Motion Graphic Notation:
A tool to improve live electronic music practice

Christian M. Fischer
Department of Composition, Estonian Academy of Music and Theater, Estonia
mail [at] c-m-fischer.de
http://research.c-m-fischer.de

In electro-acoustic music, only a few examples of notation like Stockhausen's 'Studie II' can be found. Regular staff notation is simply not feasible for synthetic or concrete sounds. Visual representations of sounds like spectrograms are significant analysis tools, yet they are not useful as a score. Most electro-acoustic composers would even argue that there is no need for notation in electro-acoustic music as it is primarily produced and performed using computers. However, in live electronic music, communication between a computer musician and performer using acoustic instruments like a piano or violin is vital for interaction and profound performance practice. Using oral agreements, a chronograph or score following techniques has its drawbacks. Additionally, the performance of musicians using acoustic instruments is easy to follow for the audience, while the actions of performers using a computer, mouse, keyboard or twisting knobs on a MIDI device and the generation of live electronic music itself, often remain a mystery. This paper discusses different graphic approaches and proposes computerised Motion Graphic Notation to communicate actions, musical structure and dramaturgy for all performers and the audience. This includes not only a sequence of musical events but also indications regarding pitch and dynamics for acoustic instruments, indications regarding source, quality and definition of a sound, for live electronics and the development of sound over time. Motion Graphic Notation is based on animated graphics that support logic implications regarding their sonic counterpart.

Giving sounds and music a visual manifestation for retention purposes using graphics goes back to ancient Egypt and other advanced civilisations around 2000 B.C. In the Middle Ages monks used neumes and in early renaissance antecedents of our modern staff notation can be found that also facilitated graphics like Baude Cordier's rondeau 'Belle, Bonne, Sage' in heart shape (Daniels / Naumann 2009). Modern notation, using bars and a five-line staff that is commonly used in western music today, derives from 200-250-year old classical music paradigms. Iannis Xenakis assumed in the 1950s that acoustic and visual structures can be directly alternatively connected or even translated (Daniels / Naumann 2009). At that time composers like Earle Brown and John Cage in the US and Karl-Heinz Stockhausen and Roman Haubenstock-Ramati in Europe began to experiment elaborately with alternative forms of notation using graphics (Thomas 1965). These approaches were conditioned by the need for finding alternative ways of expressing new musical ideas especially when using electronic sounds. In 2009 American musicologist and author Theresa Sauer presented her recognised book "Notations 21" (Sauer 2009). Within this still ongoing project she collected and published 166 distinct scores that reveal the potential of static graphic notation. However, motion scores are not included. Due to technological developments divergent hybrid forms of audio and image in arts and media have emerged in recent years. Therefore, we need to clearly specify distinct forms of graphic notation and other audio-visual representations before we are able to proceed. However, we have to keep in mind that none of the following approaches deals with the specific issues and needs of live electronic music and abstract sounds (Truax 2000). The use of notation and implications regarding live electronic music will be discussed later.

Graphic notation

Sometimes the terms 'graphic notation' and 'musical graphic' are synonymously used. However, if we take a closer look in music history, there is a particular difference regarding their compositional purpose. Graphic notation as it was used by John Cage was widely used and discussed in Europe and the US in the 1950s and 1960s. There was a demand for new ways of notating music as staff notation was no longer sufficient for contemporary compositions, performance practice or electronic sounds (Thomas 1965). Back then some composers even claimed a need for a new notation to be able to compose new music (Daniels / Naumann 2009). Since then composers have used graphic notation more or less intensively. Some composers simply enrich regular notation by using additional graphical elements, while others like Anestis Logothetis developed their own sophisticated graphical system to express their musical ideas (Logothetis 1999). Composers of graphic notations often design their own unique set of conditions. Usually it is up to the musician how to interpret them using the predefined set (Karkoschka 1966). This leaves the performer a determined amount of freedom. Thereby a graphic notation, compared with a musical graphic, always implies an extensive analysis by the performer. Many graphic notations are strongly rooted in regular staff notation. There are bars, black lines, dots or other familiar elements. This practice has a strong impact on motion notations as well. However, it seems only few composers dare to ask musicians for a profound graphic score examination (Bourotte 2012).

