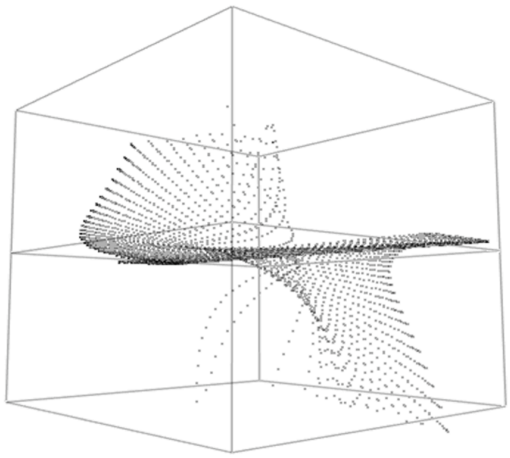
SEQUENCING SPACE



First Phase Thesis

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0. Introduction

Music will always be time dependent, without repetition and movement over time, not only could we not construct musical forms and structures, but also sound as a phenomenon could not exist. With the progression of music creation, composers have always sought to re-invent and discover new methods of sound composition and arrangement. The modern composer has even been defined by Dick Raaijmakers as being a futurist. Within this endless search for newfound methods and resources, aesthetical forms of no obvious relationship to the temporal domain have also been brought up to contribute to the process of music and sound composition.

In this paper I will deal with certain compositional interpretations of sound, which are mostly inspired by ideas relating to structural qualities of form and matter. Within the abstractions of these aesthetical issues, there is a mutual relationship between the two elements, where certain transformations of abstract matter, relate to compositional treatment of musical form. The manner in which one can approach musical arrangement can also relate to the way the musical elements are presented in an imaginary space, and how we can represent their inner spatial relationship and spatial characteristics within a musical work frame.

Through the exploring of spatial treatment to musical composition, I have encountered difficulties in approaching ways of articulating spatial gestures through musical praxis. These different complexities in extrapolation methods, which will be discussed in detail later on, lead me to the main issue I would like to deal with: The expression of spatial relationships through musical composition.

For the creation of substantial grounds to discuss the expression of space through musical time, I wish to bring to light the different concepts of time, time perception, and time levels within music. I will try to interpret different philosophical ideas of time and discover how, within the sphere of sound and music composition, we can use them as composers, and relate to them as listeners.

Further, I wish to discuss different articulation methods for the generation, composition and transformation of sound and musical structure, while trying to find a relationship between the structural qualities of the abstract elements and the progression of musical material. Basically introduce different methods one can use to express space through time.

Later, I will debate the applicability of different articulation methods and their functionality, compositionally or within synthesis environments. Doing so while keeping in mind the different perceptual modes of morphological characteristics and temporal relationships.

1. _____Space_____

When experiencing architectural structures, which are obviously very much linked to space, the observer encounters all the clues about the volume, the structure and the general spatial characteristics of a single space simultaneously. Through the size, the shadows & lights, the reverberation in the room, the tension between materials and any visual clues, the observer receives a sense of relationship between himself and the structure, and a global idea about the inner complexity of that structure. Obviously these clues and sensations are processed sequentially in the brain, but the overall experience of a single space is perceived as an instant sensation.
In contrast to the overall spatial perception, the global perception of music requires time to be perceived. Sections within a certain musical space are presented sequentially; the listener must interpret section-by-section, phrase-by-phrase and note-by-note in order to receive a faithful account of the form and structure of the musical piece in hand. As we shall see further on, with the articulation of electro-acoustic music, operations on the micro (sample) level in some cases, are of important significance to the coherence of the musical material.

How can one project ideas of a constant, timeless form of structure through a completely time dependent art form that requires different articulation methods for defining its structural qualities?

Looking into this correlation we can see that the problem lies within the transformation of structural tools from one field to the other, and the possible solution might exist within the articulation methods one uses to define the spatial-musical relationship.
When a composer or performer of musical material wants to express any "architectural" idea about space, volumes, and structures in a temporal based art form such as music, he needs to transform these terms and ideas into time based events whether it is a tonal gesture, a timbre, a rhythmical or structural relationship, These transformation tools could be applied on different time levels and be realized on different compositional levels.
One can of course control the location of the sound source as well, but not the exact positioning of the sound, unless he uses more complicated methods of controlling 3D sound production systems, such as wave-front synthesis, where the exact wave front of the sound is reproduced as if coming from a certain position, rather than an averaged simulation of its location, as done by delaying versions of the monophonic signal, or level differentiating

between sound sources. This process is done through a complex speaker instillation system, and is controlled by extensive calculation of the parallel codependent sound sources. Since this text deals with musical & compositional aspects of spatial sound, I would like to leave more complicated technical issues aside, and focus on the translation of the spatial elements of the sound and the score into temporal flow of musical material, and how these elements react to each other when existing in the same compositional sphere. To be clear, I would like to define some aspects of the compositional space in which these relationships exist.

•Sound Objects

Within the framework of electro-acoustic music, the composition and treatment of sound objects has been expressed in many different ways and defined in various contexts. At the same time it has always been linked to a well defined and somewhat complex relationship of different sonic elements. This relationship has been signified, mostly in the context of being an abstraction to a certain perceptual model, as being a tangible object one can mold and shape. The sound object could be defined as the correlate product of reduced listening in the context of Pierre Schaeffer's acousmatic listening. Within his well-defined method of interpreting sounds in their purely acoustic relevance, he gives the composer the ability to judge the sonic qualities of the sound as an objective listener.

In a more modern context, as treated in the sphere of synthetic sound composition, in contrast to the use of concrete sounds, the sound object represents more complex relationships between different sonic and structural elements that are incorporated within a digital code or synthesized sound. These sound objects still have the same function of being a sonic element that could fit certain typological groups and though controlled by synthetic methods, functions on a purely acoustical level.
Through having its own qualities and perceptual dimension, the sound object can be perceived as a whole, as an inherent texture. While the different layers and relationships within the structure of this object could be exposed and transformed, the sonic representation (or report, in a neo-plastic sense) of the object will always contain a structural or textural quality that would appear related, perceptually and esthetically to the foundational elements of the structure.

Composer and researcher, Horacio Vaggione talks about detailed articulation of sound objects and textures. In a slightly more practical sense, he proposes the perceptual and compositional intention can be enhanced through techniques controlling degrees of temporal decorrelation of waveforms in a multi-channel setting. Vaggione relates the

predefined object to the spatial properties of the sound, and introduces methods of temporal based transformations within multiple channel mixing and on different time levels. He suggests the distortion of the phase spectrum in a certain degree that increases the disposition of the sound along the horizontal axis. This, he does in addition to amplitude variations and delay of the signal between sound sources. By adding the spatial decorrelation of the phase spectrum, to the panned signal, one can manage to eliminate the problem of sound spatialization on a large scale, where next to one speaker you receive an unfaithful representation of the multi-channel mix. When using such operations, which distort the phase spectrum, the location is masked from all points and creates a global impression of space, instead of being perceived differently from different positions.

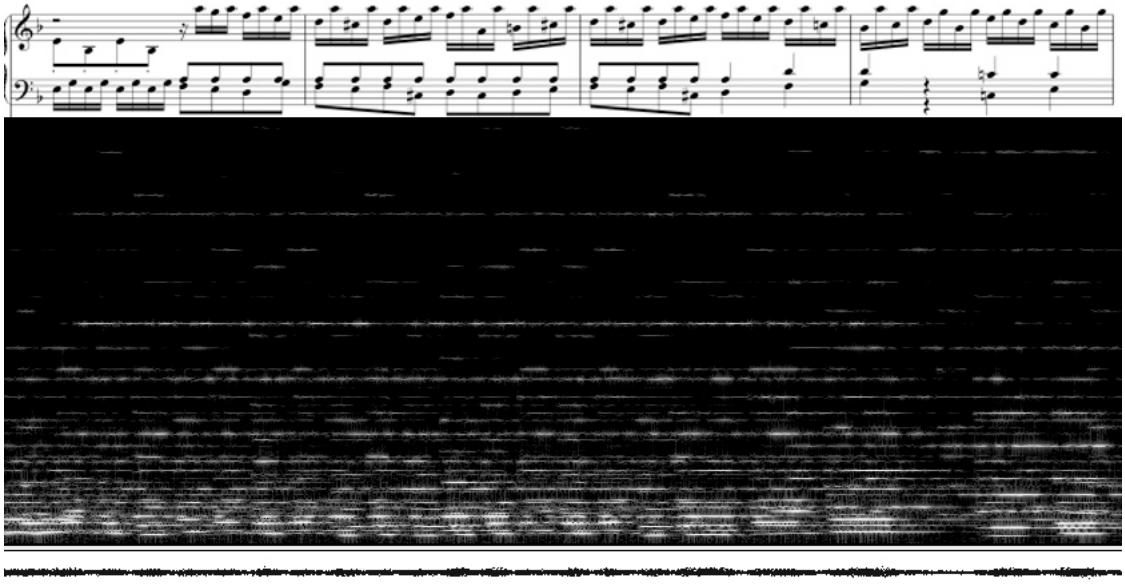
Within his work, while using these different techniques of decorrelation, he merges multiple layers, which belong to different time scales, and creates a sense of spatial definition. The listener can perceive the separate elements. Phase decorrelation proves to be useful in portraying broad spatial characteristics in a narrow stereo setting, as could be easily recognized while listening to Agon *(Vaggione, 2000)* for multi-channel tape on a pair of headphones.

Disposition and diffusion of sonic material seems to be a useful tool to articulate the spatial characters of a certain object, and can work in different musical contexts.
Defining relationships between different sound sources can be done by altering the temporal qualities of a signal, while operating on the difference between the wave shapes of the different sources, or by transforming different spectral qualities along a number of localized sound sources. I will come back to techniques of spatialization, such as spectral panning in the final section of this paper, and discuss benefits of different operations for different time scales and different compositional purposes.

The idea of imagining a spatial object that represents different sonic values and relationships requires a certain ability to think in an abstract form. With this abstraction one can compose a certain form of matter that in accordance to set rules and guide lines will represent and eventually give way to sonic material, either spectral or temporal.
By doing so, a composer could link different types of structures to any arbitrary sonic values and create a compositional model that can statically or dynamically produce and transform sound.

Although complicated models of sound objects require an understanding of the abstract compositional process, simple and obvious conversions of spatial characteristics to sonic values have been around for as far as composition has been. The idea of high and low pitches

being converted onto staves, for example, is still being used until today, and allows us to picture the sonic relationships.
Looking at a Bach fugue we can easily understand the movements of the different voices in their counterpoint-based relationships.
As we conceive these voices to be crossing paths within their spatial relationship, all we actually hear is a parallel movement of different sounds that consist of different fundamental frequencies, which simply vibrate in a slower or faster rate.



•An excerpt from 'Toccata et Fuga' by Johan Sebastian Bach (bars 39-42)

•As seen in the image above, the spatial relationship depicted using notation emphasizes the contrapuntal relationship that exists between the parallel melodies. The different voices are clear, and their relationship to each other as well.

•In the more detailed description of the physical properties of the sound in these 4 bars, referring to the sonogram depicting frequency (y-axis) over time (x-axis) as well as amplitude (color brightness), the individual voices are completely hidden from the eye, and cannot be analyzed properly.

•One would recognize this piece much easier by looking at the notes, than at the detailed description of the sonic quality of the piece.

•Dick Raaijmakers' 'Morphology of Electric Sound'

In 'Cahier <M>' *(Raaijmakers, 2000)*, The composer, Dick Raaijmakers, introduces his theory, 'A Brief Morphology of Electric Sound', which he bases on different esthetic guidelines thought up by Mondriaan in the early 1920's, with regard to the concept of morphology, introduced through the work of French physiologist & cinematographer Etienne-Jules Marey.

By linking the work of these two pioneers, Raaijmakers manages to relate the significance of each field to the issues of electric sound composition, and the composition of more global structures.

Raaijmakers deals with the composition of sound objects, and the interpretation of these objects into musical structures. He deals with the way these structures can and should be perceived and proposes different methods of using them as compositional tools.

Throughout the whole text Raaijmakers brings to light different composers and various works. With his writing he manages to relate all these remote issues to his own theory. While they have no obvious link to his frame of work, he can still reinforce his theory by referring and relating to them. This shows the coherence of his musical interpretation model.

Raaijmakers talks about horizontal and vertical arpeggios, dealing with repetition of sound and form as a compositional process. Through an introduction to his spatial interpretation of the acoustical qualities of sound he suggests a new way of articulating a certain compositional repetition of sound, not through a vertical or horizontal arpeggio, but as diagonal sound, which repeats into depth.

If we consider a vertical arpeggio to be a repetition of a movement along different scales of pitch or density, we con look at a horizontal repetition as being a repetition along the time axis.

Imagine a sound wave, in its static form (as it does not have any property which changes over time) we can see one "mother shape" repeated, over and over. Until someone turns the generator off, changes the frequency or wave shape, the sound will stay static, throughout this repetition form.

Layered sound will have the same static quality, but in the sphere of sound objects, will be treated as a spatial shape, that repeats, not along the time axis, but into depth, thus creating a sound field of repetitions. Later in the compositional process these repetitions can be modified and constructed further. Further in the text I will deliberate more on the compositional applications of this conceptual sound treatment method.

