided into finer and finer sections making it less natural and putting more pressure on individuals. Ancient people did not have the advanced technology of modern man and in order to measure time they observed the world around them. They realized that time could be ‘read off the heavens’ (Barbour) and so astronomy was born. One of the earliest and most successful astronomers was Ptolemy (150B.C.). His system of measurement was important because he referred to sidereal time (of or with respect to the distant stars) rather than to the time in relation to the Sun or planets in our Solar system. This resulted in great accuracy and his system of measure was so successful that it remained unchallenged for almost two millennia. (ibid.).

The ancient civilizations of Babylon, Egypt, Rome and Greece each had their own calendar with slightly different divisions, but the main units of time were derived from nature. In particular, the Earth’s rotation on its axis, the Moon’s revolution around the earth, and the Earth’s revolution around the Sun; it is these that underlie *‘the most widespread units for measuring time, a day, a month, and a year* *respectively'.* (Holford-Strevens, 2005,intro) However, the division of a day into hours was introduced as early as in ancient times. It is important to distinguish this division as an artificial one with no real basis in the natural world, being pure inventions of humans for our own *'convenience'*. In the later Middle Ages, we find a new sexagesimal division of an hour into *primae, secundae*, and *tertiae minutae*. This system, already used for degrees of arc, has given rise to our 'minutes' and 'seconds'. (Holford-Strevens, 2005,p.9)

According to Stephen Kern (2003), some of the most momentous developments in the history of uniform, public time were the invention of mechanical clock in the 14th century and introduction of standard time at the end of the 19th century. They both had a substantial impact on human lives. The invention of clock introduced a division into shorter time measurements (Conrad, 2004), which got embedded into human mind and their way of perceiving the reality. During the 17th century, the metaphor of the clock became the metaphor of the new mechanical philosophy of Galileo, Descartes, Boyle, and Newton. '*By the end of the 17th century, the clock universe was a widely accepted model. It fitted the discoveries of science, the revelations of the history of nature as well as new brands of philosophies'.* (Fraser, 2007,p.225) Further industrialization led to a need for coordinated transportation schedules, particularly railroad schedules to organize the traffic flow (Conrad, 2004) and consequently, to the introduction of standard time. It introduced a new level of time keeping, as Kern puts it: *'Never before had the temporal precision been as exact or as pervasive as in the age of electricity'* (Kern, 2003,p.15). Although it was useful for practical and economic reasons, at the same time it started the collapse of independence of local times (Kern, 2003). Another negative effect was that people felt more under pressure. Already at that period the negative consequences of omnipresent clocks have been noticed. The codification and dehumanization of time measurement started to act against humans, instead of working for them.

A1.2 Time Derailed – From Modernism On

'The structure of history, the uninterrupted forward movement of clocks, the procession of days, seasons and years, and simple common sense tell us that time is irreversible and moves forward at a steady rate. Yet these features of traditional time were also challenged as artists and intellectuals envisioned times that reversed themselves, moved at irregular rhythms, and even came to a dead stop.'

(Kern, 2003,p.29)

Technological and scientific advancements of the early 20th century had a significant impact on how humans perceive time (Trippet, 2007). Inventions worth noticing here are electric light, sound recording technology and cinema (Kern, 2003). Electric light had a widespread effect on blurring the division between the day and night. People no longer had to obey the old pattern of sleeping and working. The cinema and sound recording technology both allowed time manipulations that had been unthought-of before, such as reversing, re-playing or stopping time. *The American filmmaker Edwin S. Porter discovered that time could be compressed, expanded, or reversed in a more versatile way by editing the film.* (Kern, 2003,p.30) Intervals of time could be literally cut out of a sequence and temporal order could be modified at will. Other techniques included freeze-frame, which gave an illusion of stopping time and running film backwards through the projector and thus reversing the flow of time. (Kern, 2003) Similar processes could be applied to the domain of sound, the passing of time could therefore be objectified, recalled and relived (Trippet, 2007,p.538). I will delve deeper into this topic in the chapter about time and music.

Further division and refinement of time measurement was happening fast, one could say that time was speeding up. Astronomers replaced sidereal time by ephemeris time only in 1952 and then introduced atomic time in 1979. (Barbour) Nowadays, humans are able to measure extremely short time intervals with help of atomic clocks, which count the transitions of a cesium atom as it fits back and forth between two of its energy levels. The universal time standard is driven from this *superclock.* It is so accurate that it does not err by more then one second in 20 million years. Still though a better clock is in research phase. An optical one, thousand times more accurate: '*It wouldn't have lost a second since the universe began* (Strogatz, 2003,p.131). Do we need this kind of accuracy? Where does this obsession of controlling time come from? Tony Conrad (2004) puts the blame on a clock function as the primary instrument of social discipline and control. Until the nineteenth century, it was enough for most people to have their hours coordinated by a few bells here or there during the day. Everyday events dictated the way in which duration was perceived with time of religious events having an important role. *'Then, with the introduction of a labor market, and pay-per-hour, it was necessary for capital to impose calendrical and horological regularity upon the work force*.' (Conrad, 2004,p.1)

In science, the old paradigm of Newtonian system was challenged and overthrown, mainly by the Einstein's theory of relativity. And so the '*Absolute, true, and mathematical time' ... which flows equably without relation to anything external'* (Fraser, 2007,p.160) has been proved to be relative and dependent on space. (de Bertola, 1972). The new, emerging sciences, such as psychology and sociology, made a distinction between personal, social and clock time, providing further arguments against seeing time as monolith.

The digital era has seen yet further acceleration of time and nowadays we live in a shizophrenic age (Kramer, 1988) of multiple times. This madness seems to be deepening, which becomes clear when we look at the mainstream media and global political and economical situation. The once praised technological progress, which was to save us, has become our damnation. Mental problems are more common, stress caused by modern lifestyle is becoming unbearable. Although the way we treat time cannot be fully blamed for the situation, it might be considered as one of the reasons behind it, as well as one of the symptoms of it.

Is there a way out of this madness? One of the answers to this question comes from Jonathan Kramer, (1988) who says that turning into individual and subjective time is what modern people do to create their own time and to stay sane, while submitting to external, absolute time only in the social arena. Similar opinion has been stated by Robert Erikson (1963) who, points out that: *'Our clocks may easily lead us to believe* *that minutes and seconds are somehow ultimate time particles, and that psychological time is illusory and of no moment. On the contrary, psychological time is primary to life, and therefore to art.'* (Erickson, 1963,p.177)

In this section, I described the process of evolution of horology and how the perception of time in the human culture has been changing, leading to the current situation that is often described as an obsession with time. In later chapters, I will discuss more in detail how technology has influenced music and what were the consequences. I will also try to show some alternatives to the current time-obssessed culture.

A2 –Time in Religions and Philosophies.

The notion of time has long been associated with such other concepts as those of God, death, fate, faith and eternity.

(Fraser, 2007, p.258)

It is a big simplification to say that the Western tradition has primarily a linear concept of time, whereas the dominant idea in the Eastern cultures is that of cyclical time. In the (post)modern world, the boundaries are blurred and we might as well say that the notion of time is in constant flux. However, there are some concepts associated with traditions of East and West which can be interesting to distinguish. In later parts of this chapter, I will focus on another idea of time, which appears in many cultures, beliefs and world views, which might be a remedy for the time-obsessed culture that we exist in. Finaly, I will briefly discuss the idea of time (perception) as continuous in comparison to that of discrete, as was argued by some philosophers.

A2.1 Time's Arrow or Circle?

Phiosophies and religions reflect the human nature and its deep need to explain the purpose of life and to define the best use of our time on the planet. That is why it is interesting to look at their different explanations of temporal nature of our lives. We can look for the roots of the Western modern civilization in the culture of ancient Rome and Greece, with philosophy at its core. One of the first and most influencial philosophers from that era was Plato. He believed that the world we live in is made of temporal things which are just pale reflections of the ‚ideas‘. In his opinion, only the ideas were true, eternal, perfect and immutable entities, while earthly things were just copies of them and thus worthless. We can see a clear split between the eternal ideals and temporary forms, which will be reflected in the later times (Wonsuk, 2009).

On the other hand, when we investigate the foundations of the Chinese civilization, namely Confucianism, we see that in their view, all things were temporal (Wonsuk, 2009). In Buddhism, time cannot be conceived of as an entity existing independently of temporal phenomena, but must itself be regarded as a set of relations among them. That is, the only mode of existence that time has, is as a set of relations among empirical phenomena or as the provisional distinction of before and after. Apart from these relations and distinctions, there is no time (ibid.). In order to clearly show the differences in time perception in the East and West traditions I have put them in the table (see figure 2.1).

Western	Eastern
Rooted in Greko-Roman philosophy and Judeo-Christian religion Time Linear and Finite, Outside of the things Promise of paradise, life after death Redemption Telos, Final goal, Eschaton Time and Space separate	Rooted in Confucious, Yijing Time Cyclical, Infinite, Fundamental aspect of matter Eternal Return No Telos, no final goal Time and Space inseparable

Fig 2.1. Time in Western and Eastern traditions – based on (Wonsuk, 2009)

Let me mention other cultures and traditions that can be classified according to this distinction. Cyclical time can be found in the culture of Etruscans, Hinduism and Buddhism, while linear time belongs to Arabic, Persian and Iranian traditions (ibid.).

Chang Wonsuk (2009), The author of the article that I refer to, concludes that neither cyclical nor linear time were dominant in the East, instead, what is suggested, is the spiral idea of time: '*time in the Yijing is asymmetric, creative, and irreversible, as much as cyclic, cumulative, and preserving.'* (Wonsuk, 2009,p. 227) A proper way to describe time in Yijing can be as proceeding in a spiral motion. (ibid.) However it might seem the Western and Eastern civilization in terms of time perception are in a strict opposition, it is not completely so, as there are also similarities in the ways time was treated in both cultures. One important example that I will mention later in this chapter is a parallel between Buddhism and the philosophy of Heidegger.

It is intresting to note that the Newtonian idea of time that exists even in the absence of things can also be traced back to the Platonic tradition (ibid.). The first one to reject the Newtonian absolute time was Immanuel Kant in his *The Critique* of *Pure Reason* (as in Kern, 2003, p. 11). He concluded that time, as well as space, are creations of our minds. They are the 'a priori' given subjective categories of human perception, without which human knowledge would be impossible. (ibid.) Even though things exist in time, time can only be perceived by resorting to space: '*A line traced by hand is made as a succession of points, which is a manifestation of the passage of time.'* (de Bertola, 1972, p. 27) Developments in physics further undermined the notion of Newtonian absolute time. Minkowsky introduced the theory of space-time continuum into physics, which later was used by Einstein in his spatial theory of relativity to prove that time is relative (ibid.). In Newtonian system there was nothing that could influence the way that time flows, but *'Einstein argued that the relative motion between an observer and an object makes the passage of time of the object appear to go more slowly than if it were observed from a point at rest with respect to it'* (Kern, 2003, p. 33)

A2.2 Time Continuous or Fractured?

Around the same time as the Einstein's theory of relativity, other inventions and technological novelties were made, which changed the way people experienced and looked at time and gave new arguments and metaphors for discussing time. One of the most significant of those technological innovations was the development in chronophotography in the late 1880s, such as Edison's Kinetoscope and the Lumière brothers' Cinématographe (Trippet, 2007). They offered new tools for interpretation of the mind's cognitive processes. Deriving his metaphors from cinematography, philosopher Henri Bergson explained, how human perception fails to understand the duration and the process of becoming. What prompted him to do that was the way that the real time experience and (the 'durie') was distorted by spatial representation on a clock .

> *Such is the contrivance of the cinematograph. And such is also that of our knowledge. Instead of attaching ourselves to the inner becoming of things, we place ourselves outside them in order to recompose their becoming artificially. We take snapshots, as it were, of the passing reality. ... Perception, intellection, language so proceed in general. Whether we would think becoming, or express it, or even perceive it, we hardly do anything else than set going a kind of cinematograph inside us* (Bergson, as cited in Trippett, 2007,p. 528).

In the argument concerning the distinction between the continuous and atomistic nature of time and perception, Bergson was arguing in favor of the former. One of the strongest arguments against him came, not surprisingly, from the Newton's calculus, which envisaged time as a collection of infinitely small but discrete parts (Barbour).

Bergson's reference to the Cinématographe was to show our inability to truly understand motion as a metaphor of duration. Movement, like time, is an indivisible flux and so is time. '*We cannot consider movement as a sum of stoppages, nor time as a sum of temporal atoms without distorting their essentially fluid nature*.' (Kern, 2003)

A2.3 The Timeless Now

Because human beings are able to remember and anticipate they have created time and its categories: past, present, future. Of these categories the most interesting (and the one most misunderstood) is the present.

(Erickson, 1963, p. 174)

In this part, I would like to mention a unique idea about time. It has appeared in many contexts during my research and presents an interesting alternative to more conventional notions of time. In this view, time acquires a special, almost mystical or magical status. It has been referred to in many ways, such as timelessness, magical time, being (vs becoming), sacred time (vs profane), consciousness, presence etc. The Western civilization usually diminishes the role of it or completely ignores its existence, because it does not fit into its rational mode of thinking. Nowadays, the dominating time in a daily life is the profane one. (Kramer, 1988) It marks *'minutes and hours, days of the week, months of the year, years, decades, centuries – the entire explicit, taken-for-granted system that our civilization has elaborated'.* (Kramer, 1988, p. 50) In contrast, the sacred time is 'repeatable and reversible' (Kramer, 1988, p. 47), and it does not change. In mythic time, people stop to exist in ordinary time; they became magic (ibid.).