Musical graphic

Earle Brown's famous piece 'December 1952' is recognised as the first musical graphic. However, it was Roman Haubenstock-Ramati who coined the term in an exhibition of scores in Donaueschingen in 1959 (Daniels / Naumann 2009). As Brown described in detail in his writings, a musical graphic is meant as a motivation, a trigger to improvise music. He demanded high flexibility or variability of his works within the actual performance (Thomas 1965). Therefore, a musical graphic aims for spontaneity and direct interpretation and can therefore be categorised as associative. Its ability to store a musical idea, regarding pitches, rhythm, actions or sounds is rather limited. On the other hand, a graphic notation is symbolic or instructive. The terms 'symbolic', 'instructive' and 'associative' (Logothetis 1999) will be described in detail later. Both graphic notation and musical graphic refer to static images. There are approaches that deal with moving images meaning film, video, animation or live generated graphics, though.

Other terms

One term that pops up very often dealing with music, graphics and motion is visual music. However, it has nothing to do with notation. Visual music derives from the attempt to translate music into colours (colour organ) in the 18th century (Lund, C. / Lund, H. 2009). Thereby a reasonable connection between colour and sound should be established. Two hundred years later, along with Wassily Kandinsky's theories regarding sound and colour and along with the invention of colour film, artists experimented with abstract films and animation techniques for music. Oskar Fischinger invented the 'lumigraph' in 1955. With this device one could create abstract live imagery to accompany music (Lund, C. / Lund, H. 2009). Today this approach manifests in VJ culture and other contemporary artistic composites of sound and image. These examples, however, refer to the translation of music into visuals. Visuals accompany music or support the communication process (Lund, C. / Lund, H. 2009). The visual result of this translation, regardless of how it is achieved, does not work the other way. Meaning the visual output is neither meant for nor capable of storing musical structure or specific musical events. It could work as a form of musical graphic that inspires improvisation though. Another rather radical approach is Dieter Schnebel's Mo-No: Musik zum Lesen (Mo-No: music to be read) from 1969 (Daniels / Naumann 2009). The graphics in this book are to be read/perceived while the music is just to be imagined according to individual sound memories. Thereby Mo-No could be regarded as a book full of musical graphics.

Apart from occasional individual works, serious lasting approaches facilitating moving images for music notation or even establishing a framework can hardly be found. According to Julia H. Schröder one explanation for this lack is the inverse development of composers and visual artists since the 1970s. She claims:

> Their interest in the individual handwriting manifesting itself in musical graphics is greater than that of composers, who were concerned with the establishment of a new, normative graphic canon. [Schröder 2009: 151] (Daniels / Naumann 2009)

Additionally there are all the technical and theoretical obstacles for composers when dealing with (unknown) visual media in a profound way. The disposition amongst composers to learn a second way of creative expression cannot be taken for granted. On the other hand we should not expect visual artists to create graphic notations that fulfill composers' expectations and needs.

Notation frameworks using graphics

Nevertheless, there are diverse projects, software, tools and methods to connect graphics, music and notation. Each of them has its own objectives and approaches. 'IanniX' is a graphical open source sequencer based on Iannis Xenakis' works, especially his UPIC system. It is a tool for graphical real-time audio-visual composition that synchronises events via OSC (Bourotte 2012). 'IanniX' is exemplary for much software. These tools could be used for notation. However, they are not made exclusively for notation purposes. Additionally they do not follow any kind of graphic language or framework. Furthermore this software is often highly specialised and lacks intuitive usability. Therefore, let's take a closer look at three examples that specifically deal with motion graphics to annotate music and that are applicable without prior knowledge. The selection reveals how complex the practice of motion graphic notation and how different and individual approaches dealing with it actually are.