In "Cahier <M>" Raaijmakers presents his ideas about the morphology of electric sound through the introduction of a new way of treating sound as being inseparable from its visualized product. Raaijmakers suggests a way of treating composition as an audible walk through an abstract architectural structure of sound fields. The path that the listener takes through this object defines the sonic qualities of the compositional outcome. Raaijmakers looks to the composer as being the guide through a specific composed path, which is one of endless possible paths one can take around or within a particular pre-organized structure. It is that specific task of selecting a certain route through this structure that is the act of composing, according to Raaijmakers. Later he even brings up a kind of futuristic musical experience, imagined by a number of post World War II avant-garde artists, where the composer constructs and arranges the sound field structure, while the listener is free to move through it and thus create his own unique musical experience. Leaving the conventional walks aside and bringing room to improvised walks, where the number of possible acoustic works, depends entirely on the number of listeners/walkers.
Not only was this an impossible idea, and probably still is today, but Raaijmakers rejects the idea on the base that improvised walks merely clarify the position of the sound in respect to the sound field and the listener's momentary location. On the other hand, the conventional walk, where the composer walks ahead and the listener follows, deals with the internal structure of the sound field in a much more refined way than could ever be achieved from the outside of the sound bodies themselves. The composer can define and describe the structure to the finest detail. Although the independent improvised walker can never achieve such a well-defined experience, he is still free to choose his path and is quite happy to do so. Eventually Raaijmakers suggests that reaching a fine balance between the two approaches might be the best way to achieve a quality work of art.

I wish to point-out here that even if within 'Cahier <M>' itself, it is not always clear whether the sound is a product of the graphical structure or the other way around, considering the idea of sound objects as presented earlier on, the chicken-egg anecdote is of no significance, as the sound/image is treated as one object.

•Neo-Plasticism

As mentioned above, Raaijmakers introduces the morphology of sound through different angles, one of which incorporates the ideas & rules of neo-plasticism, thought of by the artist Piet Mondriaan in the 1920's. Although Mondriaan's ideas of neo-plasticism regarded mostly new esthetical rules of the plastic arts, his vision related to any kind of compositional form. In a short text from the early 1920's, while arguing his ideas, Mondriaan talked about neo-plastic music, as another possible way for expressing his aesthetical ideas.

Even if Neo-Plastic music could not exist in the physical world, it had many implications on the way post World War II composers could look at music. The new way of thinking about composition as a spatial construction of structures or fields came from these neo-plastic ideas of standing sound waves, surrounded by silence, and composed using oppositions. Mondriaan actually imagines standing sound which is non-moving and timeless. This sound is only audible when it is passed respectively (either it moves or the viewer moves in respect to it)*. The composed sounds should be surrounded by silence and organized in such a way that they connect to the other elements of the structure within the context of a whole complete compositions. Mondriaan imagined this music to be produced by means of electric, magnetic, or mechanic generators, which will avoid any undesired interpretational distortion of the compositional intent by an arbitrary performer. What Mondriaan Though up, (more than 20 years prior to Pierre Schaeffer's Musique Concréte, and to the electro-acoustic music composed in the Köln Studios) was the transformation of modern music from the hands of the human interpretational performance, to the studio's produced, refined and detailed production of the musical, and constructional content.

**Raaijmakers offers two different approaches to the reproduction of sound in this sense, 'Plaque Fixe' & 'Plaque Mobile' they will be discussed later on.*

•Opposing Sound Elements

Amongst the different composers Raaijmakers brings to light in "Cahier 'M'", the composer, Karel Goeyvaerts, one of the first serialist composers, speaks about these standing sounds and imagines new music that is composed of 'dead sounds' that do not move and construct together music without drama, evolution or tension, composed strictly out of serial guidelines and using electronic tools. He regards sine waves to be the closest one could get to this sort of sound. More than three decades after Mondriaan's text regarding neo-plastic music, Karel Goeyvaerts attempts composing layers of sine waves as if the audience approached them in a silent space as a standing object of layered sound, in his composition K5.

Goeyvaerts also talked about the way sounds interact with each other in the compositional context of musical elements constituting opposite sounds. Raaijmakers compares his thoughts on the subject to Mondriaan's vision of composing sounds against non-sounds, just as he did in his paintings, following the aesthetic guide lines of neo-plasticism, creating colors divided by black lines or white space. One might look at this extraction as tones composed alongside or against silence or noise. (Mondriaan even dreamed of having his standing sounds

surrounded by silence or blocks of noise containing hidden tones one must walk through to discover).

What Goeyvaerts was talking about, a bit different from Mondriaan's intensions in my opinion, was about different sound elements that, through the musical movement, collide and influence each other. As Raaijmakers quotes Karel Goeyvaerts: "standing sound structures are to be organized as oppositions, they cross each other, they constitute a graphic intersection. Around this intersection there are structures that evolve in opposite direction rather than to one and other."

Thinking about traditional counterpoint and the way a certain movement within a musical structure crosses paths and intersects with another movement, while contradicting or enhancing musical tension, it is possible to propose a theory of counter-movement, where in the sphere of sound objects and graphical structures, the morphological characteristics of the different elements determine the inner relationship of the global structure.

In the case of Karel Goeyvaerts the best way of articulating the contrast between separate elements of one composed structure, in his opinion, was to compose the elements as oppositions. The "opposite" sounds would best characterize the different cross-points and collision between the elements. Further they would inspire movement in opposite direction from one and other.

Unfortunately the use of sine waves alone to define these different objects gives no perceptual clue to the listener, and movement is very hard to perceive within K5. Using timbral characteristics, instead of 'dead-tones', to define sonic elements could prove to be more successful.

Probably the danger of aspiring to compose "music containing no evolution or tension, using 'dead-sound'" is, that one could very easily end up with a boring piece of music.

In the next section, I wish to discuss the temporal implications of musical structuring, later I will return to the issue of spatial sound composition (as well as spatialization of sound), while debating the importance of having a rather complex internal relationship between the structures elements, to provide an interesting result in the audible domain.

2. Time

As mentioned in the introduction to this text, and as we have seen within the exploration of musical space, the temporal properties of perception and articulation of musical elements, as well as the understanding of time, with its many implications towards the experience of musical form, are all of utmost importance for the creation and production of music, More ever in the sphere of electro acoustic music, where issues of well-defined organized structures aim to express different states and relationships within the temporal-timbral domain.

Many different concepts of time have been established throughout the centuries in many different fields, ranging from philosophy, to physics, mathematics and to the different arts. These concepts have changed and morphed as the human understanding of nature and science has developed. The issues philosophers and scientists have been dealing with, regarding time, are numerous. Questions regarding What is time, how is it perceived, is it finite, absolute, relative, etc'… have been asked over the centuries, only leading the human mind to find more questions. Just as any other philosophical difficulty, the more you search for an answer, the more uncertainties you reveal.
In order to understand the implications that the complex relationship between the multiple time concepts have on music, I wish to define a few of them through a brief exploration of different ideas, throughout the history of philosophy and science, regarding time.

•Time & Mind

In order to answer a question such as 'how does time relate to mind?' we must focus our research on our psychological and cognitive experience of time. Basically, we should analyze the perception of time. The irony of the matter is in fact, that our perception of sequential or (pseudo-) simultaneous events, as well as the perception of change, is one of the definitions of time itself.
The question is if time actually exists external to our perception.
Aristotle raised this question when he said: "Whether, if soul (or mind) did not exists, time would exist or not, is a question that may fairly be asked; for if there cannot be someone to count there cannot be anything that can be counted…" The problem introduced here is actually if time is the conscious numbering of movement, or instead is the capability of the movement to be numbered due to consciousness.

This is the first problem many philosophers encountered while trying to define what time is.

This leads us to the first and most obvious distinctive notions of time, 'Objective Time' vs. 'Subjective Time'. The idea of having subjective time in comparison to the actual (namely objective) time, which is global and absolute, is due to our different perception of time's flow, in regard to mental or emotional state, context, or rate of change within a certain duration of the objective time. Objective time could be measured by many clocks, and with all clocks result in the same measurement (to a certain degree of accuracy) while filling up a bucket with water for example. The same bucket, being filed with water, under identical conditions to the one being measured by the different clocks, would seem to be filling up much slower, to a person putting out a fire, than to a person washing his car on a Sunday morning.
When time is a critical factor, and is focused on, it seems to be moving slower. The same happens when a person is bored, or wishes to be elsewhere. This is due to the psychological state in which time is perceived. This is why subjective time has also been named 'Psychological Time', although this term was introduced only later. Subjective time has been around in early philosophy and linked to Psychology just after being scientifically understood.

Looking at the history of time, it is often supposed that first there was time (if it started with the birth of the universe, or existed prior to the universe's existence is another issue), then there was a sensation of time, then, with the evolvement of consciousness the idea of time came about, and only then the word time, which appeared in our vocabulary and allowed us to express ideas we had regarding time.
As early as the 11th century Avicenna, the Persian philosopher was talking about psychological time, while arguing that time exists only in our mind and that it's due to our memory and expectation. This point is crucial to the time factor in music and gives us an insight into how musical progression is perceived.
9 centuries later, musicologist and music Psychologist, Leonard B. Meyer, talks about these exact same issues of temporal perception in a musical context in his book 'Emotion and Meaning in Music' *(Meyer, 1956)*. Meyer brings the idea of external and internal structural elements within a musical piece that through our conscious or subconscious memory create expectations.
It is up to the composer to decide which of these expectations should be fulfilled and which should not. According to Meyer, a good balance between the two possible scenarios would contribute to the emotional impact of the piece. He even goes on to state this process could portray the meaning of a certain piece. Although emotion and meaning are quite personal and indeed subjective, I do believe the issue of expectation and memory in music,

contributes to the tension and release within a musical piece or section. Further, I do think that our *subjective* perception of change, repetition, movement, and of course time, plays a major role in the processing of musical material.

In the 13th century, after a long evolution of our awareness of time, the philosopher, Duns Scotus, accepted the idea of the existence of both 'objective' and 'subjective' time.
In the 20th century Henry Bergson published his essay, 'Time and Free Will' (*Bergson, 1910)*, where he focused his ideas of temporal perception on what he titled "the Immediate Data of Consciousness". Bergson presented his ideas while considering time as being a sort of flux, and rejects Newton's point of view that time is atomic and can be split up into numerous sections *(see next section, 'linear vs. non linear time')*. Bergson also talks of time as being a conscious sensation; He supports the idea of the existence of subjective time, while he argues that the intensity of a conscious state is not of a quantitative nature. *"People say they are more or less warm, or more or less sad, and this distinction of more and less, even when it is carried over to the region of subjective facts and unextended objects, surprises nobody" (Bergson, 1910).* Further, he argues that these non-quantitative intensities are given within the 'Consciousness', and not within the molecular or physical movement of a certain stimulating movement.

The definition of different time concepts is still changing today. With new discoveries in the science world, our understanding of the flow of time changes and adopts according to our understanding of the universe.
For instance, the fact that the universe is accelerating was discovered not long ago. It was known for long that the universe is expanding but up to a recently, scientists believed it was slowing down. This changes the idea scientists have about the flow of time, and the capability of mankind to trace it down to the source, to find out how and where it began.

•Linear vs. Non-linear Time

Somewhere between the 13th and 20th centuries, where ideas of time were already debated for quite a while and the modern laws of physics were being realized, the English Physicist, Isaac Newton argued that time, as well as space, is an infinitely large container of all events and that this container exists with or without the occurrence of these events. He stated that space and time are both not material substances, but like substances, they do not depend on matter or motion to exist. This was argued by Newton in the 17th century, and clearly depicted his belief in the existence of objective time. Bergson on the other hand had the idea that time is a flux and is not quantitative, and therefore cannot be set into absolute

duration at all unless it is represented by symbols in a certain space. This does not argue against linear time in particular, but rather objects to the idea of time being objective and absolute. In that sense, time cannot be defined as being completely linear or non-linear, as it has different sensational affects on multiple conscious states. While taking an extreme stand in debating only subjective or objective time one can avoid many difficult issues, but seeing as they both have evidence arguing in their favor, we must take them both into account.

In regard to objective time, looking at it as being a container of events may be useful for the understanding of time as a continuum of instants, these instants must be seen as being equal, for they are infinitely small, due to the fact that they exist in an infinitely large container. If these instants would be equal, the immediate conclusion would be that we are dealing with linear time.

When talking about time as being linear, it is important to state that with the concept of circular time, such as believed by Plato and most other Greeks and Romans, due to the cyclic cosmic motion, the idea of linearity still exists. Time might be represented along a circle according to these philosophers, but its linearity is not conflicted, because a segment of a circle is also a linear continuum. In 19th century, the idea of linear time (as opposed to circular time) became dominant in both science and philosophy of the western world.

For the sake of the argument between linear and non-linear time, let us accept the notion that time contains endless possibilities of durations, which contain a linear continuum of instants; we can then consider time to be linear. Think of the most obvious abstraction of time, the time line, where the variable **t** changes with equal proportion as it advances further along the 'time axis'. Another example would be the everyday clock, which rotates with equal steps, for as long as it is powered.

With the idea of subjective time, and the important role it plays in our musical perception, the proposal of time being linear results in a conflict of interpretation. As we have seen earlier, subjective, or more precisely, psychological time, is accompanied with a feeling that a slower or faster 'flow rate' of time exists. Different suspension of musical expectations being resolved, referring to Leonard B. Meyer, could have an affect on the experience of time within a musical piece. Musical elements, change, and movement are not perceived to be changing with equal proportion within their progression, while the numerical instants of a time line within a given musical duration is. This presents us with a problem. Time is linear, and where as the experience of musical time is not.

Before dealing with this specific issue I wish to clarify a few points regarding instants.

At this point, it is important to explain the difference between durations and instants.

As mentioned earlier, a duration could be any specific part of time, with a defined beginning and a defined end. A duration could also be seen as being an ordered set of instants - not a whole or sum of instants. In other words, instants are members of durations, not parts of them. Durations are infinitely divisible, into smaller intervals, which are new, smaller durations.
A singleton set of an instant should be looked at, as being a subset of the duration. The instants are locations in time, but should be considered as members in a set, and not as parts of a whole.

Although it has never been measured beyond 10^{-43} seconds (the so-called Planck time) it is believed that between every two instants a there is a third and therefore any duration is also infinitely divisible into more durations. This concludes that time is made up of infinitely small and equal parts and is therefore linear.