All civilizations have recognized the experiences of timelessness. These states have often been referred to '*as privileged, linking directly to an almighty and everlasting divinity'* (Fraser, 2007, p.305). It could also be described as a trance-like or hypnotic state, a state of blank consciousness, of meaningless tranquility and anonymity. In the Eastern tradition, especially Buddhism, it is one of the key ways to enlightenment – stepping outside the world of Maya, the world of material things and ever-changing reality, which causes the human suffering, into the eternal time, through meditation, contemplation and asceticism. One of the first and few philosophers in the West who investigated this idea was Heidegger, who believed that from the beginning of the Western philosophy, time has been *'the perspective governing the disclosure of* *being'*. (Heidegger as cited in Morrison, 1978, p. 192) He is considered to have brought time within the scope of metaphysics, breaking through the ''gap' between 'temporal' being and 'supra temporal' eternal being,' *which has remained a fundamental distinction throughout the history of the Western philosophy*. (Yao, 2007, p. 520)' Heidegger's phenomenological approach also extended from the static perception to a living experience of human existence. This brought him closer to Buddhism, whose entire strategy is to experience, analyze and transcend human existence. (ibid.)

There are many ways of entering this altered state of time, such as: ritual, meditation, exposing to drugs, experiencing mental illnesses and vertical music, among others. As psychiatrist Roland Fischer points out, drugs only provoke symptoms, which are already present within the cerebral organization. (Roland Fisher, as cited in Kramer, 1988, p. 381) '*Tautologically, we must inherently have the capacity for psychedelic experiences if drugs are going to be able to induce them'* (ibid.) It turns out that music also plays an important role in the 'sacred' time. Here I would like to refer to very interesting book by J. Kramer (1988) ‚*Time of Music*', where the author draws parallel between linear time and philosophical idea of becoming on one hand, and the nonlinear time and being on the other. (ibid.) These two descriptions of time have been important topic in the philosophy for many centuries. The concept of becoming is found most importantly in the linear logic that has its roots in ancient Greece and culminated in modern Western philosophy and science. The idea of being, has been mainly developed and cultivated with the inward-looking, highly disciplined Buddhist philosophies in which Zen plays a prominent part (ibid.). In the linear mode, time has direction, carrying us from the past into the future; the present is always passing away behind us...*'In the nonlinear mode, however, the present is all that exists*.' (Kramer, 1988, p. 53).

According to Kramer *nonlinear music can induce in a dedicated and sympathetic listener a truly extended present, a real dissociation from the past and future, a now that is eternal even though it is destined to stop.'* (Kramer, 1988, p.382) This could suggests that certain kind of music, characterized by extended duration and minimal form is better predisposed for evoking this state of mind. Tony Conrad (2004) presents similar line of thinking in his essay 'Duration'. He quotes Barbara Rose talking about music of La Monte Young. '*She specifically suggests, in this context,* *that "[t]he 'continuum' of La Monte Young's [sic] Dream Music is analogous in its endlessness to the Maya of Hindu cosmology,'* [296] (as cited in (Conrad, 2004)) I would only add here, without sounding too New Agey, that this timelessness or sacred time has been often used by counter cultures and avant-garde art movements and it might represent an alternative way of looking at our time-obsessed modernity.

A3 TIME IN SCIENCES

At the heart of the universe is a steady, insistent beat: the sound of cycles in sync.
(Strogatz, 2003, p. 14)

This chapter looks at science and, again, tries to describe the most interesting ideas that could be applied to the practice of electronic music. I decided to look at the sciences that deal with the natural environment. Whereas the previous topics I discussed were more familiar to me, the disciplines I am going to talk about in this chapter were new for me and they turned out to be very fertile and inspiring.

A3.1 Temporalities - The Hierarchical Theory of Time

I will start by presenting a fascinating theory introduced by Julius Thomas Frazer, who was an important figure and contributor to the interdisciplinary study of time. Before giving more details, I need to introduce the term *umwelt* and explain how Frazer understands time in this context. *Umwelt* is defined as *"the circumscribed portion of the environment which is meaningful and effective for a given animal species".* (Fraser, 2007, p.409) Time, in his understanding, had its genesis at the birth of the universe and has been evolving ever since and remains evolutionary open-ended. By gathering and merging knowledge about time-related teachings from various disciplines with facts known about human temporal experience, he described five distinct temporalities, which relate to the organizational levels of nature.

The five temporalities are: Nootemporality, biotemporality, eotemporality prototemporality, atemporality. The first temporal layer is the most familiar to us. It is temporality of human everyday thinking mind, which is able to remember past events and anticipate the future, living in the mental now. It may be represented by an icon of a long, straight, arrow: shaft, head, and tail. Next is *biotemporality,* the temporal layer of the biological kingdom of all animals, including human, in his biological functions. Like animals it has limited awareness of past and future, living in organic present. Its pictorial representation is a short arrow. The layer of – *eotemporality* – is the time 't' as used and understood in the physics. It is temporal reality of astronomical universe and matter. There exists causation, but without preferred direction. It is demonstrated by shaft of an arrow. *Prototemporality* is the layer of particles and waves. Location and instants are only statistical. There is no direction and no continuity. Its visual metaphor is the fragmented shaft of an arrow. Finally there is the temporality of a world as it is believed to have existed at the time of big bang, or as it exists in black holes - a*temporality* - the time of absolute chaos, with no causation relations. Its graphic symbol is a blank sheet of paper. (Fraser, 2007)

Temporalities of lower levels are not replaced, yet included by the latter ones. They all coexist together at the same time and they evolved as the universe has evolved. Our temporality of human mind, the nootemporality is thus the youngest one. This theory might at first sight seem not very inspiring in terms of musical output, but it gains more appeal when combined with other ideas, e.g. Kramer's association of various musical temporal structures with the Frazer's temporalities. (This will be looked at more closely in chapter A4)

A3.2 Biological Clocks and Oscillators

In his book ‚*Geometry of Biological Time*' Artur T. Winfree (2001) talks about natural processes that repeat themselves regularly. He calls them *'temporal morphology, of shapes not in space so much as in time'* (Winfree, 2001, p.2). In order to examine them, he applies the logic of periodic functions, which he calls ‚*circular logic*'. He mentions angles, compass directions and phases in a cycle, (time of day or season of the year) as quantities, to which this logic applies. In practice, mathematics of things periodic and rhythmic is mainly about points on the circle. (Winfree, 2001) One of the keywords used throughout the book is phase, which signifies the position on a circle, on a cycle of states. This term, very familiar to anyone working in the field of electronic music, conveys an idea of an oscillator and, indeed, the term oscillator is often used to express the phenomena that repeat periodically in nature. Winfree (2001) gives a very exact description of the models and applies his circular logic to many periodic phenomena found in nature, such as the growth of plant cells, photosynthesis in chloroplasts, respiration in mitochondria, chemical reactions, electrical rhythmicity and excitability in cell membranes etc. I learnt from this reading that biology discusses certain topics with very musical metaphors. For example, a common way to talk about cells and organisms is by using a metaphor of an oscillator or a clock. Frazer describes a *'biological clock as any reliably oscillating cell or system of cells that serves as a control of the timed functions of a living system.'* (Fraser, 2007, p.148) He uses the term biological oscillator and biological clock interchangeably. What is more, *'the clock interpretation has been important in the development of thought and experiments in several areas of physiology and biochemistry, to the extent that the metaphor of a simple clock has become the only one used in some areas'*. (Winfree, 2001, p.107) This was the case with circadian rhythms during the 1950s and 1960s: *'So profoundly did the simple-clock metaphor pervade thinking about circadian rhythms during the 1950s and 1960s that alternative notions seldom seemed to pose a challenge worthy of experimental test.*

(Winfree, 2001, p.105)
Let me allow to develop the notion of circadian rhythms (circadian comes from Latin and it means "roughly daily") in more detail, as it serves as a good example of using clock and oscillator metaphor in order to explain and describe repetitive biological functions. The scientists have noticed and examined the astonishing regularity in the behavior of many animal species (Strogatz, 2003). The research has shown that this rhythm continues even in the absence of time cues in all living bodies. According to Winfree *'it is probably the most pervasive physiological rhythm...'* (Winfree, 2001, p.390). Most living creatures are synchronized to the 24-hour day, driven mainly by the cycle of light and darkness. These rhythms are said to reflect the functioning of a biological clock. It is called "biological", as it is apparently generated from within the organism, and it is called a '*clock'*, because it measures time in a periodic way, sometimes with surprising precision, with the period close to 24 hours. (ibid.) Although it took quite some time to find where this synchronization came from, nowadays we know that it is by 'circadian pacemaker', a neural cluster of thousands of clock cells in the brain, themselves synchronized into a coherent unit. (Strogatz, 2003) The most important factor in keeping our bodies in sync is sunlight. The experiments have shown that the phase of an internal clock can be started, stopped, and reset in phase by exposures to light (ibid.).

The terms like oscillator, phase and periodicity instantly brought the idea of drawing a parallel between simple cells and organisms and musical oscillators to my mind. Now that I have learnt that single cells and organisms can be described as oscillators, the next step was to somehow connect them to play together. The following metaphor from the Frazer's book proved to be helpful, as well as the ideas taken from the book 'The Emerging Science of Sync', which I will describe as next.

So how many oscillators are there in nature, what frequencies do they oscillate at and can they be expressed in musical terms? In his essay Frazer (Fraser, 2007, p.140) compares the spectrum of biological oscillators to that of musical ones. He concludes that the spectrum of biological clocks is spread from an upper limit of 10^{16} Hz (the response of human skin to ultraviolet rays) to a lower limit of 10^{-7} Hz (the circannual period found in millions of species). (ibid.) When we map this to musical values, it is a range of 78 octaves. As we know, human hearing range spreads from about 20 to 20,000 Hz, which is only 12 octaves (Fraser, 2007), so this comparison can only have a metaphorical meaning and direct mapping of these values would not make much sense.

A3.3 The Science of Sync

For reasons we don't yet understand, the tendency to synchronize is one of the most pervasive drives in the universe, extending from atoms to animals, from people to planets.

(Strogatz, 2003, p.27)

Another source of inspiration was the so-called 'Science of Sync'. It is relatively new branch of science that has recently become popular. It was presented by Steven H. Strogatz (2003) in his book 'The Emerging Science of Sync'. He gives multiple examples of both living things and inanimate objects that synchronize and explains how it works in practice. Some examples include the flashing of fireflies, the beating of heart cells, the circadian rhythms (mentioned earlier), electricity systems, the discovery of laser, the spread of information in our culture etc. It is a very interesting subject, especially as humans used to think of nature as of a chaotic and wild force without order. Anything that displayed regularity was thought of as intelligent, but it turns out that synchronization is one of the fundamental rules governing our universe (ibid).

At the core of this science is the study of coupled oscillators, i.e. oscillators that can influence each other by a very *basic form of communication – sending and receiving* *signals* (Strogatz, 2003, p.51). When we apply it to a large number of individuals, we see interesting things happening. Very often this communication results in synchrony and all the oscillators start to move as one. These coupled oscillators can be groups of fireflies, planets, or pacemaker cells. They cycle automatically, repeating themselves over and over again at more or less regular time intervals. Fireflies flash; planets orbit; pacemaker cells fire. Fireflies communicate with light. Planets tug on one another with gravity. Heart cells pass electrical currents back and forth (Strogatz, 2003).

I would like to make a comment that, in musical context, composers, who referred in their compositional strategies to natural phenomena, usually related them to stochastic or random methods, like Xenakis (1992). The idea of natural organisms and even inanimate object (as will be shown shortly) being able to spontaneously synchronize brought to my mind the idea that musical ideas based on nature can also display regularity. Another inspiring fact that I found was that the basic communication between oscillators is as simple as the ability of sending and receiving signals. Both of these findings were applied in the practical part of my study.

Coming back to the sync, I will now describe an example of this phenomenon in inorganic objects. It was described in writing in 1665 by the Dutch physicist Christiaan Huygens and later rediscovered by Strogartz. Huygens had invented the pendulum clock a decade earlier, and now, with its help, he hoped to solve the greatest technological challenge of his day: the problem of determining longitude at sea (Strogatz, 2003). He had two pendulum clocks in his room, which were the most accurate time keepers at that time. He was confined to his bedroom for several days because of illness when he noticed a strange phenomenon:

> *These two clocks hanging next to one another separated by one or two feet keep an agreement so exact that the pendulums always oscillate together without variation. ... mixing up the swings of the pendulums, I have found that within a half hour they always return to consonance and remain so constantly afterwards for as long as I let them go.* (Strogatz, 2003, p.106)

Without realizing it, Huygens had exposed a phenomena of sync in inorganic objects. This type of synchronization is especially perplexing for us, human beings, because it happens in the material world, in the objects that are not intelligent end even not alive. We think of synchronization as of a human thing, we can sing and dance and play music together, march in steps or clap in unison, but when it happens in mindless, lifeless objects we find it difficult to acknowledge. Contrary to our intuition, sync does not require intelligence or living organisms, *'it has its source in the deepest source of all: the laws of mathematics and physics.'* (Strogatz, 2003, p.109) There is a simple experiment that can prove this kind of synchronization in practice. If we place multiple metronomes with the same tempo settings on a shared movable platform and start them all in a random offset of the phase, after a while we will notice that they start to synchronize and tick in unison. A video of this experiment can be found in an appendix.

A3.4 Time in Chaotic Systems, Chaos as a Model of Natural Phenomena

> *'These, then, are the defining features of chaos: erratic, seemingly random behavior in an otherwise deterministic system; predictability in the short run, because of the deterministic laws; and unpredictability in the long run, because of the butterfly effect.'*
>
> (Strogatz, 2003, p.201)

Chaotic processes have been used in the musical context multiple times (Choi, 1997). Some of the more sophisticated tools for sound synthesis and for generating musical structures even have built-in functions that can generate and model chaotic behavior (super collider). It is also relatively simple to build an analog electronic circuit, which acts in a chaotic way and to use it as a voltage control signal in analog synthesis. I decided to explore this possibility and it will be elaborated in more detail in the later part of the thesis dedicated to the practical aspects of my research. For now, I will provide some facts and findings about chaos theory.