INScore

INScore is open-source software, a platform-independent environment that originates from work conducted by the Grame Computer Music Research Lab. It derives from the idea of analysing a score a posteriori using computer software (McKenna n.d.). INScore provides an Interactive Augmented Music Score. An Augmented Music Score is defined by the INScore creators as "a graphic space providing representation, composition and manipulation of heterogeneous music objects (music scores as well as images, text, signals...), both in the graphic and time domains." (McKenna n.d.) This means properties for any given object within the score are assigned. Thereby they can be synchronised in graphic space according to their

relationship over time (tempo). Example: graphics indicating hints for better performance practice can be shown within the original score and are synchronised utilising an audio file analysis of the original score.

Additionally INScore offers the possibility to interact with the score in real-time. Graphic objects can be altered or arranged. It is even possible for the whole score to be generated in real-time. Graphics are mainly used to extend regular staff notation. Synchronisation of events, graphics and regular score is a core feature of INScore. Notation of music from the scratch is possible, but not primarily intended. Special features of live electronic music or its performance are not taken into account. The graphics that can be used within the system are up to the user and do not refer to a framework. Meaning colour, shape or opacity is used intuitively with no connection to existing rules. This constrains the use of INScore for music notation significantly as graphics are used to convey a very special and determined meaning for the specific user and the user's performance but not for someone else.

Severin Behnen

In his PhD thesis at UCLA in 2008, Severin Behnen discusses the construction of motion graphic scores (Behnen 2008). It is one of the very rare examples of academic work on motion graphic notation practice. He classifies three different scores: animated, interactive and plastic. Animated scores include all kinds of moving images like motion graphics, animations and video. Interactive scores are like animated ones, with an additional possibility of conscious interaction/alteration of the score by performer or conductor. A plastic score is an animated score with the possibility of rather unconscious interaction/alteration (Behnen 2008). In other words a smart score that changes according to users' idiosyncrasies and composers' intentions. One could claim that John Cage's score for 'Cartridge Music' works this way (Karkoschka 1966). Plastic scores are tools stating actions, meaning what to do, e.g. 'clap your hands twice'. The sonic result is secondary. For Behnen all motion graphic scores serve as a dynamic guide, "actively involved in the creation of the aural environment". He often uses graphics with an inherent meaning or symbols like a stylised ouroboros. The serpent eating its own tail asks the performer to repeat a certain musical structure.

Behnen distinguishes strictly between correlative and procedural symbols in his own works as well as in graphic notation in general (Behnen 2008). Basically correlative symbols are related to regular staff notation, while procedural symbols involve graphics. Correlative symbols are graphics that establish a direct connection between what is seen and what is heard. Behnen states that melody in a regular staff notation using dots on horizontal and vertical axes that represent pitch over time is correlative. While on the other hand flags and beams would be procedural symbols to indicate rhythm as they need to be placed against the tempo of the piece in a second step. Procedural symbols may also indicate a whole set of actions (Behnen 2008).

Especially when dealing with the abstract graphic scores of Logothetis, Brown, Cage and others, Behnen's two-part system becomes difficult to apply. Earle Brown's piece 'December 1952' consists only of solitary lines of diverse thicknesses and lengths arranged strictly vertically and horizontally (Thomas 1965). There are no correlative or procedural symbols. Whether one line is to be regarded as a single note (correlative) or rather as a set of actions (procedural) is not defined. It is intended that the same line will sound quite differently with each interpretation as Brown composed the graphic to be a source of inspiration for improvisation.

The use of graphics in Behnen's own works does not follow a compelling pattern. Apart from some symbols, abstract graphics, forms and shapes are used that have no inherent meaning. Neither do they follow commonly used patterns. The meaning is defined beforehand by the composer. Thereby images and icons (e.g. a lion) that are not clearly defined are used to evolve certain attributes. Regular staff notation is also widely used. Some of Behnen's pieces even fall back on regular paper notation. Furthermore it is not entirely described what compositional purpose the application of graphics follows. The way he describes the use of symbols supports the conclusion that he experimented with certain graphics and put them into a loose framework according to his own design decisions. Although using partly live electronics, a distinction of electronic sounds and acoustic instruments within the score cannot be found.