To further address the issue of Linear vs. Non-liner time, we can accept the fact that objective time is linear and subjective time could be differently perceived.
Musical material is represented and played in a linear time format. The magnetic tape, which was the primary tool in early electronic music composition, represents time in a linear fashion, where going from point A to point B constitutes continuous movement in a steady speed. Any variation in speed would result in detuning of the musical material, and distortion of the musical content. The fact that the musical material is reduced to the registration of pressure over time in an absolute fashion, allows us to transform the material in various ways. Going from point A to B is not the only possibility, by reversing the operation, the composer can go from point B to A. Reversing the concrete sounds themselves, in contrast to the inversion of the actual notes, for example, like done with traditional notation, results in new, rich sounds and produces more compositional resources. In respect to the representation of time, the difference between the magnetic tape and traditional notation is the actual representation of the linear absolute time, where the distance corresponds to time, or merely representing time using different symbols. With magnetic tape the sounds them selves go backwards and result in reversed pressure waves. Time itself cannot change its direction, but using this tool the operation can.

Even if the physical distance from point A to point B presents real absolute time on a magnetic tape, the progression of material can vary according to the speed of the tape. One can transpose material; change the pitch and rhythmical values, by changing the rate of audio reproduction in respect to time, which stays constant.
Until today, where musical material is represented, processed, and transformed in the digital domain, it is still most often represented with respect to pressure over time, just as with the magnetic tape. Another form of representation is the positioning of notes over time in the

form of a piano roll. This process is different than traditional notation in the sense that it is truly linear; the distance corresponds to time. In traditional musical notation different symbols represent durations, and there is no one-to-one relationship between distance and time.

Another form of digital sound representation is the display of the spectral characteristics of the sonic material. This type of musical display suits the processing of the spectral characteristics of the sound, and lacks the presentation of the sounds larger-scale temporal qualities. The matter of spectral treatment of sound, will be dealt with further on, although in the sphere of temporal significance, let me just add that more advanced presentations of spectral characters exist, which integrate methods of linear time representation, such as the windowing function incorporated into the Fast Fourier Transform and more advanced transformations, as the Wavelet Transform.

While musical material is represented in a linear fashion, and therefore reproduced and heard on a linear scale, many musical processes are non-linear and relate to our non-linear perception of musical matter. If we think about musical material, which is organized along the linear time axis, it is not necessarily have to be generated in a linear fashion. Many processes that produce interesting sound results are linked to their temporal outcome in a non-linear manner. Granular synthesis, for example, is much more suitable to be controlled by means of statistics and probability. To generate grains through immediate operation on the time line, by multiple layers of cutting and pasting material, would be extremely time consuming, and probably result in less interesting sounds and a less interesting musical progression. Using a method where boundaries of parameters are defined, and a certain amount of control is left to the user/composer, but more significantly, where there is no direct relationship between operation and obvious temporal outcome, results in a much more playful, exciting, and musical environment. When talking about parameter control, there are also cases of non-linear relationship between the gesture and the parameter change. In many cases the gesture is linked to different 'hidden' processes that are inter-linked to the outcome of the system. In this case we are talking about parameter space and the way in which navigation within this space results in a temporal output. This issue will be dealt with in chapter four, where the relationship between space and time within the composition of sound and musical structures will be discussed. The important thing to point out here is that the relationship between the gestures of navigation is not linearly related to the temporal result.

Looking into the contradiction that exists between the linear fashion of which music is displayed at, and the non-linear fashion of which musical time is perceived and controlled through, the question of how should we analyze music comes to mind.
Regarding objective time as being Linear, and at subjective time as being non-linear, one wonders if we should we actually judge music on a subjective level. Is this actually our only option, or should the perceptual aspect of music be analyzed separately than the musical material itself.
Maybe articulating the relationship between the two temporal characteristics is what we should aspire to as composers. That is, treating the objective, absolute aspects of musical elements and at the same time dealing with the subjective, relative aspects of music itself.

In the words of Horacio Vaggione:
"In music, as in all things, temporal coincidences are only ever relative and connected to a particular temporal scale. This absence of the absolute with regards to the simultaneity of musical events is however not a problem. On the contrary, we can profit from this to create living sounds that encompass multiple and complex movements." -Vaggione, from (Sedes 2005).

•Simultaneous vs. Non-simultaneous Events

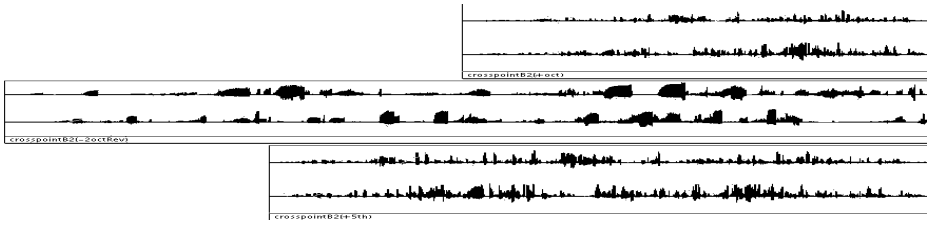
The issue of events happening simultaneously or sequential in time, could be looked at from different points of view. From the view of an absolute theory of time, two events could happen simultaneously, and be perceived simultaneously as well, no matter the relationship between the source and receiver.
According to Einstein's theory of relativity, two events perceived by someone to be simultaneous, could be perceived to be sequential by a person traveling in a different speed. Einstein's theory basically argues that time is considered to be relative to the movement of the observer. The most common example is the example of a speeding train, where two lights are flashed, one at the front, and the other at the back of the train. For a person seated inside the train the flashes appear to occur simultaneously, where as for a person standing in place, as the train passes him by, the flashes appear to be taking place sequentially. The front of the train passes him by first causing the light on the front to be perceived as flashing earlier than the light flashing in the back of the train.

Within a musical context, there are obviously many events that occur simultaneously, but with computer-generated material, there is no sequential operation. Computers work by sequencing calculations and never operate on more than one task. Although sounds generated by computers, may seem to be heard at the exact same moment, they merely give

an illusion of simultaneity, being generated through a sequential process, which happens at a very high speed.

Looking back at traditional music we can find the use of sequential and simultaneous composition of material. The sequencing of musical events could counter the presentation of simultaneous events. Thinking of the temporal qualities of music, one immediately understands the significance of sequential organization of material, though the presentation of simultaneous events plays an important role in traditional composition.
By composing two or more parallel fragments of sequential movement, using musical material, one can achieve polyphony. By constructing and formulating a set of rules on which the composition of the parallel movements is based on, we can realize an ordered way of composing the sequential material from a simultaneity perspective, and create an interlinked movement on these two different perceptual levels.
Within a simultaneous presentation of sequential material, one can focus on the parallel movement, one can focus on the chronological movement, or one can focus on the overall affect of the two or more layers that are stirred by this compositional process.
For example, the same note can have a different musical function within different contexts. These functionalities could be presented through a sequence of other notes, within a melody, or in harmony with other notes. With the combination of parallel melodies, these different functionalities of the same note could be presented simultaneously. These ideas could be seen to be what lies behind the laws of traditional counterpoint, with addition of the restriction of certain intervals, which were banned for religious, political, or any other ridiculous reason.

A different combination of the tow forms of sound presentation could also be seen within the editing of magnetic tape material or multi-channel mixing of audio material. While layering different transformed versions of the same sound source, one could create a simultaneous occurrence of all sound layers that due to the different transformation methods, have different temporal qualities, and therefore result in new sequencing of events, which are hidden in between the transformed layers.



•Three different transformations of one sound source, aligned using 3 stereo-channel mixing

As will be seen in the next chapter, within the musical context, there are multiple time levels. Earlier, I have mentioned Horacio Vaggione's quote about the absence of the absolute *(p. 18)*. This absence is due to the simultaneity of musical events that occur on these multiple time levels. Having no objective time, only the subjective context of a certain time level, presents us with quite a powerful compositional tool.
Treating the musical material on all time levels simultaneously could enrich the movement and contribute to the ambiguity of certain musical points. Although presenting the material on all time levels could be used in an interesting fashion, it should be controlled using methods fit to the operations of certain time levels. As we shall see later on, articulating sonic processes on different time levels requires an understanding of the different time levels, and the finding of fit articulation methods for each one of them.

•Reversible vs. Non-reversible Time

We have already seen that using modern tools, such as the magnetic tape, or the modern-day hard disk recorder, one can reveres the direction of the sound waves in respect to time, and create new transformations of the original sound source, without manipulating time itself, but only manipulating matter in respect to time.

It is clear to us that as composers we cannot manipulate time, but we can definitely articulate musical gestures that give us clues about the flow of time. Further, we can always manipulate the direction of the musical material in respect to time, and control its diffusion along the timeline to generate more variety in timbre and complexity in structure.
While the material can change dynamically, time is a constant property.
But does this actually mean that time has a direction, or a flow? Or is it due to our perception of time. Considering our psychological experience of time to be linked to our subjective time perception, one would assume that the flow of time would be perceived differently by different individuals, though everybody agrees that time has a direction. There is no argument over the order of events in their sequential appearance.
If we adopt Newton's point of view and consider time as being a container of events, then these events, due to their rate of change, contribute to our sense of flow, for if these events would not exist, time would still be there (in it's absolute sense), but would cease to be perceived, and therefore not exists to us.

Theories of time flow could be divided into three main groups. The first group suggests that the flow of time is basically an illusion, due to the perceptual nature of time.

The second group of theories supports the idea of subjective time; it is more focused on the cognitive experience of time.
The third group proposes that time flow is objective, and is due to the objective nature of time, it will exist whether we would perceive it or not. *(Dowden, 2006)*

Perhaps our sense of flow developed from the perception of the repetitions around us, and the cyclic motion that represents what time is. From early philosophy until modern astrology and physics, the cosmic laws and the cyclic behavior of the universe were studied, in order to unravel the essence of time. In biology we can easily find repetition as a key factor in many processes. Those are our natural understandings of time, from the cyclic motion in which we exist all to the perception of the circles of nature, of life, and even of our everyday routines. With adaptation to cycles, shaping and dominating our perception and later the understanding of time, we created an illusion of this flow.

In Newton's laws of motion we can always find the initial conditions, given that we know the outcome. We can trace our steps backwards, because time is represented within a set of linear equations. This rule also applies for linear processes in music. A Reversed sound could always be reversed back to its original state by repeating the same operation again. The same could be done with delaying a signal on the time line, or changing the gain on the amplitude scale, as long as the linear factor of the transformation is known, the operation can be reversed.
On the other hand, different processes that are projected over time, but are ruled by statistical 'one way' operations, do not allow the determination of past conditions. It is not possible, for the rules of which determine the outcome give multiple solutions for any set of initial conditions. Because the initial conditions of a certain statistical, or random process cannot be found, reversing the operation is impossible as well. The unknown factor of where a process would exactly lead, or where it had precisely originated, gives us, as composers, an additional level of complexity we could choose to use within a compositional context.

Another interesting phenomena, which incorporates the arrow of time is its appearance on one time level, but its lack of appearance on another level. Most physical processes are one directional in a sense that they can occur in one direction, which would be perceived in that direction by all spectators. This means that we cannot truly reveres the operations that occur over time, Even if we are dealing with a linear process, in the sense that we can understand its initial conditions.

It is clear to anyone that the process of mixing a hot cup of coffee with cold milk would result in the cooling down of the hot coffee to a cooler temperature. This process cannot happen in the other direction, a warm liquid cannot naturally decompose into two separate liquids, one cold and one hot.

If we record the thermodynamic change over time, and then reverse the registered data, we could easily tell which is the correct registration and which is the reversed one. This could be seen in recorded sounds as well. A reversed recording of any acoustic sound signal would stick out as being played backwards, our perceptual processes can immediately trace the clues for any reversed sound. For example, a lot of acoustic sounds are initiated with fast attacks and decay in an exponential fashion. Reversing these sounds would result with very distinctive differences between the original attack and decay and would immediately stand out.

Although these operations on the macro level, whether they happen in the physical world or in a musical context, are perceived to happen in a certain direction, due to the arrow of time, temporal behavior on the micro level, does not incorporate the arrow of time, as our perceptual sensitivity towards the directionality of time decreases on smaller time scales of dynamic events. If we record the movement of two electrons bouncing of each other and then reverse the recording, there would be no visual way for us to tell the difference between the two recordings. The arrow of time does not appear to exist in this process, or is merely insignificant. This is peculiar, seeing that this process, which occurs on the micro level, happens simultaneous to the macro process and is in fact a significant part of the macro level process. While the macro process does feature the arrow of time, the inner micro process does not.

In the sonic domain, we could look into the relationships of the individual frequency components of a certain sound as representing the micro level behavior of that sound's particles. At the same time we could consider the time function that represents the sum of these vibrations over an objective time line as being the behavior of that particular sound on the macro level.

Considering these sinusoidal movements as being the building blocks of these sounds, we encounter the same phenomena, whereas the sound in itself would be sensitive to being reversed, the sinusoidal components, which are circular (and endless) in nature do not depend on their direction of rotation to be recognized. Their amplitude relationships are actually what reflect on the overall sound quality. The phase relationship between these components could contribute a bit to our sensation of the sounds broadness, depth or direction. But the direction of these sinusoidal rotations in the micro level is of no significance to the to the macro level, and could not be perceived as different.

In the next chapter I will deal with the different time levels in more details and focus on the way in which we could treat them in a compositional context.

3. _____Time Concepts in Music_____

Apart from having many concepts, theories and modes of appearance, time has many implications towards the act of composing and the experiencing of music. In addition to music's dependency on time, and its sensitivity towards temporal deformation, aspects of time, and the way it is perceived are of special significance to the art form of music. This dependency and inseparable bind that joins music and time, could supplement the format of a composers work frame and inspire inner musical relationships to be composed. The ability to understand and operate different temporal behaviors on multiple time scales, in a way, could induce musical progression, contribute to an outline of a certain musical form, or produce textural and rhythmical richness. With this in mind, it is clear to see that musical time is a very broad term and practically deals with every musical issue that may come to mind. The complexity of musical time, leads us to the definition of several time-based processes, which are the act of composition. Within the sphere of musical time there are different levels of operation. In regard to the context of the musical matter in question and to our perceptual thresholds, the same physical phenomenon of simple molecular vibration in different ranges appear to have different functions, cognitively and musically. These different temporal scales are inter-linked and happen on a multidimensional scale of time levels. This multiplicity of temporal relationships could correspond to the multiplicity of consciousness, of which Henry Bergson talks of, and could be linked to a multidimensional space where these relationships are represented by the mapping of data amongst different dimensions within a predefined sound object map *(See next chapter, 'Articulating musical space')*.