An important scientific finding of the 20th century was chaos theory and its applications into modeling and examining phenomena occurring in nature. It is important to distinguish the colloquial meaning of chaos from the scientific one. In the former context, chaos means a state of total disorder, in the latter, technical sense, chaos refers to:

> *'a state that only appears random, but is actually generated by nonrandom laws. As such, it occupies an unfamiliar middle ground between order and disorder. It looks erratic superficially, yet it contains cryptic patterns and is governed by rigid rules. It's predictable in the short run but unpredictable in the long run. And it never repeats itself: Its behavior is non periodic*' (Strogatz, 2003, p.198)

Even thought, the ideas about chaos had been known to mathematicians before, (ibid) it was only in 1963, that chaos theory was noticed in a wider context. It was thanks to Ed Lorenz, who tried to apply mathematical equations in order to explain the unpredictability of the weather. During his experiments he wrote down a set of three differential equations – nonlinear ones – which looked like they were simple to solve for a student of mathematics, but they proved to be impossible to solve, they generated chaos. (Strogatz, 2003) During the first few years after he had published his paper it did not get much attention. The situation changed in the 1970s and 1980s, when scientists from various fields started to notice strange behaviors, which could not be explained in simple terms. Studying simple models of the dynamics of animal populations, ecologists found chaotic behavior even though there was nothing random in it. Instead of repeating cycles, the virtual population unexpectedly boomed and went down erratically from one generation to the next. Other areas that displayed chaotic behavior included noisy voltage oscillations of some electrical circuits or the dripping of leaky faucets, to name just a few.

Chaotic systems are generated by nonlinear equations. Let us briefly talk about the difference between linearity and nonlinearity. In short, a linear system means that the whole is exactly equal to the sum of parts. The output is proportional to the input and the graph of linear equation is a straight line (ibid.). In nonlinear system, on the other hand, the whole is not equal to the sum of the parts and when we plot the input vs. the output on a graph, we get a curve. Linearity is often an estimate to a more complicated reality. Most systems behave linearly only when they are close to stability, and only when we do not push them too hard. But life depends on nonlinearity. Our nervous system is built from nonlinear components. Our perception is nonlinear as is perception of music. (ibid.)

One more interesting fact about chaotic systems is that due to their extreme sensitivity to changes and initial conditions it seemed impossible to synchronize them even when differences in initial conditions were infinitesimal. However, one scientist proved the opposite to be true. Lou Pecora believed that synchronizing chaotic systems could be used for communication (ibid.). After some failures and experiments, he succeeded in synchronizing two chaotic systems. It was hoped that this invention could be useful in encrypting communication. It also had other implications, presenting *'a dazzling new kind of order in the universe, or at least one never recognized before: a form of temporal artistry that we once thought uniquely human. It exposes sync as even more pervasive, and even more subtle, than we ever suspected.'* (Strogatz, 2003, p.218)

As stated at the beginning of this part, the ideas derived from this chapter were were inspiring and suggestive for the practical part of my work. The concept of time resulting from non-linear equations and chaotic functions, which could additionally be synchronized with other such systems, was one of them. Consequently, a lot of phenomena described here have found ways to their practical applications, which will be treated in the corresponding chapters of the second part.

A4 Time and Sound – Time Manipulations, Impact of Sound Technology on Time, Linearity and Non-linearity in Music.

Time is, of course, vital for the perception of music, and—as commentators from Aristotle to Luhmann remind us—it forms a basic condition that distinguishes music from graphic or literary art forms.

(Trippett, 2007)

Music is primarily a temporal art form and is intertwined with time by a network of intrinsic connections. I will try to explore some of them in the following section. I will start by discussing how music can influence and shape our perception of time in a powerful way. Next, I will focus on the technological innovations, such as recording technology and computer, which had made new ways of working with time and distorting time in listeners‘ perception possible. Here I will also mention some of the difficulties that arise from using computer as a compositional tool. I will also try to show how this growing importance of technology in the musical realm has been one of the factors contributing to the increasing spread of non-linear music in the 20th century.

A4.1 Music's ability to create, shape, distort and destroy time.

We should start by reminding the distinction, made in the first chapter, of psychological, individual time and subjective, absolute time made by psychology, sociology and other sciences. It is important to note that the time primary to art and to music is the subjective time, as opposed to the absolute one. As Erickson (Erickson, 1963, p. 177) puts it: *'Psychological time is primary to life, and therefore to art. ... . Beyond the practical and social world of clock-ordered events there is the inner world, the world of feeling, the musical world, where we live.* Another interesting thing to note is that we simultaneously experience musical time and ordinary, or absolute, time while listening to music (Kramer, 1988). As stated above, these two times are different and this difference is crucial for us. A piece of music performed in a concert or recorded on a tape takes a specific amount of clock time, but the way that this piece is composed, the way it treats time evokes a different time. This distinction *'between the time a piece takes and the time which a piece presents or evokes'* (Kramer, 1988, p.15) has great importance, because '*it is from this conflict between time taken and time evoked, that the richness of musical meaning comes'* (ibid.)

Another way of looking at these two times and their mutual relations comes from looking at the interesting and often quoted question posed by Kramer: *Does music exist in time or does time exist in music?* (Kramer, 1988, p.5) Before we give an answer, we should consider the consequences it will have. If we decide that music exists in time than *'we take time as an absolute, as an external reality, as somehow apart from the experiences it contains'* (ibid.) If, on the other hand, we answer that time exists in music, we then start to see how powerful music can be in creating and distorting time. The type of time he means is not the absolute one, but the objective (Kramer, 1988).

A trivial example of how music can shape our time would be the one that nearly everyone has experienced, that of attending a concert that we find uninteresting, but we are not able to leave (for whatever reason). In such a situation, we very often say that the performance 'lasted forever' or that it was 'never-ending'. Interestingly, if we submit ourselves to the music, instead of opposing it, it can affect our brain in an interesting way. Another type of musical time, that has the power to influence time perception is the one present in rituals; it plays a role in creating, enhancing and sustaining a feeling of timelessness, moving the participants outside regular time into the sacred one (as discussed in chapter 2).

If we become aware of this power of music to distort time, does it suggest that we can use this fact in music making? Are there techniques that can be purposefully used in composing music, in order to influence the listener's time? This question is particularly meaningful to me and I will try to answer it referring to the concepts found in Gerard Grisey's essay 'Tempus Ex Machina' (1987) that discusses the ideas of his composition with the same title. Among other things, Grisey presents a scale of complexity of musical durations, (ibid.) which range from periodicity to aperiodicity (fig A.4.1). These two poles correspond to a total predictability of musical durations on one hand and to a total randomness and unpredictability on the other. The total periodicity, which equals the exact repetitions of musical durations (and mechanical time), quickly becomes tiring for the listener. Likewise, the total randomness of musical durations has the same effect, resulting from too much information. Grisey (1987) compares these two extremes to the perfect and thus redundant time of a musical sequencer on one side and the serial music, which has got rid of all temporal periodicities, on the other. (ibid) The next thing we find out is that human perception of durations, like that of pitches and other musical qualities, is ruled by the same mathematical law, namely logarithmic (ibid). What this means in practice is that in order to have the same perceived proportion between durations of musical events, the differences between longer events have to be proportionally longer than those between the short ones. (ibid.)

a) *Periodic*	maximum predictability	ORDER
b) *Continuous-dynamic* 1) continuous acceleration 2) continuous deceleration	average predictability	↓
c) *Discontinuous-dynamic* 1) acceleration or deceleration by stages or by elision 2) statistical acceleration or deceleration	slight predictability	↓
d) *Statistical* complete redivision punpredictability of durations maximum discontinuity	zero predictability	DISORDER
e) *Smooth* rhythmic silence		

Fig A.4.1 Grisey's scale of musical durations

Referring to the facts that we have just learnt, Grisay talks about utilizing time curves as a technique to change the perception of time in the listeners' mind. He mentions acceleration and deceleration as the two main ones. *'Acceleration makes present moment more dense, the arrow of time is at full speed'* (Grisey, 1987, p.249). Deceleration creates the opposite result where *'the listener is pulled backwards, since the arrow of time had somehow turned in the opposite direction'* (Grisey, 1987, p.252). He also presents various ways of using acceleration and distinguishes between different types of accelerations.

Other time manipulations were made possible by technological innovations. Sound recorded on tape could be reversed, spliced and cut, creating the feeling of time going backwards and of discontinued time. Using computers as a compositional tool brought yet other possibilities of time manipulations, such as randomization of durations or statistical distribution. Next part is dedicated to that topic.

2 Technological Impact on Time in Music – Manipulating Time

The perception of time—went through critical changes in the early decades of the 20th century, largely in response to rapid technological innovations

(Trippett, 2007)

In the earlier parts of this thesis, I talked about the influence of technological inventions on how time was treated and perceived. Here I would like to expand on these ideas and to talk about them more particularly in relation to music. They could be divided into two groups: recording technology and computers.

As stated many times before in this thesis, by the end of the 19th century time had been made uniform by introducing standardized time (Kern, 2003). The Newtonian paradigm was still the dominant one, with more and more clocks measuring time in distinctive steps. The ability of manipulations was introduced by invention of tapethe tape recorder. Sounds recorded at different times could be made adjacent, creating a new link that had not existed before (Kramer, 1981, p.7). Composers were more attracted to the opposing effect of splicing the tape, which can result in an 'overpowering discontinuity' (ibid.). *'The listener is instantaneously transported from one sound world to another.'* (ibid.) Kramer suggests that this is what influenced Karlheinz Stockhausen to write his first self-consciously discontinuous '*moment form'*. The aesthetic of discontinuity has spread far outside the tape music and even composers with no interest in electronic music composition have used this techniques extensively. (Kramer, 1981)

The availability of repeated hearings, brought by gramophones and tape machines resulted in the reduction of repetition and redundancy in the early 20th century music. This lack of repetition resulted in a higher intensity in compositions of Arnold Schoenberg and other early atonal music (Kramer, 1988), which led to further reduction of repetitions in musical form found in serial, stochastic and aleatoric music. The early 20th century music became more complicated than ever before and this tendency of growing complexity has continued. An extreme example of reducing repetitions in musical compositions was the so-called ‘mobile form’ (ibid.). In this type of compositions, sections can be put together in any order, making each performance different. Even if we record a performance of such a piece, we only hear one possible realization of the many. These new compositional practices could be seen as a reaction to the *‘tyranny of repeated hearings’* (Kramer, 1988, p.69).

Recording technique has also disrupted the interdependency of time and memory (Trippett, 2007).In earlier times, memory could be nothing more than an inner, ‘subjective faculty’. (ibid.). By introducing the possibility of sound capturing *‘the passing of time, could be objectified, recalled, and re-lived; our existence—allied to that of time—could, with the aid of technology, be re-presented indefinitely.’* (Trippett, 2007, p.538) Interestingly, the primary use of gramophone suggested and advertised by Edison was to *‘record and store the dying words of one’s relatives’* (ibid.) and not as it is used today.

Moving further into 20th century we encounter more advanced technological innovations, with computer being one of the most important one. Composers were eager to explore new possibilities provided by computers, however their attitudes differed. I will show these differences by looking at the ways that Iannis Xenakis and Gotfried Michael Konig treated computers as compositional tools. Next I will mention some problems, arising from using computer as a tool for composition.

In the days of early computer music, two composers coming from different traditions commented on what this innovation meant to them. Iannis Xenakis and Gotfried Michael Konig both appreciated computers for the reduction of long-lasting calculations, but this was as far as the similarities went. Xenakis, referring to the ancient Greek philosophy and science (mainly mathematics and physics) as sources of music, drew parallel between the stochastic laws and the kind of global phenomena found in nature, (Xenakis, 1992) such as the noise of rain, street noises, or movements of a human mass in a street political demonstration. He stated that using some of these global laws inspired him to bypass the *‘crisis of serial music’* (ibid.). Konig, on the other hand, came from a serialist tradition and saw the use of computers in the musical composition as a logical progression of history (Konig G. M., 1967) and believed that algorithms should be generated based on the (serial) musical tradition, using aleatoric procedures (ibid.). For him, music was completely artificial, having nothing in common with nature (ibid). His approach to working with time in a computer-aided composition was to treat it as a basic entity. He specified the length of time, and then distributed points along the time-axis according to some rules (Konig G. M., 1983). Both Xenakis and Konig used randomly generated values in their compositions, but they derived them from different sources. We can see here that the use of chance operations to generate musical structures was one of the most characteristic features of computer-aided composition (Konig G. M., , 1997).

Computers offered huge possibilities in the field of musical composition, but there were also some problems, which I would like to point out by referring to Vaggione's (Vaggione, 1993) criticism of Xenakis's method of stochastic composition and Konig's remarks about computer music. If we look at the tradition of tonal music with its advanced structure of interrelated layers of time and harmonies, we see that it has an advantage over electronic and computer music, which lacks such a structural base. Vagionne (ibid.) proved it by an example of music of Xenakis. As we found out earlier, Xenakis used stochastic methods in his compositions for creating clouds of events, which he then manipulated in an arbitrary way. (ibid.) Here is where Vaggione points to a problem in the Xenakis's method. *'This process did not establish an explicit structural relationship between the two levels. It is roughly a one-sided domination of the local by the global. By using global laws, he negates the singularities of these events, keeping only their one-sided aspect, external, subject to global law'* (Vaggione, 1993, p.9). Xenakis believed that he created 'mass-polyphony' with his global laws, Vagionne proves that stochastic cloud is imbedded in global time and that for this reason interaction between the levels cannot take place and all he achieves is a kind of 'homophony'. Konig also talks about some difficulties that come with the introduction of computer-aided musical composition. He mentions problems in interpretation and communication (Konig G. M., , 1967), which are caused by the introduction of technology. The machine does not understand the music, it has no musical taste and thus a problem of translating musical ideas to the computer and in computer language arises (Konig G.M 1982). Interestingly, he also points to the idea of musical layers and the fact that they can be valuable compositional aid and useful for generalizing compositional ideas into algorithms (Konig G. M., 1997).