The matter of organizing musical material over time, while maintaining different relationships between elements is one of the basic principles of composition. Due to the multidimensionality of time, approaching the process of arranging sonic and operational elements over time should, to a certain extent, be specific to the time level on which the operation or sound occurs. This could be one of the clues towards formulating proper temporal relationships within a context of a certain piece, where a non-linear development of musical tension & release, expectation & fulfillment, and flow & discontinuity is presented through the linear flow of the objective timeline on which it is arranged, creating a sense of flux that is tuned with respect to our perceptual behavior and to its functionality.

Within the domain of electro-acoustic music, and especially in studio produced and purely electronic tape music, the control one could obtain over the temporal relationships on these different time scales is extremely accurate, and distinctive, allowing the composer to deal exactly with these issues within this medium and therefore portray a faithful description of the relationships of which he deals with. Advanced tools such as digital signal processing, filtering techniques, and physical models, which are at the electro-acoustic composer's hands, allow him to focus not only on the rhythmic and pitch relationships between certain sounds, but also on the timbral qualities of the sound itself, and to articulate his micro-temporal ideas as well as the macro-temporal processes.

In this chapter I will present these three topics of (1) temporal relationships, (2) how we can use them to generate sounds and structures, and (3) how they are articulated in electric music, through the problems that might occur with trying to bind different musical and structural behavior and rules, which might make perfect sense in a theoretical manifesto but prove to produce dull material in a musical context. After establishing the possible use of these resources, in respect to what can and what cannot be useful in a musical environment, I will resume the role of space in music in the next chapter. Returning to issues of musical space, I will try to show how, through an understanding of temporal behavior and its control, we can better articulate spatial aspects of sound and translate spatial movement into temporal gestures.

•Time Levels - *a perceptual threshold*

Repetition is a key action in the compositional context; Pierre Schaeffer talks about repetition as differentiating events from music: "To distinguish an element (to hear it in itself, for the sake of its texture, its matter, its color)… …To repeat the same sonic fragment: there is not an event any more, there is music" *(Schaeffer 1952)*.
Dick Raaijmakers brings up the act of repeating elements while describing the compositional process of 'Canon-1' *(Raaijmakers, 1964)* in his book 'Cahier <M>' *(Raaijmakers, 2000*).
While describing the organizational structuring of his sound fields, which repeat into depth just like an initial waveform is repeated along the time line to create a certain sound wave, he describes the repetition of the initial sound element, which he uses to compose and to develop his musical progression with, as being the key aspect to his sonic morphology. Raaijmakers chose to use the smallest sound entity that can exist. Compared to the point on the traditional musical notation symbols, he decided to use the point on the edge of a needle, simply using a tiny impulse (jumping from zero to maximum amplitude and back in the smallest time interval possible) that would go unnoticeable without repetition.

Raaijmakers describes the act of repeating a sound as differentiating composed sound from just any sound:

"Placing one single point is not enough for expressing something. At best, this would be a demonstration of a sound that does not sound and hence has an abstract quality. Such a sound is related to nothing because there is only itself that sounds. This situation changes when a second pin is added because that creates a relationship between these two needles that can be pinpointed both physically and musically… …The second pin does not appear 'randomly', by the way, it is the work of someone who has carefully chosen that exact position of the second pin with respect to the first one. Through this opposition of pins, this 'someone' proves to be a composer in the true sense of the term ('com-ponere' – put together; arrange)."

The repetition comes back in its pure form everywhere in music and contributes to different musical functionality when it happens on a different time scale.

What are these time scales? How can the same behavior seem to have a different quality when it happens in a different time scale?

These questions can be answered if we look into the physical properties of sound, the perceptual processes that allow us to interpret these sounds, and then return to find what their musical implications are.

When a pressure wave changes from being positive to negative in a certain rate, meaning that it is fluctuating around a certain equilibrium position, it is said to be vibrating.

In natural acoustic sounds this vibration can have many shapes and forms, though is often a complex mixture of sinusoidal partials that give an overall sinusoidal shape to the acoustic wave.

A simple (sinusoidal) vibration or any complex vibration has a certain shape; this shape hides all the acoustic signatures of the sound that we hear and contains within itself all spectral qualities of the sound. When this waveform begins to repeat itself, the single waveform from its very beginning until the next repetition is called one period. If the period duration happens to be in a rate, which is faster than 20 times in one second (20 Hz) in average, we hear this vibration as a tone, or pitch. If the same vibrations happen in a rate, which is slower than 20 Hz, we would cease to hear a certain tone and perceive the individual waveforms as repeating beats. This also happens the other way around.

Let's say we take a recording of a certain percussive sound, it incorporates some pitch information, and even if it has a very fast decay, we can still perceive that pitch. Actually, our pitch perception is highly sensitive to repetition, and operates extremely fast. As long as we have more than one waveform repeating with the same period length, we already recognize the pitch of the sound. The sound of one single percussive note can be repeated in a rate of 8 times a second (i.e. 8 Hz), whether this happens synthetically (by means of copying and

pasting a recorded sound along the time line) or just by playing 8 notes per second, is of no relevance for the sake of this example. The resulting sound would thus be of repeating 16th notes in a tempo of 120 Beats Per Minute or 8th notes in a tempo of 240 BPM. The recorded sound would sound as a beat. Repeating this fragment of sound a few times and then speeding it up to 35 Hz, where the single sounding percussion notes would repeat every 1/35th of a second, we would no longer perceive a beat, and we would start to hear a complex tone with a low pitch. The individual percussive strokes would merge together into a complex and rich texture with a certain frequency, which is dependent on the speed of playback.

What about the pitch information that exists within the individual percussion notes?

If our finished product of speeding up a certain beat, results in a pitched signal, where the pitch is dependent on the playback speed, then the pitch of the percussion sound which existed in every individual beat has disappeared. Or has it?

The original pitch information that was audible in the percussive sound, is still hidden within the audible outcome of the transformation, but now plays a role in the texture of the sound. As described earlier, the resulting sound is a complex waveform. The inner-structure of each period is what controls the texture and the spectral qualities of the sound. The content of this inner-structure is made up of what was originally the pitched information, just on a different time scale. By the transformation of the percussive sounds from the rhythmic level to the meso level, the pitch information that existed within every individual beat was transformed into the timbral time domain, where temporal relationships between different components, result in specific textural distinctions that constitute the timbre. It is this intermediate zone between time levels that could be of special interest to us, as composers of electro-acoustic music composition.

The ambiguity of timbre-pitch relationships could inspire musical tension.

In my opinion, in Raaijmakers' 'Canon-1' (1964), the use of this intermediate scale is where the gravitational center of the musical tension is centered. The musical peaks in 'Canon-1' center around the speeding repetitions that emerge out of a timbral flux, and virtually "scrape" the pitch time-scale, resulting in ambiguous tension points that are beautifully obtrude, yet subtle as they stick out and blend in the overall flow of the music at the same time.

As we can see, the same rules of repetition and proportion between elements play completely different roles within different time levels.

The distinction between micro, meso, and macro time is very global and indicates different domains ranging from form to timbre, though many different distinctions between time levels have been defined within different contexts. The macro level can also consist of the

global structure of a certain piece, and therefore the rhythmic relationships must exist on a smaller time scale. The important issue is that the behavior and relationships between musical elements are relative and are not bound to one absolute time line.

•Formulating Temporal Relationships

In his essay "…how time passes…" *(Stockhausen, 1956),* composer Karlheinz Stockhausen wrote about the similarity of processes on different time levels, and offered to use the resemblance of the temporal behavior on these time scales in order to enrich the composers rhythmic variety, and to allow more developed rhythmical systems than the traditional symmetric system, which is based on sub division of rhythmic values.

Stockhausen compares the traditional notation for pitches with the traditional duration notation, and finds that with the rhythmic division there is much less variety than the chromatic scale, which is not build of whole number multiples or divisors of a fundamental unit. He looks at different ways that a scale of differing durations might be established, while searching for a chromatic scale of duration, on which he can apply to his serial composition principles.

Stockhausen also raises the esthetical-stylistic problem of poly-rhythmical composition as he suggests the notion of group structures, where the individual relationships among notes are lost in the texture of the whole group. This Group-structure is one of the musical solutions, which Stockhausen applied, in his piece Gruppen *(Stockhausen, 1959)*, where fanfares and passages of varying speed, which was based on the harmonic series, are flung between three full orchestras, giving the impression of movement in space. In Gruppen, Stockhausen managed to take the serial system beyond the limits it reached using pointillism, where the parameters of each note were treated as isolated individual elements and the music had an overall static effect.

Treating the transition of Stockhausen's musical form as being an elevation of serial form out of the pointillist figuration comes out of the critique one could have towards complex yet meaningless relationships between specific elements. This critique could be compared to the criticism on linear polyphony in traditional music, brought up by Iannis Xenakis, who was a big critic of serial composition:

"Linear polyphony destroys itself by its very complexity; what one hears is in reality nothing but a mass of notes in various registers. The enormous complexity prevents the audience from following the intertwining of the lines and has as its macroscopic effect an irrational and fortuitous dispersion of sounds over the whole extent of the sonic spectrum. There is consequently a contradiction

between the polyphonic linear system and the heard result, which is surface or mass. " (Iannis Xenakis from (Koenigsberg, 1991)).

Stockhausen talks about the "harmonic scale of perception" and argues that there is an inherent contradiction between the inner structure of continuous musical tones, which are composed of overtones related harmonically and their organization in 12-note series, which have no harmonic or any other hierarchal structure.
Stockhausen suggests introducing this contradiction on the time scale of the rhythm structures. He argues that the structural quality of a rhythmic section in one time level, which corresponds to a certain note in another time level of the pitch sphere, should be treated separately from its location in regard to other rhythmic sections in a rhythmic series, which relate to the placement of a single tone somewhere in a 12-tone row.
By looking at the rhythmic-pitch relationship of elements in the piece regarding their placement in series, which operate along the same ground rules, He could express the natural harmonic structure of *relative* sub-divided rhythms, within an individual rhythmic unit. At the same time, such an approach will also allow his serial system to treat that entire harmonic structure as a single unit, to be placed anywhere, in respect to other different units in accordance with the proportional series governing the macro structure of the piece.

I would imagine that in Gruppen *(Stockhausen, 1959)* these temporal manipulations, and advanced constructions of inner-related series contribute more to a certain degree of spatial effects than to temporal significance, due to the positioning of the separate orchestras in respect to the solo instruments and the audience. The relative aspect of time to a certain point in space contributes to the perception of different time scales of composition. Even so, formulating a strict temporal connection between time scales, which might prove to be affective in the mathematical domain, does not always prove to work on the esthetical framework. Even Stockhausen had to refine quite a few notes in his final score for Gruppen according to his aesthetic guidelines, after finally hearing all orchestras playing simultaneously. More so, notating these complicated rhythmic values, has logistic, procedural and practical implications. When composing instrumental music, one must at all times be aware of what is and what is not possible, amongst his instrumentalists.
And finally, there is always the issue of our perceptual processes, and our ability to interpret these fine tuned differences between rhythmical values. After all, the effective change between the period repetitions on the different time scales has to do with our perceptual threshold, and obviously it is easier for us to perceive pitch intervals on a chromatic scale with equal steps of the 12^{th} root of 2, as in well tempered tuning, and rhythmic values on a logarithmic scale with equally divided steps. Though any sort of scale division can be trained,

the question is, if it is necessary for the artistic integrity and the esthetic form of a certain piece.

Regarding the notation of a new rhythmic system. The composer, Henry Cowell, was dealing with the same issue of complex rhythm structuring, and talked about applying the chromatic scale to rhythmic composition as well. In 1919, Cowell had begun writing 'New Musical Resources' *(Cowell, 1930)*, which would finally be published after extensive revision in 1930. In this book Cowell focused on the variety of innovative rhythmic and harmonic concepts he used in his compositions.

Cowell's writings on Harmonic Rhythm, as discussed in his book reflected the exact musical problems that Stockhausen was dealing with in '…How Time Passes…' 26 years after Cowell published 'New Musical Resources'. The only difference between the two is that Cowell looked into formulating harmonic rhythmic relationships as a way tow enrich and refine rhythmic composition in general, while Stockhausen did so out of the need to adapt serial processes that would fit the composition of rhythms.

Cowell's interest with rhythm led him in 1930 to commission Léon Theremin to invent the Rhythmicon, or Polyrhythmophone, a transposable keyboard instrument capable of playing notes in periodic rhythms proportional to the overtone series of a chosen fundamental pitch. The world's first electronic rhythm machine, with a photoreceptor-based sound production system proposed by Cowell, it could produce up to sixteen different rhythmic patterns simultaneously, complete with optional syncopation. Cowell wrote several original compositions for the instrument, including an orchestrated concerto, and Theremin built two more models. (*Gaan, 1997*) Very quickly though, the Rhythmicon was forgotten, and has stayed that way for over 20 years until it was re-introduced into the music scene, by producer Joe Meek, only now to be part of the pop world. *(Wikipedia)*

These examples of using the multiplicity of time levels in composition show us how composers would want to deal with time to enrich their musical resources, but when talking about electronic music, we can dive deeper into the different definitions of these multiple time levels, and better determine the control over the musical elements, that exist in them, and that define them.