The last result of introducing the great time-keeping machines that I want to mention is the distinction of a new kind of time, the perfectly rigid and quantized time – the machine time, which differs from ours – human time. No matter how hard we try we can never play rhythm on the perfect grid, we always introduce some slight irregularities (Kramer, 1988). Sequencers and computers, on the other hand, *'produce coldly regular rhythms, far more precise than any human could perform.'(ibid. p.72)* This distinction was very meaningful for me. I have worked with musical robots before with various results, however now I developed new ideas I that I wanted to implement. Another source of inspiration about how to use time of machines and make music with them came from Paul Hindemith. His approach was to make compositions for musical machines authentic by achieving *'total abstinence from traceable human activity'* (Trippett, 2007, p.556). I will come back to this topic in the corresponding chapter of the practical part of this thesis.

The introduction of new technologies influenced all aspects of life. In case of music, it was one of the factors contributing to the collapse of tonal system and linear mode of thinking. Kramer noticed the growing importance of non-linearity in the twentieth-century music as a result of an increased influence of technology (but not in opposition to it) (Kramer, 1988). Interesting to note here is another approach going against praising and glorifying new technologies which provided even more precise control over any variables in music (Conrad, 2004) and *'colonization of subjectivity by scientific rationalism infected thinking'* (ibid. p. 2). I am referring here to the introduction of extended durations in the time-based arts in the 1960s, as described by Tony Conrad (2004) in his essay 'Duration'. He argues that these techniques, seen in the works of composers like La Monte Young or John Cage were in a direct opposition to the *'rationalistic temporality'*, (ibid) prevailing in music at that time. These extended durations had another effect on the audience, evoking the state similar to the one that Kramer describes as sacred time and Conrad refers to as *'altered states of sleep, trance or meditation'.* (ibid.) They in turn have made them (audience*) realize the distinction between the subjective experience of durations, memory and the present as opposed to rational clock-time, thus becoming 'demonstrations of the non-linearity of experienced duration'* (ibid.). This brings us to the next part, in which we elaborate on this distinction in relation to music.

4.3 Linearity and Non-linearity In Music

Thus music has become progressively more discontinuous in recent generations. The temporality of twentieth-century music (and really of all contemporary arts), like the temporality of inner thought processes, is often not linear. (Kramer, 1988)

The distinction between linearity and non-linearity has been mentioned a few times already. In the following section, I would like to focus on it more and describe how it relates to music. It can be said that the culture of the Western world which seem to be prevailing nowadays is an example of the linear one, or at least that had been the case for many centuries until the 'postmodernism'. I tried to show how some technological inventions and scientific discoveries, among other things, as well as humans' reaction to them, caused a new way of looking at the world to become more prominent in our culture. The so-called avant-garde or counter-culture movements, as is usually the case, were the first to explore those new territories. Let us remind some of the key features of these two oppositions. Linear means goal-oriented, rationalistic and predictable. (Kramer, 1988) Non-linear refers to such ideas as irrationality, unpredictability, the sum of the parts not being equal to the result, not bound by laws of causality... When it comes to music, the consequences of growing importance of non-linearity have been especially noteworthy (as music deals with time) and have brought some revolutionary changes and new concepts, which I will present next.

Let us start by listing some key features differentiating linearity from non-linearity (fig 4.2), which should make further discussion clearer.

Linear	Non Linear
TELEOLOGICAL LISTENING HORIZONTAL MOTION CHANGE PROGRESSION BECOMING LEFT BRAIN TEMPORAL	CUMULATIVE LISTANING VERTICAL STASIS PERSISTANCE CONSISTENCY BEING RIGHT BRAIN ATEMPORAL

Fig A.4.2 Lineariry vs Nonlinearity (Kramer, 1988)

The goal-oriented culture that dominated in the West between 16th and 19th century was dominated by linear thinking. It was goal-oriented, it valued progress and believed in a causal relation of events. The realization of these values in music was a tonal system, which is an ideal expression of linearity in music (Kramer, 1981). Its movement towards tonic and corresponding feeling of tension and resolution suggest moving towards a goal. Nonlinearity has gained importance in recent decades, but nowadays majority of music in our world is still linear. (Kramer, 1988). Let me present how Kramer distinguishes linearity and non-linearity in music: Linearity is *"the determination of some characteristic(s) of music in accordance with implications that arise from earlier events of the piece" (ibid. p20)* Non-linearity is defined as *"determination of some characteristic(s) of music in accordance with implications that arise from principles or tendencies governing an entire piece or section." (ibid.)* The main difference between the two is that in the linear composition, the rules governing the piece change as a result of earlier musical events, while in non-linear music, these rules are the same from the beginning throughout the piece.

I have written about linearity and its dominance in our culture and music. There are, however, cultures for which time is non-linear and it is reflected in their lives. For example, the language of people of the Trobriand Islands has no tenses and contains very few words that express progress, change or continuity (ibid. p.42). Similarly, in Bali Island, time is not seen as goal-oriented. It is more cyclical with *'their calendars marking not changes in time but ten concurrent cycles of from one to ten days in length "* (ibid.). Their music also reflects the character of non-linearity. It contains rhythms, which we would find boring with their endless repetitions not suggesting a climax (ibid.). I mention these examples to show that the Western way of thinking about time is not the only one and that the perception of time as linear or non-linear is arbitrary.

In the last part of this chapter, I will briefly describe some new musical temporalities that appeared in the 20th century music as a consequence of growing importance of non-linear time in music and its interaction with linear time. One very lucky and interesting finding I have made was the analogy of theory of multiple layers of temporalities introduced by Frazer and briefly described in chapter A3 and of Kramer's new temporalities in music.

Goal-directed linear time

It is represented by tonality as a consequence of the linear character of culture, with progress-oriented and forward-looking characteristics. In reference to Frazer's theory of multiple temporalities, linear music is the main expression of nootemporality*,* because of its clear beginnings end endings as well as anticipation (Kramer, 1988).

Non-directed Linear Time;

This type corresponds to atonal music of early 20th century composers. It still had a sense of direction and progression, but *'we didn't know where we were going'*. (Kramer, 1988, p. 6)The matching temporality of Frazer is the *biotemporality* in which time progresses without overall logic reminding a dream (ibid.).

Multiply-directed Linear Time

As name suggests it gives a feeling of multiple simultaneous motions in many directions. The directions of movement are unknown and can be present at once. *Eotemporality,* in which causality can exist, but we cannot distinguish between the cause and effect, is its temporality (ibid).

Moment Time

This time is discontinuous and lacks linearity. It was named after the Stockhausen's moment form. The pieces representative of this temporality do not have beginnings, they start as if they were going for some time and we just tune into them. This time corresponds to *prototemporalrality*, in which it is not possible to tell which events have happened first and in which causation is probabilistic (ibid).

Vertical Time

Finally, there is vertical time, in which non-linearity dominates over linearity. It does not intend to influence or manipulate the audience. It does not create expectations. Music of this time allows to make contact with subjective temporality. No events depend on the others. It corresponds to *atemporality* where there is no past or future, just emptiness. It is this type of time that plays a special role in evoking sacred time, as mentioned in chapter 2. I would add that these descriptions and earlier remarks about La Monete Young make me think of drone music as a typical representative of vertical time in music.

This chapter started by describing the ways in which music can alter time in the listener's perception and mentioning some possible tactics that could allow it. Next technological advancement of sound capturing and computer were mentioned, which altered the perception of time and allowed more time manipulations. This lead us to describing the distinction of linear and non-linear time, with the later one becoming more prominent over the last decades. Finally, the new temporalities, resulting from the linear – non-linear duality in music, have been listed.

A5 – Conclusion

I did not realize how difficult the theoretical part of this reasearch would be. After spending huge amount of energy on this part of the project I must say a lot of results were not satisfactory. Even some theories that have made their way to the final form of thesis turned out to be less interesting then initially expected. But I take this as part of the process.

One of the conclusions from this section is that time truly is ungraspable. We think we know something about it and when we try to say it, we are speechless.

So, what we do say about time, are usually abstractions, generaliztions, some mappings to the material world, or some beatifully sounding phrases, which do not say much about time.

Having said all that, I did manage to gather some intresting information, and to make some usefull discoveries, which I am going to implement in my work. Below is a very loose list of some of the characteristics or observations that I found stimulating. I am not putting them in any particular order and I am not analyzing their usefulness for furhter work. This will happen in the second part. For now these are just some observations gathered from my research:

- Time is not homogeneous, we can distinguish many opposing characteristics of time.
- Time seems to be evolving and changing.
- We can derive numbers from pariodic or regular behaviors, anything displaying such regularity can be a clock or an oscillator.
- Music and time have special connection, they can influence each other.
- Technology changes the way we experience time.
- Natural processes are govern both by random, stochastic and unpredictable processes, and by regular and periodic ones.

I am aware of quite highly personal character of this thesis, apparent in many ways. For example I have expressed some opinions about the state of our culture, which could be seen as pessimistic (I tried to suggest possible alternatives). This style is a result of my strong engagement with my work and my inability to withdraw myself from the artistic process.

I have also touched upon some fundamental philosophical issues of humanity, and have only been able to scratch the surface of them, raising many questions and leaving them unanswered. This might leave the reader with a feeling of frustration, which I also realize. On the other hand I tried to deal with some more specific areas, such as music, technology and sciences, from which I derived more concrete ideas.

To end this section let me present a list of pairs of opposing characteristics, that can be attributed to time:

ATOMISTIC / CONTINUOUS

MECHANICAL / NATURAL

OBJECTIVE / SUBJECTIVE

GLOBAL / LOCAL

LINEAR / NONLINEAR

OF MACHINE / OF HUMAN

DIGITAL / ANALOG

ABSOLUTE / RELATIVE

SOCIAL / PERSONAL

LINEAR / CYCLIC

PROFANE / SACRED

Part B – Practice

B1 Implementing Theory Into Practice - Theoretical Findings of Musical Importance

In the introduction to this thesis, I have stated that music is a primary temporal artform. It cannot exist without *Time*, and it is through *Time* that the meaning of the music becomes evoked. Taking this as a starting point, looking at ideas within various areas of human activity, I tried to pick the most inspiring and relevant ones, to then apply them to my practice.

In this part I will discuss the practical aspects of my work. First, I will present the most interesting findings, from the theoretical research, that I applied into my practice. Next, I will look at the four experiments that comprises the practical part of my research. I will follow each one with a description, indicating how each experiment reflects the theoretical findings. I will also describe some technical details, and the versions that exist so far. Finally, I will give some comments on how successful the implementations were, and what changes I would like to include, in order to improve them.

1 **Multiple Layers of Time**

The concept of *Time*, consisting of multiple parallel layers, has appeared in quite a number of publications and papers. Julius Frazer, in his theory (see chapter A3), distinguishes 5 different temporalities that co-exist together, that have evolved in parallel with the natural world. I have also found an interesting connection between this theory, and Jonathan D. Kramer's distinction (see chapter A4), of various temporalities found in modern music. They can also co-exist, and often do so, in the frame of a single composition, as a result of tension between linearity and non-linearity. Let me distinguish here, the temporalities of Kramer, together with the corresponding time-layers of Frazer, in that order:

Goal-Directed linear time | Non-temporality

Non-Directed linear time | Bio-temporality

Multiply-Directed linear time | Eo-temporality

Moment time | Proto-temporality

Vertical time | A-temporality

The idea of different, and simultaneous, temporalities, has also appeared in the context of computer-aided composition. Horacio Vaggione (1993) talks about music as a '*highly interactive field of co-present temporalities*.' (Vaggione, 1993, p. 100) The word 'Interactive' is the important focus here. He also talks about the role that the computer could play, in designing these 'interactive fields of temporalities'. (ibid.) Gottfried Michael Koenig (1997) also mentions layers as a way of describing musical structure. For him, it was an especially useful strategy for translating compositional ideas into algorithms. (Koenig, 1997)

Other areas that hint at this idea may be the *metaphorical mapping* of all biological oscillators into a musical frequency spectrum, as suggested by Frazer (2007) and described by me in chapter A3, and *the Science of Sync*, (Strogatz, S. 2003) that talks about the whole universe - from atoms to planets - being synchronised with each other.

In the first practical project – the generative piece driven by values derived from a computer clock, my first natural inclination was to bring in these time-layers, and their interactive possibilities. The theoretical findings seemed to confirm my intuition in this case, and so, I was intent on expressing this idea - literally and metaphorically - by having multiple layers of sounds, that would interact with each other. I will discuss this more in the corresponding part (chapter B2), with additional ideas that apply to this piece.

2 Biological Oscillators and Synchronicity of The World

In the areas of Biology, Physiology, and other natural sciences, the term *Biological Oscillator* is used often to describe any periodic phenomena occurring in nature. The mathematics used, for describing this kind of occurrence, is called the circular logic, and the term *Phase* is used to describe various points on the time-cycle. In another area equally musical-terms are used to describe the ability of immaterial objects, to spontaneously work in unison. These terms are derived from the books '*The Science of Sync*' by Steven Strogatz (2003), '*Time and Time Again*' by Julius Frazer (2007) and the book '*Geometry of Biological Time*' by Arthur Wenfree (2001).

From the level of molecules and cells - in all living things, to planets and heavenly bodies - everything is in sync. Humans find it perplexing, since the idea of any kind of order is seen as a consequence of intelligence. It turns out that *order* (next to *chaos*) is one of the fundamental rules that governs the Universe. This idea was very suggestive for me, and I applied it to the second practical experiment, of which I will describe further, in Chapter B3.

3 Scale of complexity of musical durations

This idea was derived mainly from the field of music[1]. I have found it interesting because it is not just based on the dualistic oppositions - such as short/long, regular/ irregular - but places the durations on a scale, from periodic to random. This theory suggests the idea of exploring different levels of periodic complexity, especially in the smooth transitions between each of these levels. I applied this concept into the second practical experiment.

I additionally applied another idea, derived from here, into the first experiment; the

[1] Alert reader might notice inconsequence here, as my research title says 'non-musical' time. However Grisey's scale of periodicity falls outside what I defined as musical time in the introduction

usage of acceleration and deceleration of musical events, in order to create a feeling of the stretching and compressing of time, within the listener's mind.