•Time In Electro-Acoustic Music

When dealing with musical material of the synthetic kind, which was electronically produced, we are able to develop very sensitive tools that are able to control details on the finest levels; Down to a 0.00002083 th of a second (using a sampling rate of 48 kHz). Our

articulation methods are better equipped to work on the smaller time levels of sound, this allows us as composers, to deal with the micro time, and to focus on textural qualities of sound. At the same time, having such detailed control on the micro level could risk losing the essence of the global form, for when working with particularly small details, sometimes, the global frame of the whole piece, which contains of these fine details brought together, gets blurry and does not communicate well. The beauty of composing such refined music thus is the fine balance that must exist within a certain composition. The space of which we can explore where the different relationships of time levels, dynamics, textures, time & space, and so much more exists. Not only does the electro-acoustic composer have all these wonderful tools at his disposal, but know he is also free (if he wishes to be free) of what instruments, and instrumentalists can or cannot do, That is, in a traditional sense. The computer and loudspeakers are still considered to be instruments, but the understanding of the detailed physical control one can obtain over the pressure wave, which is the music, is beyond the understanding of any 19th century musician.

In 'Cahier <M>' *(Raaijmakers, 2000)*, Dick Raaijmakers refers to the composer as being a futurist and inventor, using the tools that were around after World War II, the thirst for searching further into compositional resources was advanced, with the possibility to go deep into the phenomena of sound, and control its property, the composition of sound itself was possible.

Now not only can composers invent new forms and structures, but they can dwell on the production of their building blocks, they can invent their material, of which they invent their forms and structures. This might sound like composer-utopia, but as mentioned earlier, this comes with the risk of loosing the control over the structure. This goes along with the post-modern art catch of having "endless" possibilities, where making decisions becomes more difficult than producing the material.

Ranging from spectral control to Granular synthesis, the processes in the electro-acoustic composer's contribute to the timbral qualities of the sound, but have implications to the way the global structure is perceived. In this section I wish to give a few examples, from the work of Horacio Vaggione and Dick Raaijmakers, on how they deal with these relationships and how they are articulated in their music.

Coming back to the significant act of repetition in music and sound generation, I would like to discuss the translation of repeating sound fields, in the context of the 'Canon-1' *(Raaijmakers, 1964)*. The process of composing these sounds and the context in which they are presented will be discussed in detail in the next chapter, while concluding what, in my

opinion, are the significant points of spatial composition. In the sphere of certain simultaneity of time levels, the significance that lies within this compositional process is in the translation method Raaijmakers provided for repeating his *pin-shaped sound objects,* as he calls them. The translation process here refers to the shift these vertical repetition have in a respect to the linear time line. Through stacking the sound layers on top of each other, a slow progression of sound grains could be introduced and give rise to an ambiguity of timbre, rhythm and occasional pitch bursts that emerge out of the noisy gravel-like texture of which the global progression of sound consists of.

The sound objects consist of the original abstract pinpoint, which is represented by an electric pulse, and several repetitions of that 'mother shape' along the vertical axis (the vertical axis can represent any transformational quality chosen by the composer and is just an abstraction of a sonic morphology in a certain direction rather then on the azimuth of time- the horizontal axis). These repetitions are present in each instance of the sound object and their displacement along the time line is determined by the angle of which the object appears in respect to a chosen equilibrium point. In a way, Raaijmakers relates a certain phase shift of the object to its temporal translation. Raaijmakers suggests five main translation categories.

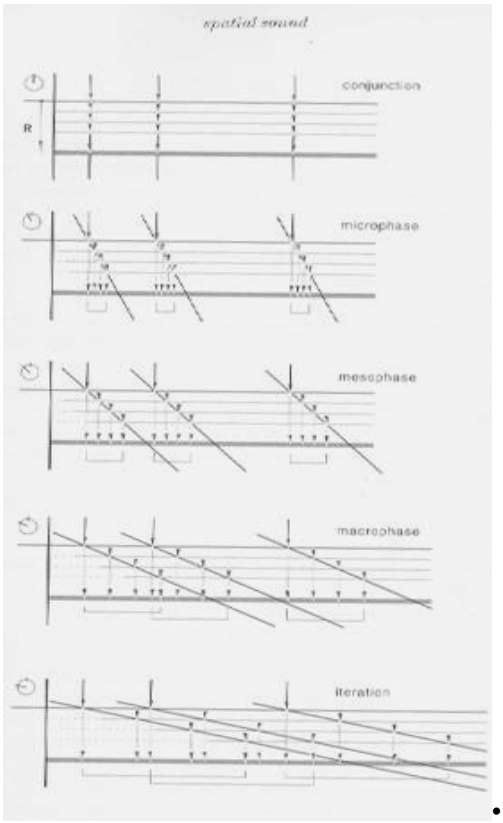
The first category would be a certain 'Conjunction', where the repetition act is executed simultaneous to the occurrence of the sound object itself. We are then dealing with the display of all copies at once and the absence of translation, so to speak. The second translation category is the smallest possible translation, meaning a minimal delay between repetitions. In Raaijmakers words: "The smallest translation refers to a 'micro phase' shift that corresponds to the distance at which the oscillation movements of tones follow one and other, i.e. intervals of about 1/16th - 1/10,000th of a second." *(Raaijmakers, 2000)*

It is important here to keep in mind that the sound object is a single impulse and by itself takes no significant time.

The third category refers to the 'meso phase', where shifts are based around intervals of 1/16th – 2 seconds. The forth category consists of shifts of intervals, which are longer than 2 seconds and is based around the 'macro phase'. Here we can already see the overlapping of repetitions with the exceeding sound objects *(see figure in next page)*. The final category of translation is described by Raaijmakers to be a certain 'iteration' of repetitions, these shifts consists of large intervals, and result in overlapping sound objects and repetition on a large scale. Raaijmakers refers to this translation as being the most consistent and most frequently used kind of repetition.

The figure in the next page shows all five categories of repetitions as displayed by Raaijmakers in his book. The repetitions of the original sound object are represented along the Y-axis, in the direction of R, the phase shift (time delay) is represented using the circle in

the top right corner of every example, and the resulting time delay is represented on the parallel lines along the X-axis. Note that the rhythm of the occurring sound objects is the same in each and every example.



•*The rotation of a sound object in space controlling its temporal delay, on several time-scales (Raaijmakers, 2000)*

This is a perfect example of a particularly sound-composed piece, (even in his description of the piece; Raaijmakers suggests the initial repetition of the very first pinpoint to be the act of composing) where a simple manner of temporal displacement, which is merely repeated onto overlapping sound levels and is superimposed along simultaneous layers to create a certain global-temporal progression. But what is even more striking is the tension which is maintained within these sound grains and their esthetic relationship and dynamically altering coherence to their grouped instances which together comprise the global form of the first and the rest of the 'canons' composed in the 60's, a time when formulating micro temporal gestures was quite laborious, using tape splicing techniques.

This leads me to the subject of Granular synthesis; I wish to mention a few points regarding Granular synthesis, due to its significance to the subject of controlling more than one time scale simultaneously. When working in a granular synthesis environment, change over the micro level and the overall temporal flux could be controlled at once.

There are numerous ways in which acoustical theorists look at sound. Helmholtz suggested that our brain analyzes the complex audio signal by decomposing the waveform into individual sinusoidal components that are harmonically related to a fundamental frequency. This observation led him to the development of the famous Helmholtz resonator, and could be compared to the mathematical Fourier transformation, which allows us today to process individual frequency components in real time using Fast Fourier Transformation (FFT). The problem of this theory though, lies in its lack of temporal presentation. The theory does not allow the change of sound over time.

British physicist Dennis Gabor, on the other hand, formulated a theory that says that sound is perceived as a series of short, discrete bursts of energy, where each of these bursts is slightly different from the last. He postulated that the ear is capable of registering one event at a specific frequency within a short time window. This was suggested by Gabor in 1947 and verified mathematically in 1980 by Bastians. This is in fact what allows us to recognize sound out of a discreet set of samples.

Iannis Xenakis suggested that sound is an integration of elementary sonic particles, of sonic Quanta. Xenakis proposed the use of computer music techniques for producing complex granular sounds.

Curtis Roads has researched and studied the perceptual thresholds in the realm of micro temporal composition from the late 1970's.

Finally in 1986, Barry Truax implemented the technique with real-time synthesis.

The idea of Granular synthesis is the linear combination of thousands of short sound grains to form large-scale audio events. By doing so, one can control events on the micro level in order to shape the affect on the macro level. These sound grains can consist of any sonic material that can be produced, and is often generated by chopping up another large-scale sound into small bursts by a certain windowing function. The size of the grain, the position of the grain within the original sound, the shape of the window, and the speed of movement within the original large-scale sound, all contribute in a different way to the outcome of the synthesized sound, though there is no direct or linear correlation between the interaction of the grain parameters to the parameters of the large-scale events.

One of the powerful points of Granular synthesis is the control one can obtain over the ambiguous area where the relationship between pitch and rhythm is blurry. That range allows us to produce quite interesting sonic gestures, though the effect of Granular synthesis

is mainly timbral and this process results in a very typical sonic quality. Another manipulation that is possible is the alteration of the length of each grain by the change of its window size. This will result in a timbral effect, while the pitch will be controlled only by the period that is between the starting points of the successive grain. In this way one can change the period duration, without affecting the pitch, but only altering the timbre of the sound.
The real-time processing allows dynamic control over the synthesis parameters that define the timbre of the sound, and at the same time allows the shaping of the overall temporal flux, through the creation of fluctuating textures.

The final example I would like to present regarding temporal elements within electro-acoustic music is the work of composer and music theoretician, Horacio Vaggione. The work of Vaggione is highly significant to the issue of multi-temporal articulation methods, due to his deep understanding of temporal-spatial behavior, his extensive compositional skills from both the acoustic and the electronic worlds, and his understanding of the computer's role within music composition as mentioned by Jean-Claude Risset: "…not merely for problem solving, but rather as a component of a complex system, which intervenes in a genuine polyphony of processes involving a multiplicity of time scales. His musical works evidences concern and imagination concerning morphology: he builds sturdy structures from minute grains. His music reveals novel figures: while bringing to the ear a world made up of atoms, it manifests the arrow of time." (*Risset, 2005)*

Vaggione also recognizes the need for a balance between algorithmic composition and direct intervention. 'To articulate a highly stratified musical flux by statistical means is unthinkable. On the contrary, it depends on singularities: discontinuities, figures, contrasts and details' *(Vaggione, 2003)*. Unlike music governed by strict methods of composition, Vaggione has a sense of natural playful elegance within his musical structures and forms, and through his multi-temporal structuring, every individual section within his compositions compliments the global form of the piece.

As mentioned in the first chapter *(*Space / *Sound objects)*, Vaggione deals with the composition of sound objects in the context of his work. He looks at the multidimensionality of time as being a single unit of inseparable qualities, in order to articulate the inner-relationships that these sound objects incorporate within their internal structures. Vaggione had to understand the significance of the micro-temporal behavior of transients and phases in relation to the recognition of instrumental timbre, as an acoustic instrumental composer, in order to be able to pave the way towards developing his syntax of micro-time scale composition and his complex methods of sound synthesis. Vaggione also

talks about the morphological salience of a sound, as being a momentary experience that can reveal a certain timbral richness, which can be further developed. These morphological saliencies could be seen as the instants of a specific duration, in relation to the information being embedded within a temporal unit. Just as the instants are members of durations, these momentary morphological saliencies are members of a certain timbre.

With the timbral qualities of the sound defining the essence of each sound object and differentiating between them, Vaggione creates a network of sound objects where each one of the objects is a network in itself, combining within it synthesis and transformational tools, allowing an integration of several temporal levels through the articulation of gestures in the spheres of pitch, polyphony, rhythm, timbre and space. Even though the sounds themselves inspire the movement and the global structuring of the piece in hand, Vaggione encourages the intervention of the so called 'action/perception feedback loop' that is the studio environment. There is always a micro-temporal control over the elements of sound in his music, specified by the digital codes that represent his sound objects.
Within the context of his music, Vaggione manages to create his own syntax of coexisting temporal scales by making his object network flexible and dynamic. The relationship between the different dimensions is articulated through the connection points that merge the different temporal scales and allow the object to constitute a 'plural entity'.

Vaggione talks about 'figures' that are being regrouped into objects. These 'figures' are to be seen as a musical 'theme' in a sense that they embody the morphological characteristics of the object and represent the core of the complex sonic entity that represents form and content as a whole. The 'figure' is the basis of the sound object and could be seen as the parallel to Raaijmakers' 'mother shape' that is the single first abstract particle of the piece, which is expanded through repetition to formulate sounds and structures. In this sense we can speak of a new dimension of polyphony, which is composed around the morphology of sounds.

The multiple time scales in Vaggione's music are defined through their functionalities and operational quality; there can be as many of them as there are dimensions of operations. Obviously they can fit into perceptual categories of micro, meso, and macro levels, but the flexibility of the composer to navigate in between them and define spatial relationships by dynamically interchanging the listeners' perspective throughout the progression of the global movement of the music, calls for a procedural definition of smaller, separate time levels on which these operations occur. Achieving the control over the micro level structures allows him to articulate stratification and differentiation of the sonic flux, through timbral and

'micro-rhythmic' counter. By favoring contrast, and detailed discontinuity the counter elements compliment the global form of his music.

In respect to the musical space in which his sound objects are organized, Vaggione also deals with the acoustical space in which they are presented. The translation of his digital coded objects into their localized acoustic bodies requires certain micro-temporal operations that give the listener a perceptual spatial distinction between multiple elements. This localization technique will be dealt with in detail in the next chapter, amongst other temporal solutions to spatial articulation in music, while discussing aspects of musical space.

4. _____Articulating Musical Space_____

There are many aspects of the abstract musical space that play part in the composition and experience of music. Terms such as timbre space, pitch space, and performance space all have to do with an organizations of certain parameters within a composition, and allow the composer or performer to 'navigate' within this space and control these parameters. When taking the composition of contemporary electro-acoustic music in account, the use of space as a parameter is not merely a metaphor, but a critical property of musical structure. Spatial composition is directly related to our perception of relationships between the musical elements, and is of course linked to our ability to localize sounds within the performance space, and to differentiate elements that are spatially ambiguous. The experience of music is a procedure of dynamic information processing, unfolding in real time and requiring the listener to constantly update and refine his mental representation of the composition. This is true to the spatial aspect of the composition as well, while the 'real world' sense of the term space, describes some static non-changing quality of a certain structure.
Articulating the spatial aspects of a certain composition boils down to the displacement of musical elements around the performance space, and the construction of musical form on the multiple time-scales, for the time aspect of music could be seen as the representation of the experience of a spatial construction. This idea is part of what defines Dick Raaijmakers' morphology of electric sound. This will be dealt with in the following chapter.