Similar ideas of exploring boundaries between the randomness and periodicity of musical events, has been suggested by Vaggione (1993).

4 Time Continuous, Time Atomistic

Here, I will refer to the discussion between philosophers (towards the end of the 19th and beginning of the 20th century), mainly Henry Bergson, who was the first to oppose the Newtonian view of *time* consisting of infinitely small, but distinct points. The idea of *time,* made up of discrete parts and separated (like the boxed days on a calendar), was the popular dominant viewpoint (Kern, S. 2003). But, other innovative ideas were being introduced at the same time, saying that 'Private-time' was the real, and that its texture was fluid. (Kern, S. 2003, p. 34)

It might be too far-reaching a comparison, but what this distinction has done, has helped me think with more clarity, towards the differences between the analogue and digital domain (especially important for sound). In the analogue domain, such as in the concept of duration, we can infinitely divide values, and there will always be a smooth and continuous line without discernible steps. As we know, digital audio is made up of discrete steps, i.e. samples. They are frequent enough to deceive our perceptions into thinking of them as continuous, however, if we zoom in to an extremely micro level, we will be able to see the individual samples on a time-line.

I found this idea useful when working on the third experiment – *the SoundLapse,* where instead of making smooth transitions between samples, I kept them as 'snapshots' of time / memory. Another idea generated from this theory, was the juxtaposition of smooth transitions (between points in musical parameters), and the 'jumps' (between those points, such as 'Sample and Hold').

5 Performed vs. Programmed Rhythm

Musical sequencers and computers can keep perfect, steady musical beat. They are also capable of producing very complex rhythms. Human beings, due to their limitations, cannot play faster than certain speeds, and will introduce slight irregularities in their timing, even in the simplest of rhythms (Kramer, J. 1988).

Having worked with musical robots before, making them so that they could play any type of rhythms that I could imagine, the idea of trying to make them play human-like rhythms seemed almost out of place, and unnatural. During this research I found ways of writing music for machines, '*in an authentic fashion'* (Hindemith as cited in Trippet, D. 2007 p. 556), with '*total abstinence from trackable human activity'* (ibid.) This applies to the second practical experiment.

6 Music's ability to shape Time

This idea seemed particularly relevant to me. I implemented it in the first practical experiment, aimed towards creating a feeling of time-stretching and compression, whilst approaching the end of certain time-units. Here, I also applied some techniques found in Gerard Grisey's (1987) essay, *Tempus Ex Machina*, such as acceleration and decceleration, of which I will discuss in the corresponding section.

7 Linear vs Nonlinear Time

Last, but not least, I should mention this distinction, which was one of the most prominent topics in the first part. I did not base any particular experiment on this distinction, but it will be usefull for describing all the projects according to it. For now I can certainly say that experiment 1 is mostly linear, and experiment 4 non linear. I will refer to this when discussing each project individually.

Some other ideas and final remarks

I would like to mention that there are other ideas that are too small to be listed here, which nevertheless have found their way into the practical part, in one way or another. I will talk about them, when appropriate, in each specific section in the following chapters. I will also trace how each project is inspired by, and derived from theoretical ideas.

I must also admit that there are some ideas that, having taken up a lot of space and time in the theoretical part, were not very fruitful in my practice, and did not subsequently inspire any particular practical project. One such area, is the idea of *Sacred time* (although I do mention it in one place). The only implementation for this that I could think of, was by introducing Drone-music or by extended duration, of which seemed far too obvious. Sacred time also requires a particular mindset, which I do not present.

B2 Time Experiment 1 - Musical Clock

'Clocks are also, and often, objects of art. They are ticking, chiming, blinking, smoldering reminders of our passage from cradle to grave and hence of love, passing, joy, sadness and beauty. They connect each clockwatcher to the change ringing cosmos, to his and her local environment and to the lives and thoughts of their fellow humans.' (Frazer, J.T. p. 99)

First Ideas, Experiments and Models

In the introduction to this thesis, I observed that one of the impulses to choosing this research topic, was my earlier work (an audio-visual installation) titled *'Cymatic Clock'*. The sound material in that work was limited (to only 3 oscillators), and I had a feeling that it could be developed further. This experiment is a direct continuation and development of ideas from *'Cymatic Clock'*.

The idea behind this project is very simple: Take the values generated by a computer calendar, and use them to feed an audio synthesis engine. In this way, I received seven numbers, corresponding to years, months, days, hours, minutes, seconds and milliseconds.[2] I wrote a simple script in Processing (see appendix 1) which sent data to another software – Max/Msp. After initial experiments, I realised that I had to make a lot of decisions; about what parameters I would want to control; how I would distribute events in time; how I could make sound-structures interesting and not too static; and what sound materials would I want to use etc. I decided to come up with a model in order to implement this work.

2 To be precise, I had to add a little patch that would generate miliseconds.

My initial model looked like this:

1. Read 7 values from the calendar.
2. Generate 7 layers, each containing as many events as the corresponding time unit (365 units in a year, 30 units in a month etc).
3. At the end of the time unit generate new time distribution of events for this layer.
4. Map the values of the higher layers time unit to the amplitude of the corresponding lower layer. (The minute value controls the amplitude of hour layer, the hour value controls days‘ amplitude etc.)
5. Map the value of time layer to its events‘ attack times.

After initial trials it became clear that there were many problematic areas in this model (having as many sound events as there were units in time measurement unit to name just one). It did not make sense to have only 365 events per year or only 30 musical events per month. The result was not very musical and my next decision was to add distribution of events into the layers, govern by a simple rule – the lowest layer has the least musical events, with each consecutive layer having more events.. This was dictated by musical choice in mind.

The part that worked in my opinion was point 4 and 5, which were designed to introduce some *interactivity between layers*. I should also explain that point 3 was designed in order to create acceleration and deceleration at the beginning and ending of time units, by distributing event along time-axis according to various statistical laws. This idea was partially derived from Gerard Grisey (1987), in order to create the feeling of time compression and stretching at the start, middle or as we approach the end of a time-unit (fig B1, B2). The distribution types I was planning to use were: gaussian, beta, exponential, logarithmic, linear, random and silent (no events). There were seven types, so each layer was to have its own specific type of distribution. I must admit I had a lot of difficulties in implementing the stochastic distribution of elements in real-time and in the first version I used pre-defined values generated in AC toolbox.

After experimenting with the patch I decided to add an LFO (derived from the slow time-units of years and months), which would control the parameters of other layers. I also found myself changing and adjusting a lot of connections intuitively whilst playing with the patch, creating a very complex nest of connections between various input values and parameters. It did not obey the rules of my model, but it made the sounds more interesting. That was the state of the project at the end of first year, and I presented it in my first-year exam with further developments in mind.

Year two.

In the second year I found more ideas, which I tried to apply to this project. Some of these confirmed my earlier intuitions, whilst others introduced new ones. The idea of *'time layers'* seemed like a strong one, as I found similar concepts expressed in other various places throughout my research. In Chapter A3, I briefly described the theory of multiple temporalities of Julis Frazer (2007). In a more musical context, I found this very suggestive idea about interactive musical layers, described by Horacio Vaggione (1993), as having the potential to creating a '*richness of musical meaning*' (Vaggione, H. 1993, p. 94). In his opinion, tonal music had built-in forms and conventions (metro/rhythm/harmony etc.), which made it easy and natural to create

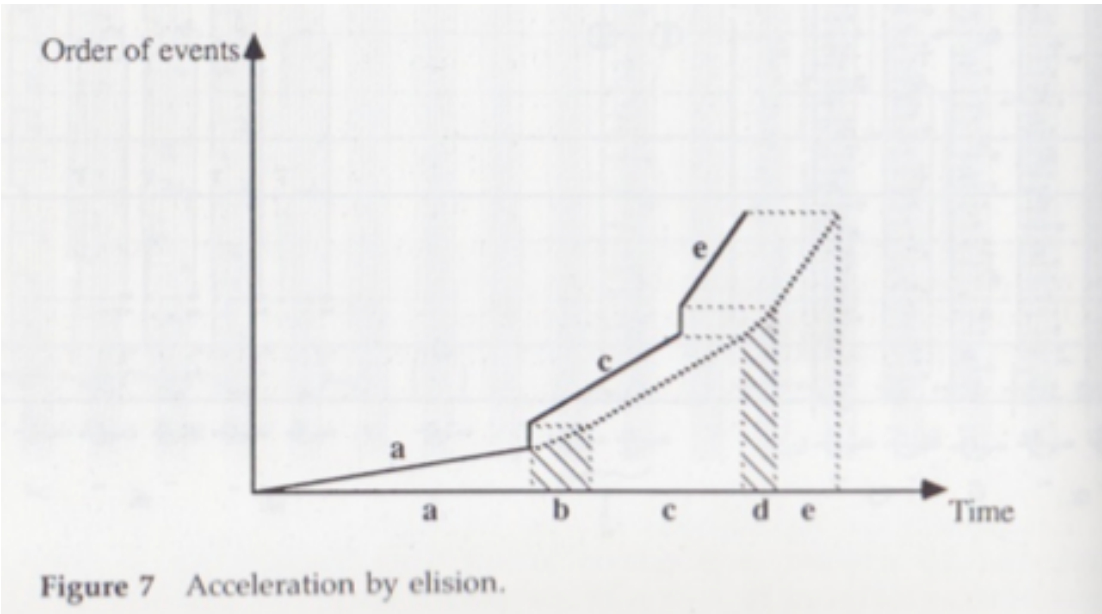


Figure B2.1 – Acceleration by elision (Grisey, 1987) ‘*multiple layers of interrelations’* (ibid.). In the field of computer music, however, there is a difficulty in the designing of these interactions, due to its relatively young age, and lack of standardised vocabulary. (ibid.) My aim for this piece was to create layers that would interact with each other in order to represent various time-layers' interactions. I tried to achieve this by controlling all synthesis parameters, by the same values derived from a clock, and scaled in multiple ways and by introducing techniques similar to that described in first model in points 4 and 5.

I also realised, after reading some of Goetfried Koenigs‘ texts, that my approach in this project was in a way a continuation of some of his compositional methods. I was focusing on musically important parameters (amplitude, events distribution on time axis, attack times etc.) and I was also using chance-generated parameter values (within a range-tendency mask). I also created a model before applying it in practice. All these factors bring it close to ideas described in *Programmed Music*. (Koenig, G.M. 1985) What differentiates my approach is that I have an external (non-musical) process at the core of my model (the clock values), I use the same time intervals over and over again (from clock - deterministic), and I fill them up with events, adjusting the parameters and controls of my model arbitrary after I had created it.

Another idea in this piece was to suggest the passage of time in the listener’s mind, and to shape and change their perception of passing time. This was partially inspired by the quote, '*Music is capable of lengthening or shortening the duration of a minute in our perception.* (Hans Heinz as Cited in Trippett, D. 2007, p.537)

In order to do this, I applied the techniques derived from Grisey’s *Tempus ex Machina* (1987), mainly the acceleration and deceleration (fig B2.1, B2.2), by using logarithmic time-curves, corresponding to the fact that our perception of duration is also logarithmic (ibid.). This way, at the beginning, middle or end of every minute (depending on the random choice), the listener experiences a stretching and compressing of time of different *time* layers. I think the implementation of this technique was quite successful.

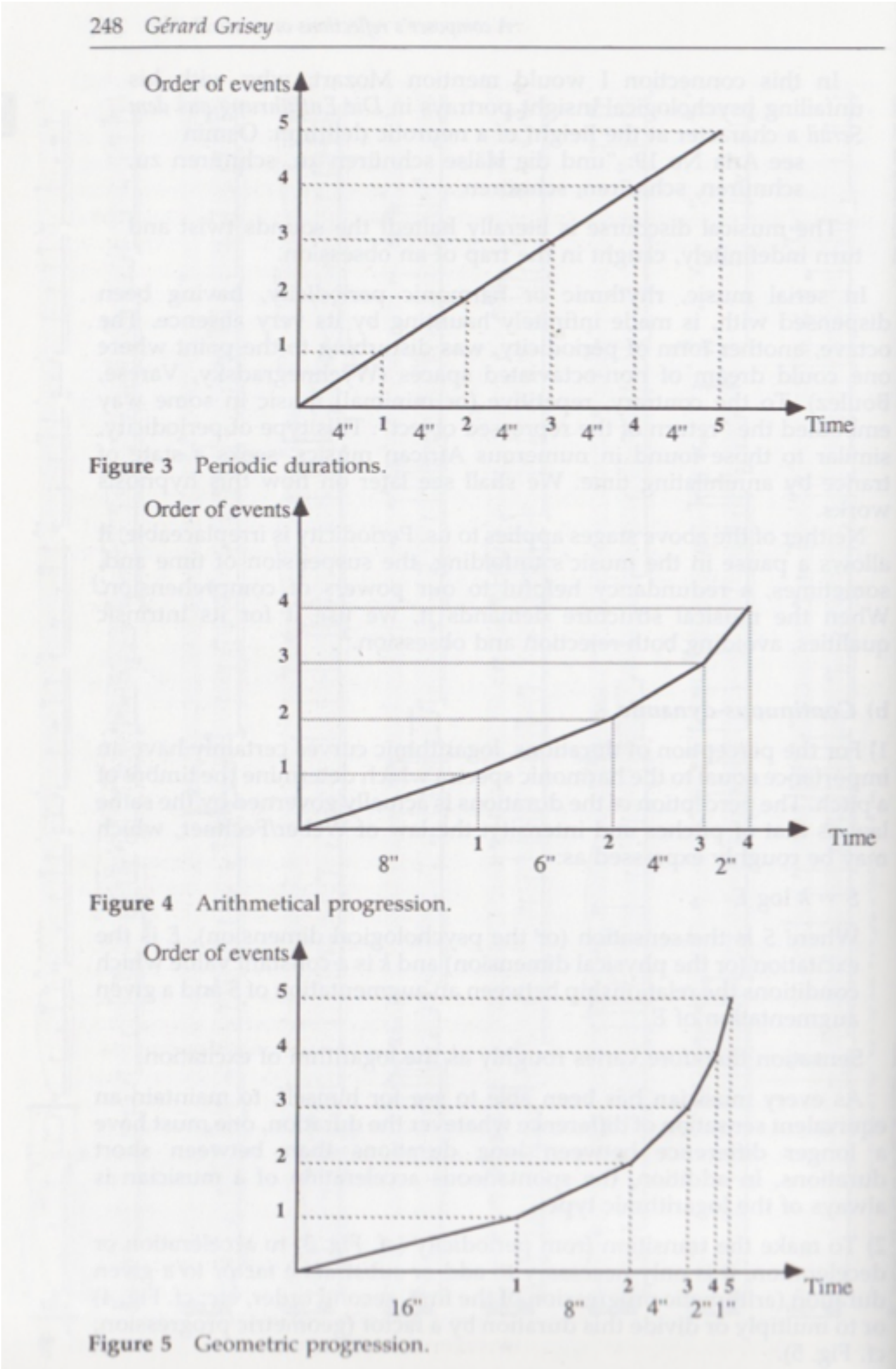


Fig B2.2 Figure B2.2 – Various distribtions of durations (Grisey, 1987)

Other Ideas Derived from Theory.

I was researching, theoretically, the history of clocks and calendars, and time measuring. What I began to learn, was that, it was just an arbitrary process of deriving numbers from periodic phenomena, found in nature. From this realisation, I began a fresh idea of creating my own time measurement, even to create a different one, at the end of every time-unit. Eventually I have decided against this, in order to try and see if I can manipulate the listeners' perception of time. One thought that was derived from this area of research, was the usage of extremely short musical durations, corresponding to extremely short divisions of time in modern clocks.

The idea of time, memory and their relations, was also translated into this work, by introducing a buffer, that recorded sounds of other layers, and replayed them at a later time, but heavily manipulated. This is (perhaps a naive) way to symbolise memory and how it digests time.

Let me mention briefly of another small idea that has found its way into this work. From the distinction of *time* - perceived as flux - against *time* - understood as atomistic – I pursued the idea of sliding and jumping between certain values of parameters.

Final Comments

What type of time does this piece present?

I found this project interesting for one reason particularly: It made me think about some of the ideas derived from the research on time. I decided to keep the time-units unchanged. Every minute, we have a new repeating cycle - a new beginning, which would suggest a cyclical time. On the other hand, I tried to create a feeling of tension, of a direction heading away from the beginning, towards the end of the minute – this evokes the linear type of time. Finally I have created some layers which are always there, very low and very slowly changing, which could be described as a drone, associated with the idea of the *extended now* or *timelessness*.

At the time of this writing the project is at a satisfactory level. I am still willing to introduce some changes and improvements before the final presentation. This includes adding more sound sources, making a multi-channel version, and improving interactions between the layers.

B3 Time Experiment 2 - In Search for Sync

If the electrical oscillations were mechanical instead, a splay state would look something like a row of dancing robots, all performing the same contorted sequence of moves, but arranged arbitrarily in space: One robot does something, then far down the line, another does the same thing, then back somewhere else, another srarts in. All permutations are allowed. The robots can dance in any order; each ordering is a valid splay state. They differ only in spatial arrangement, not in the moves performed or the timing beween them. (Strogatz, S. 2003, p. 161)

As mentioned in the introduction to this thesis, I like to work in various media and technologies. An important aspect of my work, is making musical instruments and objects. Before coming to Sonology, I had just completed a project that I had been working on for some time – a drum robot. It gave me great satisfaction, I could program it to play any rhythm that I could have imagined. The problem here was only that I was not sure of what kind of rhythms I wanted it to play. After starting my research in Sonology, I could foresee ahead of me a solution to this question.

Introduction

This practical project was inspired by the findings in the fields of Biology, Physiology and Physics on one hand, and technological advancements on the other. The most fascinating and inspiring book for me was *'Sync - The Emerging Science of Spontanueous Order'* by Steven Strogartz (*2003*). In an interesting way, he describes how, over the years, scientists have begun to understand how the phenomena in the natural world are in natural synchronisation with each other. People were reluctant to accept this idea, and it took a long time before its acknowledgement. This simply was because of the way we have thought of synchronisation as a result of a higher intelligence.

A lot of human activity involves syncing – playing music, dancing, sport, communication, transport etc. But, as Strogatz (2003) shows, *Sync* is also one of the basic rules of the Universe. At the core of this science, is the study of coupled oscillators: Oscillators that can influence each other - in the most basic form of communication – by sending and receiving signals (ibid.). This brings another interesting parallel with music, present in other books, namely that in Biology, Physiology and other natural sciences, the word 'oscillator' is used for describing any periodic phenomenon occurring in nature, and the word 'phase' to describe its location in this time period. I found these descriptions very musical and they encouraged me to apply these concepts into my practice. An obvious idea was to try to create a model of a colony of cells, or simple organisms, and their communications, and by giving them some sound qualities to see if they would make interesting sounds together. Although the effect might be interesting, there have already been quite a few implementations of these ideas into artistic work and making another one would not bring anything new.

Version 1 - Simple Conversation

I looked at the basic element of the *sync* - coupled oscillators that can send and receive signals (Strogatz, S. 2003). After some time the analogy with my instruments developed. Apart from the drum robot, which I mentioned above and which can *send and receive signals*, I had made a light sensitive interface, which also had these characteristics. (It can react to the amount of light in its environment). By putting together these two instruments – a drumming robot which can send signals by flashing LED lights and receive signals in form of MIDI messages, and a light sensitive interface which can sense changes in light and send signals to the computer, I had created the *two couple oscillators.* These two instruments could represent a very basic way of communication. The first version of this project had been created. The only addition that I made, was introducing a single time variable, which controlled how fast the two instruments communicated and responded to each other's actions. This could correspond to the controlling of the speed of phase of the coupled oscillators. I presented this piece in the Sonology concert at the Zuidetheater during the Folkspalais event and the documentation can be found at (https://vimeo.com/124267367). I called it *A Dialog of Three,* to stress the importance of communication between these two instruments (me being the third in the 'Three').

Version 2 Mechanic vs Analog Time

The rhythms and sound generated by the first version were quite slow and did not bring to mind an idea of synchronisation, rather the opposite – being out of sync. Shortly after, in another part of my research, I found the idea of *time* of the machine juxtaposed with the human *time*. (presented in chapter 4 of the first part). Let me just recall some of them here. Musicians never play on perfect grid; they introduce irregularities into the rhythms. Sequencers and computers, on the other hand, produce perfectly regular rhythm, more precise than human could perform (Kramer, J. 1988). *'We can appreciate the difference between rhythms performed by a human and rhythms generated by machinery. This difference is subtle, but the implications are enormous.'* (Kramer, J. 1988, p.73) This quote is the best summary of the ideas behind the second version of this project. I realised it, not by using rhythms of humans as opposed to the computer ones (as suggested in the quote), but by using solenoids, which hit bicycle bells hanging on pieces of rope. When a solenoid hits a bell, it starts to swing and so next time the solenoid fires it might or might not hit the bell – this introduces slight irregularities. These irregularities, which appear when we leave the perfectly quantised world of digital logic and time, and enter the analogue realm, were at the core of this realisation. By taking solenoids, (representing computer logic) outside of the computer realm, into the physical world, I automatically introduced some imperfections, which were further amplified by using long strings of rope for hanging bicycle bells. Once the perfect, binary mechanism, represented by solenoids, enters our imperfect analogue world, of bells, live performance, strings, physical laws, gravity and many other forces, it loses its binary perfection, and digital character. This split, between the two worlds, is further emphasised by the bells being imperfectly hung on the strings, resulting in many hits of the solenoids being missed. Through this experience we can appreciate the difference between *time* of the machine, and the analogue *time* of performance. I have presented this version in the 3rd CASS concert of the 2014/2015 academic year. Unfortunately, due to the poor (sound) quality of the documentation, I could not include it here.

Version 3 – In Search of Sync

The most recent, and third, version of this project, builds up on the previous ideas with some additions and modifications. I am interested here in the perfectly quantised and non-human-like execution of rhythm. I believe, that if this piece was to be performed by 'real' musicians, it would pose a real challenge in time keeping, even to the finest performers.

I was partially inspired, again, by exploring possibilities of computer time as expressed by Jonathan Kramer: *'I am hoping that composers will use the new technology to do things only machines are capable of.'* (Kramer, J. 1988, p. 74). The idea of *sync* also inspired this realisation, but here it is taken as a metaphor. The oscillators try to get in sync, and almost get there, just to loose it at the next moment, and thus never quite achieve it. Another source of inspiration came from watching a number of swinging pendulums hanging next to each other. Each one has a very slightly shorter arm and so when their swinging is initialized at the same time, after period of initial synchronization they start to go out of phase. This effect continues and becomes more prominent as the time progresses, creating mesmerising visual effect (see appendix). I tried to recreate this effect in the sound domain. It was achieved by having a number of oscillators (pendulums) with a very small difference in frequency (arm's length). Each time the oscillator crosses a zero point it triggers a solenoid. Depending on the difference in the frequency of the oscillators we have faster or slower development of very complex rhythms, which are never the same in the two consecutive cycles.

It is worth mentioning that here we explore the boundaries between two extremes of periodicity and aperiodicity, by smoothly transitioning between the different types of periodicities, as described by Grisey (1987).

This version is still in development and I hope to show it at the final concert. I am planning to add other, less rhythmical sounds, which will be synchronized with the oscillators.

I would like to point out that this practical experiment was initially inspired by nature and the science of *sync*. Traditionally, music derived from natural phenomena was associated with random structures, stochastic processes and similar, creating extremely complex and irregular movements, governed by statistical laws of distribution. By referring to new discoveries in science, such as *sync*, I try to show that sound ideas derived from natural phenomena can also be rhythmical, periodic and repetitious, whilst being complex and sonically interesting.

Linear vs Nonlinear Time

If we take Kramer's notion of linear vs nonlinear music, which says that the rules of the nonlinear musical piece are known from the beginning and stay the same for the whole piece, then this represents nonlinear time. The first realization however had a feeling of development, which is associated with linear concept. Like most music it is probably both.

B4 Time Experiment 3:

SoundLapse - Time Recorded, Time Subjective / Objective

History

This experiment can be seen as a direct continuation of my earlier work, *Around the Clock*. Its first realisation took place in Helsinki in August 2012 in the *Akusmata sound art gallery* (https://vimeo.com/53553897). The question I first posed with this piece was: Is it possible to express time in sound? (not unlike the question for the current project). We know that sound recording is bonded strongly to the space where it was recorded, we can also for instance, instantly distinguish if the sound was recorded indoors or outdoors. But, is there a similar correlation between the time of the recording? Are we able to tell if the sound was recorded at night, or during the daytime? If so, can we distinguish between more refined 'time-sections', such as the morning, midday or afternoon? Is there a subjective aspect of sound that all humans can relate to, or are these relative to our experiences? Let me leave these questions unanswered, and say that they are still relevant for the current project – *the SoundLapse*.

Old Method

My method, for collecting sounds for this project, was to record sounds at every hour of the day and night. I would select the most 'representative' sound for each hour and then let the audience choose - which hour they would want to listen to - by moving their hands *around the clock*. My aim was to see if the audience could associate certain sounds with the hours of the day. The first realisation was successful (as an event – not as the audience being able to recognize times of the recordingz), even though I had quite limited sound material.

At the end of the last academic year, I went to the SoundPlay Festival in Gdańsk, to exhibit the *Around The Clock* installation in the newer version. This was the result of part of my research for my main project throughout the first year. I spent days (and nights) recording, cataloguing and selecting sound material from various places, and trying to choose the best parts. This time, during the exhibition, I had many more sounds, from various places and cities. But, did they say anything about time?

Pragmatic Problems

Let me mention a few problems, of which I have already hinted at. First of all, how do I record sounds every hour? I might forget to press record, or press it at a different time, or I would forget to stop recording. Next problem: How do I select a representative sound for a specific hour, should I do it by listening and through conscious decision-making, or should it be decided by chance? A problem that inevitably crops up, is that I have always ended up with too much sound material, taking many hours to edit.

I should also mention here that there are probably as many styles of filed recordings as there are field recordists. Even if we try to produce minimal impact on the environment in which we record (also affected by our presence), there are many decisions that could influence the final outcome, like the choice of equipment, the microphone positioning etc. This makes field recording not truly objective.

New method

Most of the above issues could be solved, by introducing automatisation of the whole process. This would get rid of several problems including:

- the need to be physically present in the space to start the recording
- the arbitrary choice of the sound samples for each period, (by having decision made by chance),
- the large amount of sound material too choose from (only one short sample recorded per hour),
- the influence on the environment (by not being present, I would not influence it).

This is why the first version of the max patch was created, allowing me to specify how often, and how long each sample would be, that I would want to record.

Outcomes

Having worked on this project for a few months, I chose to place the microphone in a central spot of the house where I live (with everyone's consent). It happens to be quite a lively house, which makes for a perfect location. The placement is such that sounds from many corners of the house can be heard, as well as an outside ambiance.

In the first experiment, I recorded a 0.5 second-long sample for every hour for the whole month (soundlapse file 1). The regularity of the duration gave it a distinctive rhythmic characteristic, which was not necessarily a bad thing. But then, I decided to try to randomise the durations. Also, the time between recordings seemed to be too long. The next experiment was to record samples of a random duration - between 30 and 300 miliseconds, with the regularity of a minute(soundfile 2). This, of course, creates a much finer resolution, but resulted in too long sound file, when put together (losing the feeling of time-passing). So, the next experiment then was to record with the same frequency – 1 sample per minute, but the duration now would be random between 10 and 100 milliseconds (soundfile 3).