It is important to keep in mind that there is far more to music than the raw, meaningless physical signal. The experience of music involves a perceptual process of recognizing mentally constructed entities that represent the musical tension, movement, progression and discontinuity or continuity. The abstraction of structural and spatial qualities in the sonic realm requires the treatment of space as any other parameter of musical structure.

Dennis Smalley, composer of electro acoustic music, refers to the pitch range of certain instruments as the defining boundaries of their pitch space. Many electro acoustic compositions such as 'Mixtuur' (1964) and 'Kontakte' (1958-60), by Karlheinz Stockhausen, use the processing of live acoustic instruments, which have a limited pitch space as an input for an external and less limited space, where through the electronic transformations has more textural, pitched and timbral qualities available within it.

•Sound objects

A sound object could maintain the temporal qualities of any sonic element. Being a temporal entity in its physical property, it could also be seen as representing a complex timbral unity constructed out of a limited set of sound source materials.
Horacio Vaggione also describes the process of constructing sound objects and organizing them into networks in order to generate new timbre in his text 'The making of Octuor' *(Vaggione, 1984)*, while portraying The process of generating five synthesized files, employing additive synthesis and frequency modulation algorithms.
After collecting all of the generated material, Vaggione proceeded with analyzing, reshaping, multiplying and combining the different elements through relatively simple software manipulations controlling of the overall amplitude envelopes, blending sound objects into complex timbral entities and applying immediate random-access playback.
Further the sound files were segmented into small portions, regrouped into several pattern and timbral families. This classification of timbral distinctive groups can be seen as a parallel to Schaefer's typo-morphology classification of concrete sounds. The different groups are later on processed, and mixed into medium and large sound textures. These long textures emerge out of the same material that constructs the smaller sound objects and links multi-layered material that will later be presented simultaneously and contribute to the articulation of the spatial relationship, which exists in the border line between the different time levels and maintains the structural tension of that momentary component.
The product of these compositional procedures was stored as a set of new sound-object files. These files were later put together to form the global structure of the piece.

Through the digital representation of his sound object Vaggione is able to create subclasses of a specific sound object through transformations such as time stretching or pitch shifting. The transformed sounds inherit the morphology of the original sound.
In relation to abstract size and space in the context of his work, Vaggione talks about the important role of tiny textures that consist of feeble intensity, composed of multiple strata, which contrast with some stronger objects of different sizes, in a kind of dialog between the near and the far as an expression of a concern with a detailed articulation of sound objects at different time scales. Here we can see the immediate connection between the different time scales to different sizes and locations in space.

Obviously different sized entities experience time in different rates. Looking at our physical world, our size and location in space determines our experience of time. The entire existence of our planet could be, but a mere micro-existence (or grain) in the macrocosmic time, and for us contains far more events than we could ever imagine. Further more, our

existence as individuals happens on just a small insignificant portion of time in comparison to the existence of our planet, while for us it is a lifetime of experiences. This relationship of time relative to space is apparent in Vaggione's composition of sound objects.

Vaggione talks about his music as being focused on a limited collection of objects of different sizes, which appear in diverse perspectives. The work plays essentially with contrasts between textures composed of multiple strata, as an expression of a concern with a detailed articulation of sound objects at different time scales. *(Roads, 2005)*

The key element to Vaggione's work with sound objects is in its multiplicity of functionalities. Not only do they operate on multiple time levels, and represent different spatial characteristics, but the ability to control all these multi-functional elements as one entity due to the representational system of a digital nature, gives the composer a fascinating amount of unified control over all layers and functions.

Because sound objects are often composed out of common source material they often retain the morphological features of the original sources. Other objects stand out as electronic artifacts; this is often due to certain processes, which have distinctive sonic signatures, such as the sinusoidal side effect of FFT or the fluctuating amplitudes of granular synthesis. In these cases, the processing becomes the main timbre characteristic of the sound.

•Timbre Space

The textures and timbres that could be produced by reading through networks of sound objects create an inter-linked multidimensional plane, which features the multiple timbres. This leads us to wonder possibilities of layering out the material and navigating through these timbres in a coherent way that will allow an interesting and faithful description of the spatial timbral relationship.

The number of dimensions in this certain timbre space would be determined by the amount of layers of operations, in the sense that any additional process adds a new approachable timbral quality. If we consider multiple time scales to be features of a certain sound object, than we can imagine a certain operational plane available per time scale. The more time scales incorporated, the more complex the space is, and the more optional points could be described within this timbre space.

The definition of independent timbre spaces raises the question of the existence of one global timbre space. Could any timbre space be a part of a continuum, which is a global timbre space?

It has been considered in the early stages of electronic music, that with newfound, electric, compositional tools, any timbre can be created, if by synthetic or reproductive means. This utopian notion that all textures are approachable and producible was soon shattered, and quite fortunately, it has been realized that every different method of sound production proves to be unique and independent in terms of its sound quality, even in the digital domain.
The fact that different sources are needed to produce different textures, does not indicate the absence of a global timbre space, which could be imagined and inspire temporal navigation through closely related textures.

Regarding the organization of such a space, it seems possible that there is no particular relevance to the way in which the parameters, timbres or objects are sorted, and grouped. It might just be that the act of navigating through such a space is sufficient enough to maintain a dynamic shaping of the musical form, especially in a live situation.
On the other hand, the freedom to navigate in such a space could be dangerously confusing for a 'blind' user, where the operation on the micro level would result in a misapprehension of the global form. Maybe the knowledge of where the crucial points are located in the space is enough, and the arrangement of them could be done arbitrarily, without risking the quality of the music.
The organization of the parameters within the space should be left to subjective and particular cases. The possibility to navigate within the space depends on the representation of the space; whether it is discrete or continuous could be consequential to the sonic quality. The continuity of such an organized space will also determine if the user or composer have a set number of data points to refer to, or if they can smoothly shift from one random point to another. This point could be crucial in the uniformity of the musical material representation.
Further more, one could imagine a space that inspires newfound timbres just by the navigation within it, for example, that the navigation through one dimension of the timbre space would be used as an input for another dimension of that space, creating a non-linear relationship between the parameters of the space, and generating new sounds.

Just as the number of dimensions within a certain space is subjective to the number of parameters, the organization of it is also a task particular for the composer, the diversity of grouping parameters and controlling them is as divers as timbral qualities and can always be refined.

•Morphology of sound- *a temporal experience*

With the consideration of space as being a significant element in the composition of sound and musical structures, and the understanding of temporal levels of operations in music, I would like to come back to Dick Raaijmakers' concept of sonic morphology, and discuss it's applicability towards the composition of electro-acoustic music as being transformed from the spatial-structural domain to the temporal-compositional domain.

As mentioned in the first chapter, the Neo-plasticists according to Raaijmakers were trying to find the balance between opposites, if dealing with contrasting elements of a certain work or with different methods of organizing the material. Raaijmakers has also suggested that finding the right balance between the so called 'improvised' and 'educated' walks through a composed structure could be the key for maintaining the musical tension and the intensity of the material. The balance should be found between the guided sonification of the composer's structure, and the interpretational form of the music. This borderline between conceptions could also be seen as being parallel to the borders of the different time scales, where stretching one form of material to its extreme until it borders another perceptual timescale, and therefore defining the erratic intermediate area that lies in between the timescales.

Leaping further in time, and using more advanced tools than available in the 1920's, this balance between oppositions could inspire more complex structuring of musical form
As seen in many cases of modern music, such as Vaggione's work, and in Raaijmakers' Canons, operating on the intermediate levels of time also gives birth to the tension and the charged points of a musical work.
These forms of composition deal with multidimensional music that is described by Raaijmakers as *'liquid form'* or *'Architectural composition'* that is mainly composed from a constructional point of view, which compliments the temporal quality of the music.

The methods of extrapolation of form and matter into sonic qualities, or in our case the sonification of detailed structures, could be done in many ways. Raaijmakers brings to light two more or less contrasting methods of morphological concepts presented first by Etienne-Jules-Marey, the French physiologist & cinematographer in his book *'Le Mouvment'* from 1894. These concepts deal with the capturing of movement through the processing of moving pictures in a chronological fashion.

The first method is called 'plaque fixe' and describes a situation were the information is stored and presented in a static format, in the case of displaying pictographic movement, a sequence of images is stored simultaneously. This *structured meta-image*, as described by Raaijmakers, should be read as a whole. The perception of such an image is thus analytical, in the sense that the observer must read through the individual images in order to perceive the movement. The image and the carrier remain still, while the observer moves.
The second method, 'plaque mobile', illustrates the opposite situation, where the media itself is presented chronologically in a dynamic fashion, while the individual images change through the movement of the carrier and the observer stays still. Raaijmakers points out these two methods as being the fundamental difference between the plate-like disk and the string-like tape. In the tape format, we can see a faithful representation of the movement, as long as the recorded data is projected in the same speed. In this sense we are experiencing what Raaijmakers would call an educated walk through the material. The movement is objective and is presented in a linear fashion.
The 'plaque fixe' technique is analogous to the plate-like disk. In this case the data is stored as an aggregate, stored in layers that together make the whole. These independent fragments of data could be individually accessed and read from an angled viewpoint. Raaijmakers compares this method of storage to the modern hard disk. More importantly, the significant difference between the two methods is that in the 'plaque fixe' method the carrier invites the viewer to read through the information in his own pace. The carrier does not control the temporal aspect of the data; the viewer/listener is in control of his exposure rate to the material.

Marey's methodology of capturing movement, although aimed at motion of the visual nature, has many implications towards music. The magnetic tape could be seen as the 'plaque mobile' model, and computer music, where stored fragments of data are being processed, and the treatment of sound objects as being multi-dimensional sonic/data entities is possible could be considered as being the plate-like disk, 'plaque fixe' model.

In 1964 Dick Raaijmakers proceeded with implementing his theoretical ideas inspired by Mondriaan and Marey, which will only later be known as his theory of the morphology of electric sound. He articulated his ideas in the form of tape music, through composing his first piece in a series of five, 'Canon-1' *(Raaijmakers, 1964)*. In this piece Raaijmakers brings to life the movement of musical matter, soaring between the different time scales, while stirring the focus of the listener from one scale to the next, through exploring the sonic boundaries of these scales and bringing birth to textural ambiguities, such as timbres that morph into pitch, and vague rhythms that relate to structuring of material.

All this is done using the simple (yet laborious, using tape splicing) act of repetition.
The repetition act is made using what we can call a dead element, which incorporates no musical quality other then an imperceptible electric burst, the shortest possible impulse. The act of repeating this mother shape is what gives birth to the musical matter of this piece. By creating repetitions Raaijmakers created his sound fields. These fields were constructed first as an abstract form within the score and were later composed as the resulting sounds as being perceived from different angles. Guided through the pathway that was chosen by the composer, the listener perceives the constructed sound fields from the selected viewpoint and experiences the temporal registration of the spatial structure.
This specific compositional process could be viewed as incorporating both the plaque fixe and plaque mobile methods. The stored image of the sound fields, which together construct the sound object, could be seen as an abstract meta-image in the plaque fixe scheme, while the reproduced listening path is articulated using the plaque mobile method. This duality holds the key to the transformation of spatial characteristics into audible elements of designed musical structures.
By using one method to compose the static nature of the musical design, and using another for articulating the dynamic properties of the musical movement, the composer could reach the optimal state of musical production. The production in this sense relates to the reproduction of the musical material in regard to the structured sound fields that represent the morphological characteristics of the sound.

Another dimension that is added to the spatial aspect of the musical time is related to individual movement of the different fields in respect to each other and in respect to the listener. The movement relates to a rotational speed, which is constant and different to each and every sound field. The rotational element defines the angle of which the specific sound field would be read (or translated, in this sense) when encountered with the path of the listener, the other moving element. This extra level of movement adds tension to the dynamic qualities of the piece. The exact method of translation from the field's respective angle to the temporal qualities of the sound is more extensively described in the previous chapter (Articulating Musical Time / *Time in electro-acoustic music)*.

The power of having global elements that are independently dynamic and approachable, is in the ability of the composer to educate himself in the relevant points of tension that inspire interesting musical material to emerge, and to carefully choose and layer the paths, which will integrate these points and construct a temporal movement out of the spatial structure. There is still the important issue of understanding the timbral qualities and the temporal behavior that dominates different points within a certain structure. After all, we

are not interested in the control space itself, as composers, but in the musical significance of the material that the control space represents. The act of navigating through the control space in itself does not necessarily contribute to the musical form of the piece.

What is still amazing is the way in which the act of composing a space with constructional relevance that would later constitute a temporal form, can compliment very significant points in the temporal domain. I believe this is true, when the articulation methods of data transfer and translation from space to time is done on the intermediate time scales and plays different roles on different time scales. In this sense, combining the spatial compositional methods of Raaijmakers' work with the multi-dimensional sound object composition of Vaggione, a wonderful method of complex structural composition could be achieved, where the compositional process divides in to two main processes; construction of sound entities, and the composition of the reproductive translation into complex sound objects.
In contrast to Vaggione and Stockhausen's work on the temporal scales, which contributes to the spatial aspect of the musical elements along the azimuth, in the case of Vaggione (See next section on Perceptual space- *localized sound*), or in respect to other musical elements or groups in Stockhausen's Gruppen, the spatial composition of Dick Raaijmakers exquisitely supplements the temporal aspects of his musical structures. The spatial method of composition proves to be very useful in this case and the question remains if this is a particular musical scenario, or if this method of spatial construction could enrich any musical environment.

•Perceptual space- *localized sound*

In the history of music composition the use of spatially separated elements has occurred quite often. Way before Gruppen *(Stockhausen, 1959)* composers such as, Mozart, Berlioz and Mahler, have all written music for multiple orchestras, or spatially spaced orchestras. However, these cases are exceptions, and taking on such a production would have always required very complex logistical and financial resources. Since the invention of the sound reproduction system and the use of speakers in a concert setting or home entertainment systems, the production of specifically localized sound was possible. This artificial sound source could be synthetically controlled and more easily manageable than any acoustic instrument. When the composition of modern music was introduced into the world of electronics, after the Second World War, and multi-channel speaker settings have entered the concert hall, then naturally, the spatialization of sound and the organization of localized musical elements has become a suitable musical parameter, within the palate of the electro-acoustic composer's toll box. The ability to control the spatial elements of the music as well

as the sonic qualities of the music made the composer's work more diverse and gave birth to new fields of research within the study of acoustics.

Although the sound quality and our control over it has changed and morphed with the development of more complex sound systems, such as Wave Front Synthesis (mentioned in chapter 1. Space), we should be sure not to confuse the sound production system with our notion of performance space. The relevance of the performance space to the composed material could be seen easily in many stylistic musical examples. If we imagine a Gregorian chant preformed in an open field we could be sure that the preformed material, though unchanged, would be perceived and communicated differently than its intension. Although with our modern tools, the performance space could be synthetically controlled and used as a dynamic compositional effect.

Different examples of electric manipulation of localized sound can be found in many electronic works. In Poéme Electronique, composed by Edgar varése for the Philips pavilion in the Brussels World Fair of 1958, the sonic material was spread over a complex set of speakers, where the routing of the material through the (also complex) architectural structure that inhabited the piece, was controlled by a custom made analog tape.
Varése composed his music on four separate tapes; three mono and one stereo. The composed material was distributed over 425 speakers. *(Tazzelar, 2006)*
Loudspeakers were grouped in threes and fours and the movement of sound from location to location was achieved through a switching system controlled by the custom-made tape. With this complex system, different sound paths were composed independently, from each other and as a separate part of the composition.

In a more standard setting, Horacio Vaggione talks about the phase decorrelation within multi-channel mixing of monophonic material. He argues that one could control the disposition of sound along the azimuth, and how the spatial separation between his abstract objects could better be perceived, using his techniques of phase decorrelation and micro-temporal delay. To be clear, Vaggione uses the technical term of decorrelation, which relates to inverse filtering, in a self-defined context that conveys his ideas about the perception of different objects in a certain space. As Vaggione mentions, the perceptual ability to recognize decorrelation in signals gives us quite a unique affect of space in composition:
"Temporal decorrelations of audio signals are imbedded in many spatialization systems. However, my point is to show its direct use in electro-acoustic music composition. Starting with the very fact of an impossible simultaneousness, and the assessment that music benefits

of this fact to create "alive" sounds, I pointed out that our perception is sensitive to very slight temporal decorrelations." *(Vaggione, 2001)*

Composer and researcher, Cort Lippe, talks about the spatialization of sound using FFT to break the sound down into it's individual sinusoidal components, and then re-synthesizing the sound along different independent sources, each including only part of the monophonic input sound. In order to have a realistic reproduction of the input sound, a correct balance should be maintained between the individual sine wave components. The power of this tool is in the ability to link the structural (non temporal) inner relationship between the assembled components to the spatial representation of the sound throughout the performance space. Cort Lippe also points out the importance of controlling which of the bins would be moved around the space, for any random bin would not necessarily be a significant part of the signal, if it would exists in the signal at all. Therefore, there should be a relationship between the input analysis and the control parameters.
"…Using information derived from spectral analysis of audio signals to control spectral spatialization. Several techniques were developed which allow selected spectral characteristics (e.g. the amount of energy or phase position per bin) of a sound to create a spectral spatialization pattern. The sound used to determine the spatialization pattern could be the same signal actually being spatialized (a kind of "self-spatialization"), or a different signal altogether ("spatial cross-synthesis")." *(Lippe & Torchia, 2003)*

It is evident that controlling spatialized sound can add a layer of control and complexity to the musical material. Still the question in the role of localizing sound within the act of music composition could differ according to the compositional context. Adding spatially localized aspects to the synthesis process could also enrich the sonic complexity, and add to the spatial quality of the overall musical experience.

•Conclusion - *The necessity of space for the composition of musical structures*

After examining a few of the aspects of space in a compositional context, ranging from sound composition, structural composition, sound object definition and control space to localizing sounds, the question that should be answered regards the necessity of spatial characterizing of sound, mainly, is music a space dependent art form, as it is a time dependent art form? Would music exist without space? And does it still exist if we as composers do not acknowledge it. Further, one would wonder if the spatial aspect is relevant only to electronic music, which deals with timbre composition, and is this due to our inability of representing complex temporal relationships without any graphical representation of our musical material.
In a more specific matter, it is evident that the use of opposing and countering elements could be a powerful tool in the composition of music, but does the opposition of elements need to exist within a space to be articulated?

All these questions are of a philosophical nature and obviously could not be answered indubitably. All that could be said is that with the complex nature of electro-acoustic and computer music, using space as another dimension of control and parameter representation could prove to clarify specific issues in the musical context.

Another important aspect of space has to do with its close link to time and with its comparative relationship with temporal gestures in music. Using it as a compositional resource could be very successful, as seen in Raaijmakers' 5 Canons, and in the music of Horacio Vaggione. Although making a codependent relationship between architectural aspects of space and sonic qualities of music could sometimes throw off the musical intention and get the musical tension and release lost amongst the analogous area between space and time, resulting in an incorrect representation of time or space and in a lacking musical piece. In that case, all good qualities are lost and the overall constructional relationship is too complicated to prove successful.

In addition, the case of localized sound could prove to be successful in the context of composition, as long as kept within the boundaries of our perceptual thresholds, and thought of carefully as an integrated part of the overall compositional movement, in which the ordering of operations is of major importance. The composition of spatialized synthetic sounds for examples.

All together, I wish to add that, personally, I believe the addition of the spatial dimension (both abstract and physical) to the compositional process could enrich our musical resources and our musical interpretational processes, allowing to create more complex, divers and interesting relationships between the musical elements which are presented over time.

Seeing the musical surface as a Space-Time continuum, allows us to understand musical gestures as a unified element of a multi-dimensional structure, linking timbre, pitch, rhythm and structure into one.

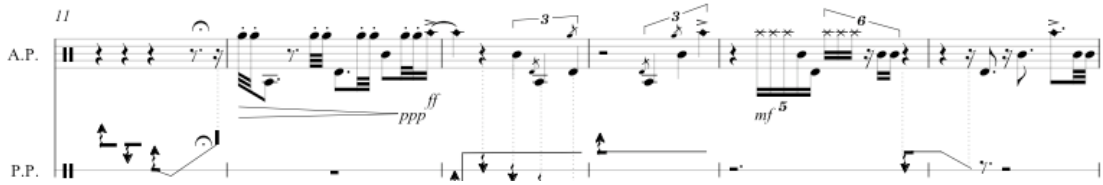
5. Appendix - *A Few Implementations*

In the following section I wish to give light to four compositional approaches implemented by myself in the last two years of my studies in the Institute of Sonology in Den Haag, these compositions are studies in the field of electro-acoustic composition and deal with issues such as the mixture of acoustic and electronic instruments, performed music vs. tape music, time articulation in music and spatial composition. The later two deal directly with the subject of this paper and are therefore presented here.

• Spring Variations- *a multiple timescale compositional approach*

With the notion of multiple time scale organization in mind, the piece 'Spring Variations' for percussion and electronics was composed in 2005, while trying to bind the temporal scales of rhythm and timbre.

The basic idea behind this piece was to merge these two time scales by introducing the causality between the scales. This was done by constantly monitoring the composed rhythms, subdividing them into phrases, and than averaging the rhythmic ratios within the individual phrases, resulting in a series of rhythmic harmonics for every phrase. The series of Rhythmic harmonics was translated into a series of harmonics for an additive synthesis patch, i.e. the average occurrence of a certain rhythmic value would result in an amplitude value for the corresponding sine component of the synthesis patch.
The synthesis patch was controlled by an electronic percussion instrument, which I have developed in 2004, consisting of 8 pressure faders. Each fader controlled a differently constructed sound object, the positioning and movement of the hand playing the instrument controlled the pitch and filtering of the electronic sound, while the rhythms played by the percussion instruments controlled the timbre of the sound. The notation for the percussion instruments was based on rhythmic themes that were developed in accordance to their timbral counterpart. For the notation for the electric drum I chose to use different rhythmic values, pitch areas, and filter glissandos. The score looked like this:



The acoustic percussion (upper staff) consisted of four woodblocks, attached with contact microphones, one piccolo snare and an aluminum sheet. The contact microphones sent

impulses into the analysis patch, which registered their durations, and divided them into groups when the duration has exceeded a certain threshold. The amount of occurrences for every quantized rhythmic value has controlled the spectral qualities of the electronic synthesized sound.

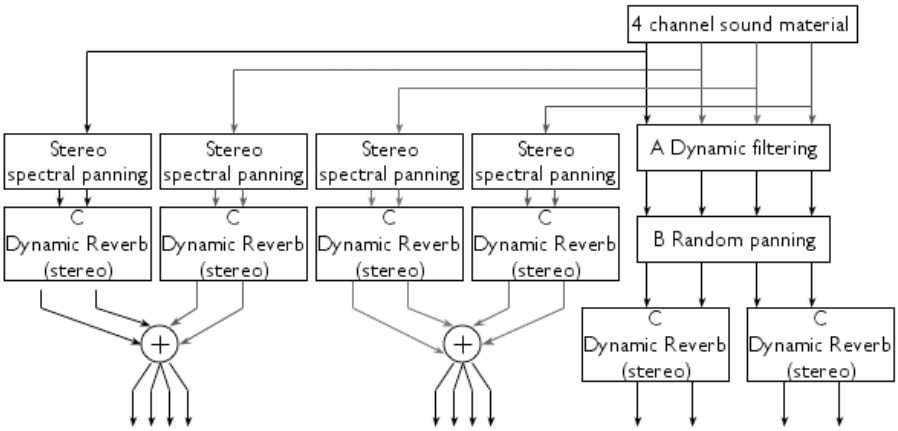
The system proved to work quite good, and responded well in real time, though the compositional quality of the piece turned to be poor, and though connected very well technically, the inter-linked time scales did not provide inspirational musical material.
In my next year of work I have moved on to try and articulate spatial sound, and spatial compositional gestures, to enrich my electronic compositional resources.

• State of Duality (tape piece 5.1) - *contrasting elements* (CD, track-1)

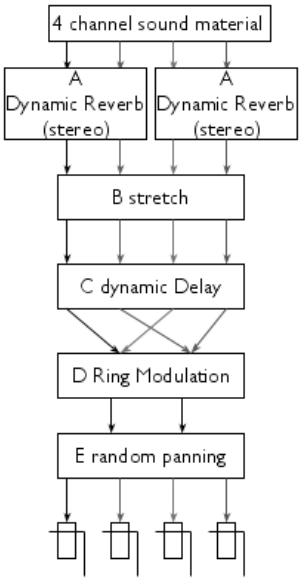
The timbral qualities of contrasting elements within a musical structure could define the spatial boundaries between the sound objects when articulating musical or timbre space. The idea behind this piece was to explore the relationship between two contrasting elements treated as oppositions in a certain space. While occupying the same composed space, the elements, through their relation to one and other, were cross synthesized to create a sonic fusion of the spatial tension between its oppositions, at different points that change through the piece.

The global form of the piece was based around a slow transition. The sound objects traverse and slowly change their positions in the parameter space (which represents the timbre space), through the movements of the objects, the musical format of the two would intersect in different morphological points and inspire movement in a new direction within the space.
This idea was based on Karel Goeyvaerts' ideas of composing intersecting sound bodies, which evolve in opposite directions.

The sound material for this piece was composed in the analog studio BEA 5 using noise generators processed in a series of sub-patches, which later comprise the first sound object, and pulse generators being processed in an opposite fashion, comprising the second sound object. The composed objects were then simultaneously played and at chosen morphological points composed as intersections, cross-synthesized in a suitable fashion for their sonic qualities. The intersections point out a 'zoomed in' point within the slow transition, which is subtly present in the global movement of the musical form. The timbral difference is articulated at those points.

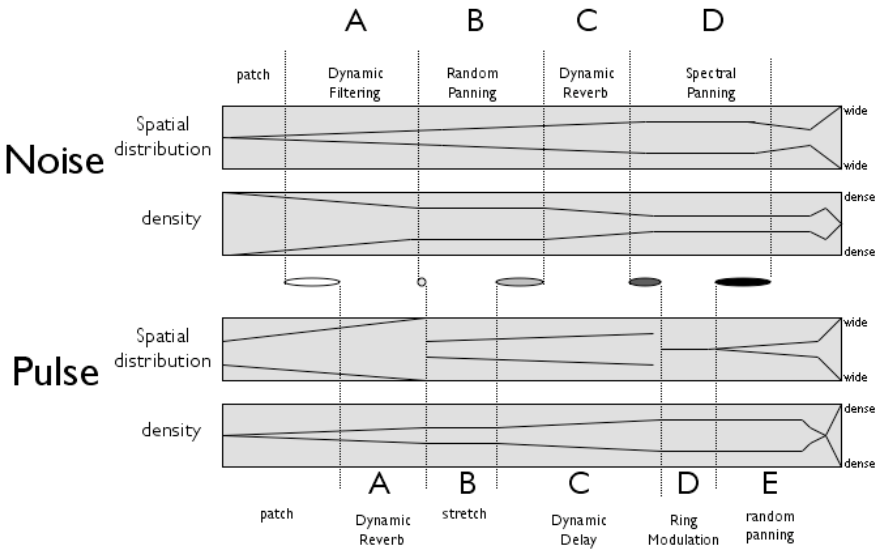


•First sound object was composed of a montage of the succeeding generations. Note that the material is being dynamically and spectrally 'thinned out' through the generations.