At the time of this writing I am experimenting with a new set up. Now I record 8 layers of sounds simultaneously. Each of these consecutive layers are less frequently recorded, and the less frequent the recorded layer, the longer the sample would be, with the durations randomized, within certain limits. This is intended for 8 layers, each with different time periods between the recordings and random durations, resulting in the same duration when put together alongside on a timeline. I am also planning to do a rhythmic version of the last implementation, and finally, a combination of random and fixed durations of different layers. I would also like to ask other people to create their *'soundlapses'* in their surroundings, in order to compare the results.

Final thoughts and Conclusions

Referring to the distinction of time and time perception as atomistic and continuous, I would of course say, that the effect achieved here brings to mind the former type of time, giving a punctured, discontinuous effect. I think that with this introduction of short samples, the suggestion of a passing of time, is stronger then in previous experiments. It is also more interesting for me in terms of the resulting sound, when compared to sounds from *Around the Clock* (but this is just an esthetic judgement). Of great importance here, was finding balance of correct time periods between recordings, and sample lengths, in order to get the pacing right.

I cannot comment on the success of presenting *time* objectively with this experiment. I can only say that it seems to be far more objective than any of my previous experiments in *Around the Clock*. The fact that we hear very short samples means that we cannot, in most cases, distinguish the sound source, which contributes to more abstract effect. At the same time, because of the jumps and quick transitions in a short amount of time (representing long period of time), we can perceive changes, in the overall mood - Noisy evening turns into tranquillity of night, followed by birdsong before sunrise, followed by more activity and events as a new day starts. The effect is quite unusual for a field recording.

I must say that I am satisfied with this experiment. Each time I put together the recorded samples, I get surprised in many ways.

Linear vs Nonlinear Time

If we look at it from the point of view of linear vs nonlinear dychotomy, I guess it is neither. It brings to mind cyclic time in a long run – because of the cycles of day/night. If we listen to a short file it might seem linear and sometimes random.

B5 Time Experiment 4:

Exploring Nonlinear Time – Time in Chaotic Systems

Theory

In the first part of this work, I tried to trace some of the changes that our civilisation had gone through in the last centuries, as a result of technological revolutions and scientific discoveries. The distinction of linearity and non-linearity has occurred multiple times in various areas of my research. In science, the monolith of Newtonian absolute-time and linear-time has been challenged by Einsteins‘ theory of relativity (Erikson, R. 1963). Later, in the 20th century, chaos theory would be described by mathematicians via the use of non-linear equations. This allowed for an explanation towards some of the natural phenomena, which earlier had been thought to be governed by seemingly random behaviour (Strogatz, S. 2003). Findings in psychology have suggested, that the *time* of human inner thoughts, has been particularly non-linear (Kern, S. 2003), in opposition to the external and absolute clock time, that which is linear. What is more, human perception has also been proved to be non-linear, as was our perception of music (Strogatz, S. 2003). In the arts, we have seen the introduction, and the growing importance of non-linear artforms (Kramer, J. (1988). The temporality of twentieth-century music (and contemporary arts), like the temporality of inner thought processes, is often not linear (Kramer, J. 1988). Technology has played an important role in undermining this linear way of thinking. Inventions of recording techniques have made possible new time manipulations, such as splicing, reversing and stopping time. Kramer (ibid.) indicates that the recording industry has also led to the creation of a more dense, and less repetitious composition, presenting non-linear characteristics.

All this has led to a shift in our culture. I do not mean that our culture nowadays is non-linear. What I am referring to, is the growing importance of non-linearity in the last centuries of western civilisation. Let me, once again, recall some of the characteristics that distinguish these oppositions: With linear, we associate goal-oriented, rationalistic, progression, predictability, temporality. Nonlinear refers to such ideas as irrationality, unpredictability, no goal, and stasis (ibid.).

Linearity and Nonlinearity in Music

The tonal system was a true expression of the *linear way of thinking,* within the centuries prior to the 19th Century (Kramer, J. 1988). Its collapse at the end of the 19th and beginning of the 20th century was not an accident, and reflected the growing importance of non-linearity in the history of Western music in the past three centuries. (ibid.) I have briefly described some of the new temporalities that have occurred in the 20th Century, with music as the result of tensions between linearity and non-linearity. Some of the composers took it to the extreme, and rejected the idea that musical events were products of the past, and preparations for the future. They suggested instead to focus on the present moment, *the Now*. I am referring here to Karlheinz Stockhausen and his ideas of 'Moment Form' (as described in. Kramer, J. 1988, p.) Another important composer of 20th Century music, Iannis Xenakis, designed and used the stochastic method of composition. He referred to indeterminism, which governs natural events, such as the movement of human crowds in the streets (Xenakis 1992, p. 9).

Practice

I was aware of experiments using chaotic functions in the context of musical compositions (Choi, 1997). I did not, however, associate chaos with the temporal domain in music, but rather with pitch and other parameter control. I decided to look at chaotic system from a point of view of time because of three reasons. First of all, Steven Strogarts (2003), in his book '*Sync*', talks about the possibility of synchronising two chaotic systems, which already sounds musical. He also points out the fact that we associate *sync* with rhythmicity, but there are important differences between the two: '*Rhythmicity means that something repeats its behavior at regular time intervals; sync means that two things happen simultaneously. The confusion occurs because many synchronous phenomena are rhythmic as well.*' (Strogatz, S. 2003, p.184). Secondly, by looking at the characteristics of chaos, I found promising terms when placed in context of rhythm: '*predictability in the short run and unpredictability in the long run*', and '*middle ground between order and disorder*'. '*It contains cryptic patterns and is governed by rigid rules*' (Strogatz, S. 2003, p.185). The third and deciding event happened (by chance), when I found a simple electronic circuit schematic - the so called – 'Chua Circuit'. (http://www.chuacircuits.com/). Chua Circuit is an electronic circuit, designed to generate chaotic behavior in an analogue system.

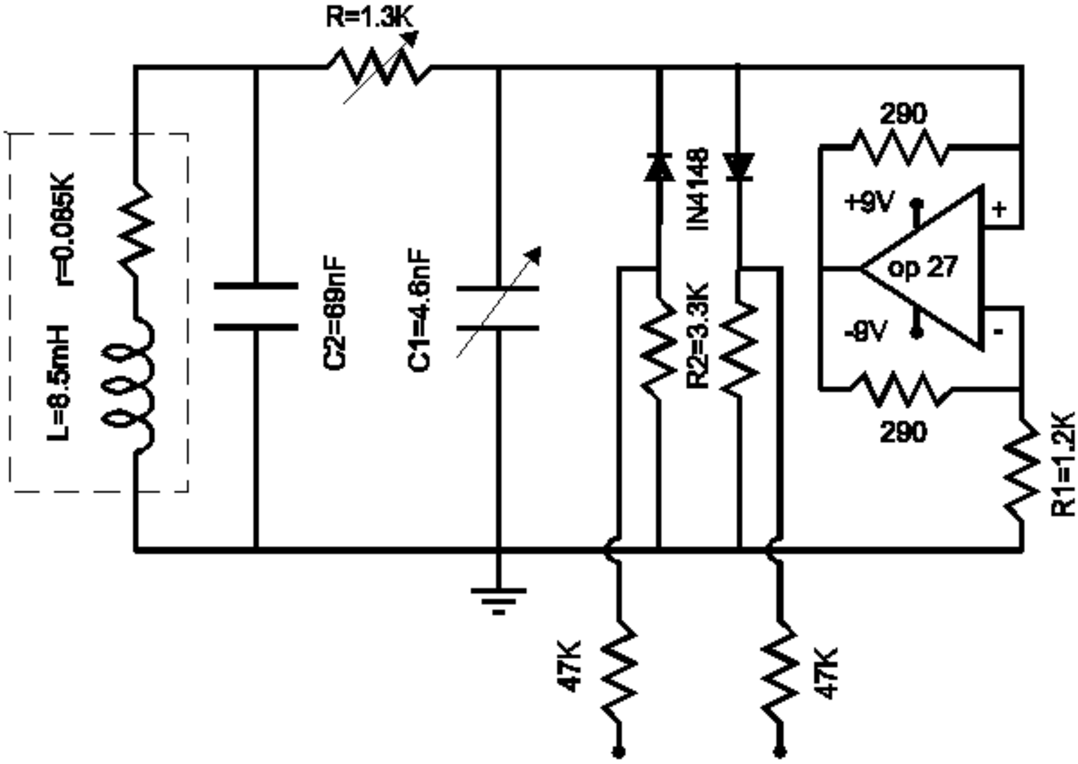
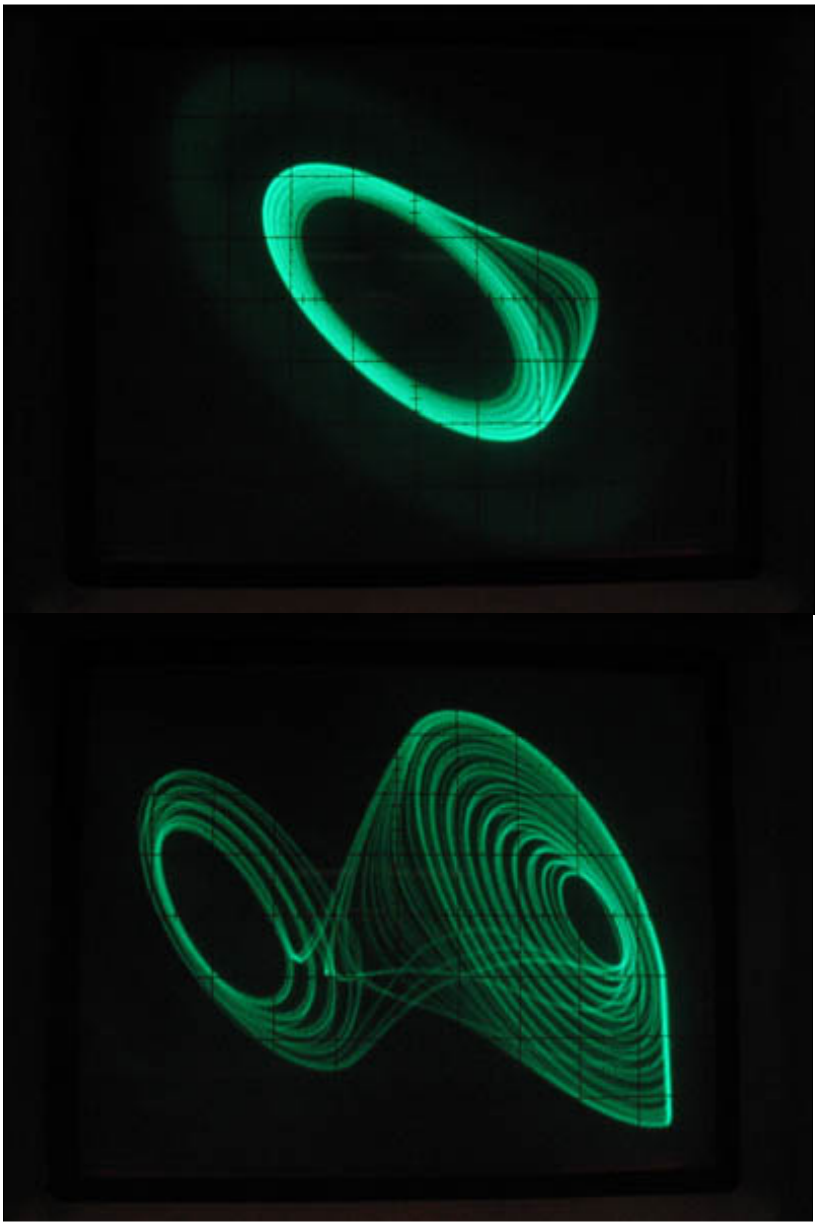


Fig b4.1 – Chua Circuit Schematics (http://www.chuacircuits.com/)

It is made up of the minimum number of components that a circuit requires in order to demonstrate chaotic behavior - one locally active negative resistor, three energy storage elements, and a non-linear element (Choi, 1997). It has fundamental features of chaos, fulfilling the working definition of chaotic systems (ibid.). It provides an economic way of generating a variety of signal patterns, ranging from simple periodic to chaotic (ibid.19) (figuresB4.6-B.4.7). The output of this circuit can be described by a system of three non-linear equations – which account for three parallel signal paths, the voltages crossing two capacitors (c1, c2) and the current through inductor L. Denoted by v1, v2 and i3 in equation 1 and 2 (ibid.) (Fig B.4.8). Each of the three energy storage elements produces oscillations, which are dependent on any changes made in the circuit. These three signals can be treated as one three -dimensional signal (ibid.). When we plot the signal across any two of three energy storage elements on an oscilloscope and adjust the control parameters accordingly, we see a familiar double-scroll image associated with chaos. (b4.2 – b4.5) I managed to achieve it. It was fascinating to look at, but the sound it produced was