•Second sound object starts more spars and builds up density along the generation scheme. Which also represents the timeline of the piece

•In the next page, a display of the parameter shift over time is presented for each sound object. These were played simultaneously. The oval points mark the merged material, which was either ring modulated, filtered, cross-synthesized, spatialized, etc'…
These cross-points where then placed on the time line of the original material.



Organizing the final material along the timeline was the final part of the composition. Originally, the material was distributed along the timeline as it was generated, going through the succeeding generations, and displaying both sound objects simultaneously. The synthesized timbral intersections should be displayed in between the cross-points along the timeline. The problem of doing so was that the slow transition between the elements would be masked and the global form of the piece would not be clear. Therefore I have chosen to display the material in two sections. The first represents both sound objects juxtaposed as existing in two separate spaces and having no significant relationship to one and other. The second section consists of the cross-points, presented sequentially and featuring a sort of fossil image of the first section, where the global movement of the first section is represented through a more rapid change of rich timbral qualities, opposed to the slow transition of the first section. Furthermore, the second section was comprised of the correlate of both materials existing in the same composed space, and reflected the spatial relationship between the sound objects.

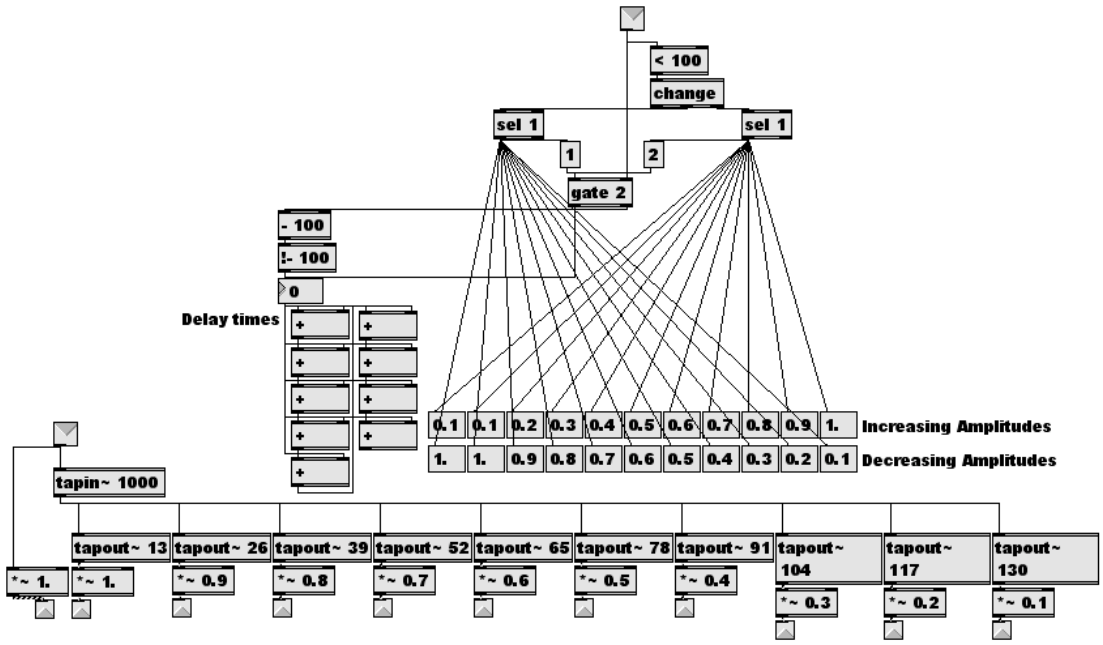
• Rotating Pulses (Examples: CD, track–2)

The piece 'Spinning plane' deals with the spatial qualities of synthesized sound. The spatial element, of which this piece is composed around, is the synthesized movement of pulses. The morphological characteristics of these dynamic pulses are inspired by the rotational element in Dick Raaijmakers' Canons.

Using a delay line, electric pulses are repeated to imitate a rotation in a chosen speed. The impulse is routed through the delay line, which consists of 10 outputs. the input is routed to all 10 outputs with a delay factor that increases with an equal amount with every succeeding output. For example, if the delay time would be 30 ms then the first output will not be

delayed, the second output would have a 30 ms delay, the third 60 ms, the fourth 90 ms, the fifth 120 ms, and so on. In addition to the growing delay factor, every succeeding output has less energy, and produces a softer output, this decrease is linear and the volume between outputs decreases by 10 percent with every next delayed pulse. These parameters are of course dynamically controlled and could be tuned to specify the desired speed of repetition. After exceeding the maximum delay time per output (100 ms), the linear decrease in volume becomes a linear increase, where the original pulse has 0.1 percent of the volume and the 10th delayed pulse has 100 percent volume. The speed of the repetition is also reversed and the higher you go after exceeding the maximum delay time, the less delay time you get. I have basically implemented an aliasing function for the rotational speed control, in order to imitate a circular movement.

For an input of 0 to 99 the delay time is 0 ms to 99 ms, and from input argument 101 to 200 the actual delay time is 100 ms to 0 ms. Together with the reversed amplitudes, the sound really gives an impression of the rotation crossing the middle point of 180 degrees and changing direction.



•*Rotation delay line, including amplitude factors and an array of equally delayed outputs.*

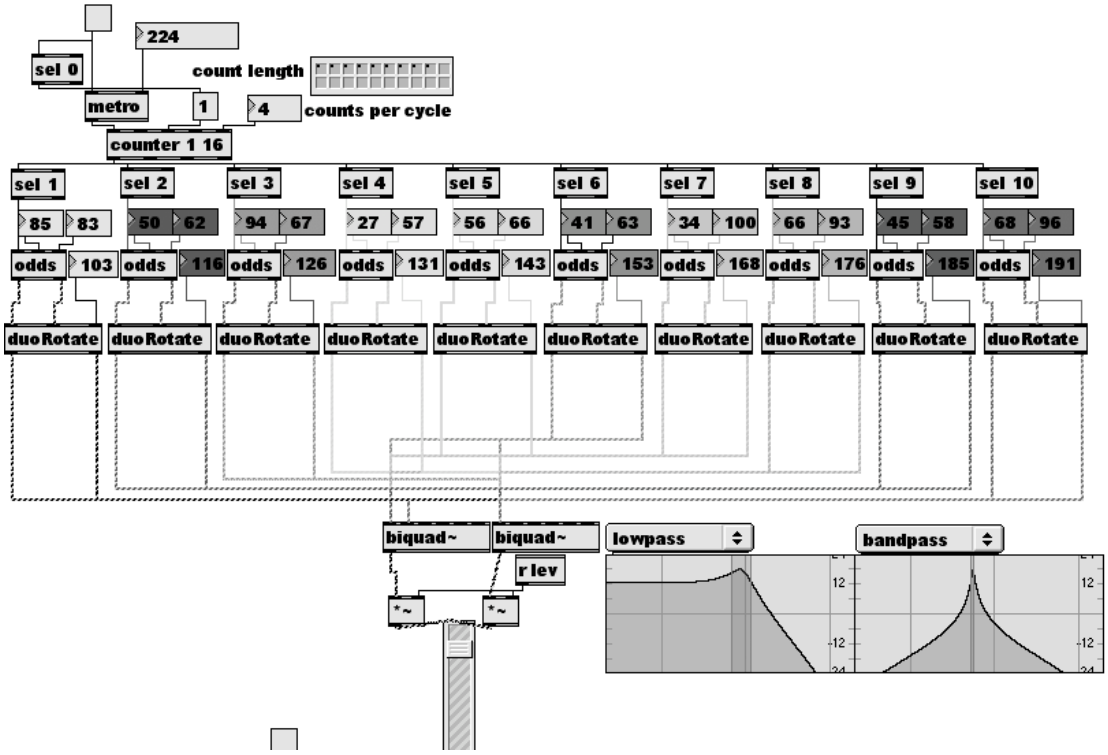
The way in which the pulses are triggered is through a statistical choice between two differently filtered pulses, which could be chosen to be played or not to be played as part of a sequence.

A simple step sequencer is constantly triggering the occurrences of notes, and each note has two choices. The first choice is whether a pulse would be triggered or not, the second is which pulse of the two would be chosen. Each note in the step sequencer has three

changeable parameters; the chance of occurrence, the tendency towards the one of the two pulses, and the rotational speed. A number between 0-100 represents the first two parameters. In the first case 0 means that the specific note would not be played and 100 means it would definitely be played, any number in between indicates the chance of it being played in percentage.

The second number controls the tendency towards the two filtered pulses, 0 meaning 'pulse A' would be chosen, and 100 meaning 'pulse B' would be chosen, the numbers in between represent the percentage towards 'pulse A' and the inversed percentage towards 'pulse B'.

The third parameter (rotation), control number ranges from 0 to 200, while the first 100 values represent the amount of ms delay for the decreasing delay line and the numbers between 100 and 200 represent a delay time of 100 to 0 ms, the same values as the first half, just backwards. As mentioned earlier, a number occurring in the higher range also results in amplitudes progressively increasing in the delay line instead of decreasing.



•Step sequencer; dynamically controlled parameters are: step duration, number of steps, filtering of both pulses, and for every individual note, the percentage of occurrence, the tendency towards favoring one of the pulses, and the rotation amount/direction.

With the use of simple statistical choices for the generation of notes, it is possible to produce of an overall flux that maintains similar morphological characteristics throughout the different repetitions, while each and every repetition is different. controlling the

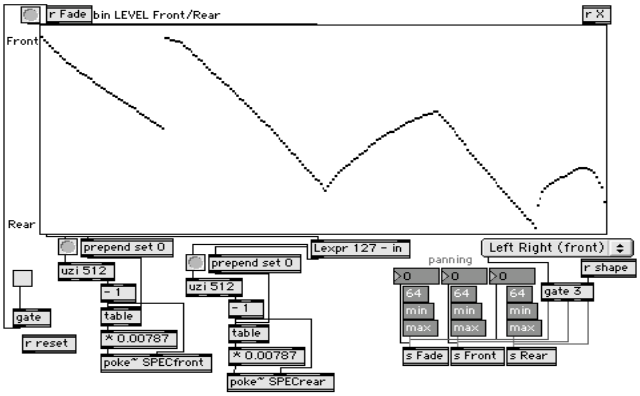
parameters dynamically allows the transition from one morphological state to another. In this piece I have chosen to focus on these transitions from one state to another to articulate the global movement of the musical form.
This movement is projected through a set of six speakers, and in contrast to the transitional fashion in which the musical elements are presented, the routing of the individual notes (specific steps in the repeating sequencer) is static.

Other interesting sonic qualities of the composed pulses, which I have tried to explore in the music, are in the overlapping of the segmented repetitions, the way in which the decreasing or increasing sounds overlap with the next note or few, and playing on the intermediate time scales between rhythm, pitch and timbre.

• Spectral Panning (example: CD, track-3)

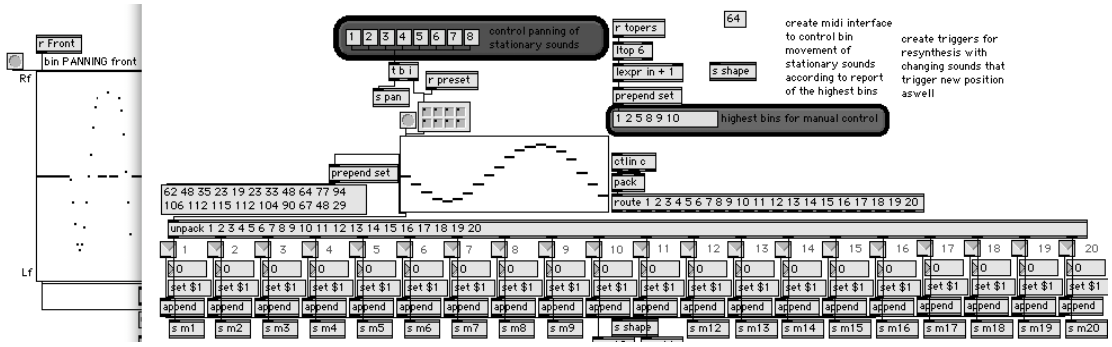
The final example I would like to discuss is the implementation of the physical distribution of sound throughout the performance space. This implementation is used in a piece, which I am currently composing for two bassoons and electronics.
The spatial distribution method, which I have chosen to realize for this piece is the Spectral Panning model *(Lippe & Torchia 2003)*.

The way in which the model is implemented is through the analysis of the input signal, and the re-synthesis of the sound through four different independent sound sources. The individual frequency components are distributed equally through the four outputs, to maintain the original amplitude and phase ratios.



•One of the three amplitude controls; the x-axis represents the frequency bins and the y-axis represents Front/Rear, Left/Right (front) or Left/Right (rear).
•In the right-bottom corner, the control for routing of the automated amplitude values to any of the three amplitude controls could be seen.

In order to control the movement of the sound, the system must recognize the most significant frequency bins. The highest energy bins, are the ones contributing to the recognition of the sound. Through the analysis of the incoming signal, the highest energy bins are found and then routed to automated spectral shapes, which control the individual sound sources.



•A preset shape being triggered (middle of picture) and translated to the highest energy bins, panned between the right and left channels of the front speakers (left side of picture)

In this specific piece I have chosen to process two bassoons, while distributing their spectral components through the performance space, I use granular synthesis for the processing of the temporal qualities of the sound.

Together with the movement of the bassoons along the pitch and dynamic scales and in relation to one and other, the spectral components of the re-synthesized bassoons move between sources, and the momentary gestures move along the time line. In this way a certain spatial polyphony is created, which inspires the movement of the individual elements.

6. CD Content

1. State of duality (2006) (stereo version)

2. Short examples of rotating pulses patch.

3. Etude for bassoon (2006) (spectral panning)
Experimenting with the bassoon's timbre and synthesized noise using the spectral panning patch,

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