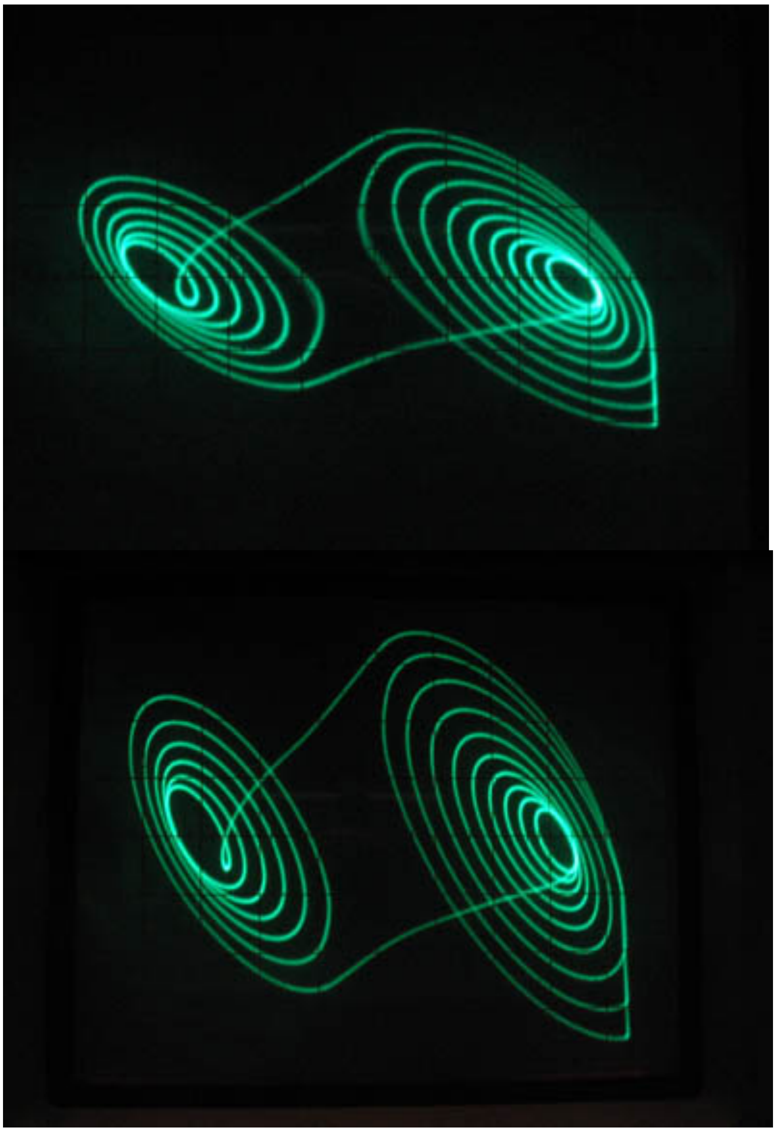


Fig b4.2 – b4.5 Chua Chaotic Waves Plotted on Oscilloscope

quite limited – ranging from sine tone to a noise texture. I found it surprising that in the quoted article (Choi, 1997) this circuit is being used as a sound signal generator. I decided it would be more interesting to use this signal to control an analogue synthesiser. In order to achieve this, I had to slow down the oscillations in my Chua Circuit. I did it by using much higher value of capacitor 1 and 2. I have built a few more of the circuits with various fundamental frequencies. I used it in a live performance during the Sonology Discussion concert no.4, of academic year 2014/2015. (see video) I was satisfied with the result, but the system needed some further adjustments.

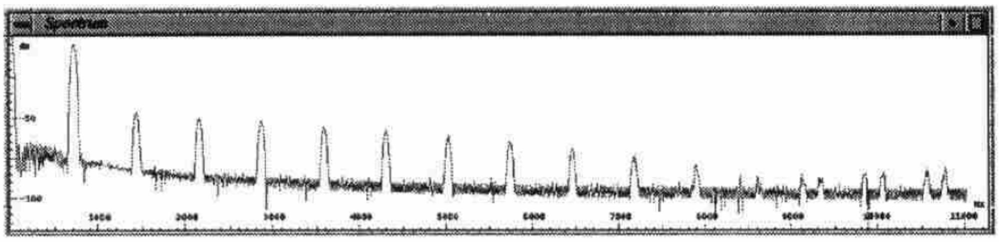


Fig. 1A. A fourier spectrum from a sample of a period-one limit cycle signal from Chua's circuit.

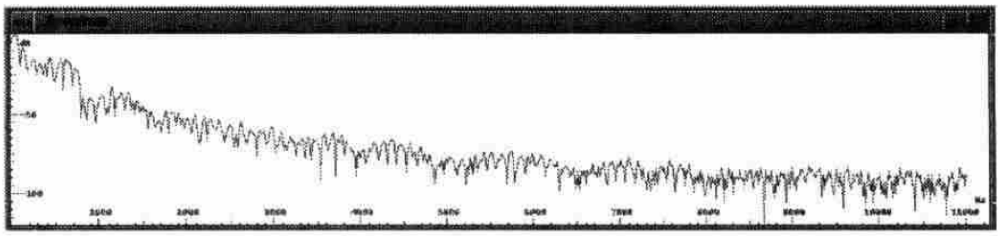


Fig. 1B. A fourier spectrum from a sample of a chaotic signal from Chua's circuit. In both figures, frequency is depicted on the horizontal axis and amplitude on the vertical axis.

Fig B4.6 Waveforms in Chua Circuit (Choi, 1997)

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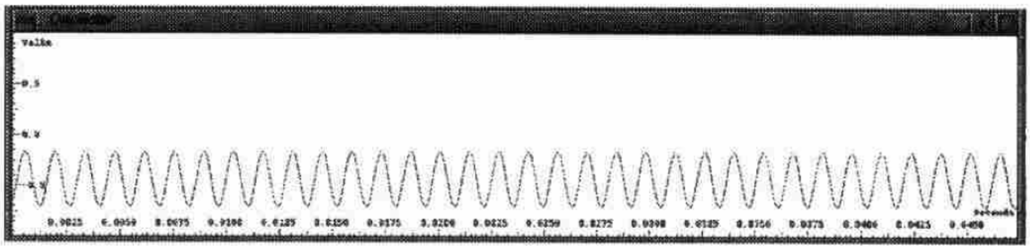

Fig. 2A. A waveform sample from the period-one signal sampled for Fig. 1A.

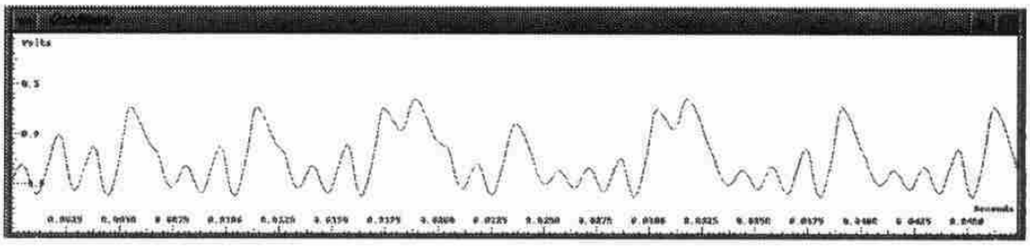

Fig. 2B. A waveform sample from the chaotic signal sampled for Fig. 1B. In both figures, frequency is depicted on the horizontal axis and amplitude on the vertical axis.

Fig B4.7 Waveforms in Chua Circuit (Choi, 1997)

$$\left.\begin{aligned}\frac{dv_1}{dt} &= \frac{1}{c_1}\left[G\ (v_2 - v_1) - f(v_1)\right]\\ \frac{dv_2}{dt} &= \frac{1}{c_2}\left[G\ v_1 - v_2) + i_3\right]\\ \frac{di_3}{dt} &= -\frac{1}{L}\ (v_2 + R_0 i_3)\end{aligned}\right\} , \qquad (1)$$

where

$$G = \frac{1}{R} \cdot \qquad (2)$$

Figure B4.8 – 3 nonlinear equasions responsible for generationg chaotic behavior in Chua Circuit

Conclusion and final remarks

This work was inspired by non-linear time of chaotic systems. What inspired me to undertake this experiment was the fact that chaotic systems are used in science to model and understand better mechanisms behind such phenomena as growth of populations or leaky integrators. This is also unlike earlier experiments, which have investigated clock time, shaping time, machine time, scale of periodicities and/or subjective time and memory.

After making some experiments with Chua Circuits I found their audio signal not very interesting. The new idea was to use them as a control signal for voltage controlled instrument. One of the ideas I wanted to explore in practice was to try and see if I can achieve interesting results by first using them out of sync, thus creating complex and quasi-random rhythms, and then synchronising two of them to get more regular patterns.

I have built 4 Chua circuits, with various frequency ranges, into one unit. At the time of this writing I am still working on the voltage controlled synthesiser, which will be controlled by the 4 Chua circuits. On each one circuit, I can have 3 independent control signals, corresponding to the values of three energy containers in the circuit. This gives a total of 12 simultaneous, independent control signals, which can be used to control 12 parameters in an analogue synthesizer system.

It is quite a unique experience to play live with a chaotic circuit and control its parameters, due to its extreme sensitivity to any changes. I could now refer to the phrase '*taming the chaos'* (Choi, I. 1997, p. 36), or putting it in other words – interplay with chaos, rather then control of chaos (ibid.) because chaotic system, due to its characteristics, is extremely difficult to control.

Linear vs Nonlinear Time

In case of this example the answer seems obvious, but it really depends on how we play this instrument. It could be played in such a way, that it would bring to mind linear time – trying to create a feeling of movement or development etc. However the way I am using it has more nonlinear character.

Conclusion

I have already summarized the most important points in the corresponding parts of this writing, describing the four practical *'experiments in time'*. I do not want to repeat myslef here. Let me just state, that I have set myself a task that was very difficult, if not impossible, to achieve: trying to connect *time and sound* and describe this connection in words. Both time and music defy descriptions, making them problematic to work with. However, I think I have succeded in greater part, at least according to my own criteria and initial aims.

Only towards the end of my research, I have realized that the word ‚*departure*', which I have placed in my reasearch title almost arbitrary, has gained a special meaning. This whole process was like departuring on a long, fascinating journey. I have lost my way many times and I had to find it again and again. Many tracks have led to deadends or to the overwhelming plethora of endless possibilities. But as I said before, I think making art should be a little bit about getting lost, not knowing your whereabouts, it should be a little bit uncouscious and not too rational.

Some of the difficulties in describing my work and relating it to existing literature were the result of the nature of my practical work, where I focused more on the process, on the time-unfolding, driving the sonic outcome of the work. I did not compose the music in a traditional sense. I allowed the time, or more precisely the ideas of time I derived from my research, to create the sonic characteristics of my work. In this respect I think I have succeded in making interesting works, truthful to my style and initial statements and goals. I was interested in processes, in unfolding of time. Many of my ideas, as is often the case, have originated as the effect of technical findings and their implementations.

Most importantly I have made 4 autonomous and interesting projects. They could all be seen as independent works, but together they create a peculiar *study of time*, where each one complements the others and looks at it from different perspective. I think experiment 2 (*In Search of Sync*) and 3 (*SoundLapse*) were the most successful ones and have resulted in the most original sonic effects, but I am still working on the other two. They all treat time differently, but with a similar, recognizable style.

As for the theoretical part, I have made a lot of fascinating discoveries, which gave me many ideas and problems to think about and solve. I have learned a lot, but probably the most insightful thing I have found out about time, was that it is truly unknowable. At the same time these ideas can be inspiring when applied in the context of creating sound.

Bibliography

Augustine, S. (2002). *The Confessions of St. Augustine.* Minnesota: Doverr Publications.

Barbour, J. *The nature of time.*

Choi, I. (1997). A Chaotic Generator as a Musical Signal Generator in an Interactive Performance System. . *Journal of New Music Research , 26 pp.*, 17-47 .

Conrad, T. (2004). duration - towards long sustained tones *http://tonyconrad.net/duration.htm.*

de Bertola, E. (1972). On Space and Time in Music and the Visual Arts. . *Leonardo , 5(1), 27*, 27-30.

Erickson, R. (1963). Time-Relations. *Journal of Music Theory , Vol. 7, No. 2*, 174-192.

Fraser, J. T. (2007). *Time And Time Again.* Leiden: Brill.

Grisey, G. (1987). Tempus ex Machina: A composer's reflections on musical time. . *Contemporary Music Review, , 2(1)*, 239-275.

Hanoch-Roe, G. (2003). MUSICAL SPACE AND ARCHITECTURALTIME: OPEN SCORING VERSUS LINEAR PROCESSES. *International Review of the Aesthetics and Sociology of Music , 34* ((2)), 145-160.

Holford-Strevens, L. (2005). *The History Of Time.* New York: Oxford University Press.

Kern, S. (2003). *The culture of time and space 1880-1918.* Cambridge MA: Harvard University Press.

Konig, G. M. (1967). The Use Of Computer Programmes In Creating Music. . Retrieved from http://www.koenigproject.nl/indexe.htm: http://www.koenigproject.nl/indexe.htm

Konig, G. M. (1982). *Some observations on the impact of Technology on Music.* Retrieved from http://www.koenigproject.nl/indexe.htm .

Konig, G. M. (1983). *The Aesthetic Integration of Computer – Composed Scores*. Retrieved from Retrived from http://www.koenigproject.nl/indexe.htm: http://www.koenigproject.nl/indexe.htm

Konig, G M. (1985) Programmed Music

Retrived from http://www.koenigproject.nl/indexe.htm

Konig, G. M. (1997). *Layers and Variants* . Retrieved from Retrived from http://www.koenigproject.nl/indexe.htm .

Kramer, J. (1981). New Temporalities in Music. . *CRIT INQUIRY, 7(3),* , 539.

Kramer, J. (1988). *The Time of Music.* New Your: Schirmer Books.

Morrison, R. (1978). KANT, HUSSERL, AND HEIDEGGER, ON TIME AND THE UNITY OF "CONSCIOUSNESS". *PHILOSOPHYAND PHENOMENOLOGICAL RESEARCH. , 39 (2)*, 182-198.

Neuhoff, J. (2011). Perception, Cognition And Action In Auditory Displays. In A. H. Thomas Hermann, *The Sonification Handbook.* Berlin: Logos Verlag,.

Neville, C. (1993). Eternity and Time's Flow.

Strogatz, S. (2003). *Sync.* New York: Hyperion.

Trippett, D. (2007). Composing Time: Zeno's Arrow, Hindemith's Erinnerung , and Satie's InstantanÃ©isme. *Journal Of Musicology, , 24(4)*, 522-580.

Vaggione, H. (1993). Determinism and the false collective about models of time in early computer-aided composition. . *Contemporary Music Review, , 7:2,*, 91-104.

Winfree, A. T. (2001). *The Geometry Of Biological Time.* New York: Springer.

Wonsuk, C. (2009). Reflections on Time and Related Ideas in the Yijing. *Philosophy East and West* , 216-229.

Xenakis, I. (1992). *Formalized music. (Rev. ed). .* New York: Pendragon Press.

Yao, Z. (2007). Four-Dimensional Time in Dzogchen and Heidegger. . *Philosophy East And West, , 57(4)*, 512-532.