DabbledooMusic

Irish music teacher Shane McKenna explores alternative ways of teaching music especially regarding the notation of music (Fober / Orlarey / Letz 2012). He utilises videos and animations to introduce kids to creative notation, music-making and composing. Starting in 2008 DabbledooMusic is a project with visual artist Kilian Redmond. An online blog featuring animated graphic notations and an exercise book work as resources to encourage creative music making and education for the primary school level (Fober / Orlarey / Letz 2012).

Within the Dabbledoo blog, there are various video scores. They are organised as a house starting from the entrance, hallway and several playrooms up to the attic that indicate rising skill levels. Scores can be used by up to four musicians, usually indicated by the colours red, green, yellow and blue. By clearly depicting rhythm, tempo and

actions over time one main focus is the interaction of performers and the application of musical structure over time. Another is an educational approach to the notation of sounds and music in general (Fober / Orlarey / Letz 2012). A constantly recurring element is a clock that plays a 60-second cycle of events *(figure 01)*.

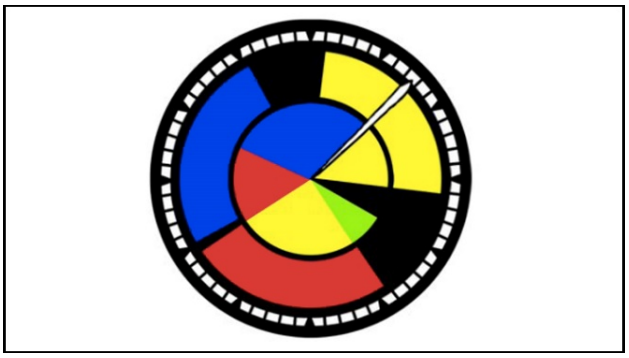

Figure 01. Dabbledoo clock featuring coloured events in a 60 second circle (Fober / Orlarey / Letz 2012).

It clearly structures musical events or simply when to start and when to stop playing for each instrument (separate colour) over time. Melody or even phrasing are not specifically displayed and thereby up the creativity and skills of the performer. Within the categorisation (see detailed explanation in 3.1.) of composer Anestis Logothetis, Dabbledoo scores are temporally determined action symbols.

To work with Dabbledoo scores requires only a brief introduction. Parameters of visuals or graphics lead to certain actions. Some indications are rather unclear and need to be creatively translated by the performer, while others are precise and require appropriate and exactly timed actions. To attend to this analysis is of course a planned part of the teaching process. Although the videos are scores, their purpose is not to store musical ideas to be repeated in the same manner over and over again. This means in practice that the same score might sound different every time it is played, as the actions of the performers and even the choice of instruments vary drastically. However, the musical structure meaning the sequence of events over time is set and therefore easily perceivable. Furthermore, repetition supports the teaching process, as students should find and improve their own way of creatively handling the score. They can try repeatedly and with various instruments (McKenna n.d.). As the choice of musical instrument is usually not defined, a Dabbledoo score can be applied for live electronic music as well. Within the Dabbledoo system the use of colour, the indication of actions and the graphics themselves are constructed and appear in a logical sequence. Additionally the graphics use already known patterns and inherent meaning, e.g. a clock is known for displaying time. This knowledge is used and makes it easy for kids to determine how the score in figure 01 works.

Anestis Logothetis

One expressive and profound graphic notation system was developed by Austrian-Greek composer Anestis Logothetis (1921-1994). From the late 1950s, he designed and applied graphic notation intensely as he considered regular staff notation to be inefficient for his music. In his influential writing 'Zeichen als Aggregatzustand der Musik' from 1974, he differentiates three types of graphics in music notation: symbolic, associative and instructive (Logothetis 1999). Symbolic graphics involve pitch symbols, similar to single notes in staff notation, as well as pictogram-like graphics. These graphics have a specified inherent meaning, e.g. pitch. Associative symbols on the other hand need interpretation and work as a trigger for improvisation. Usually they are more abstract. Performers associate meaning with the graphic and transform this meaning into music. Thereby the associative intensity varies. Some graphics are easier to understand than others. For instance a sine-wave-like form clearly indicates vibrato while the meaning of a chaotic array of lines and dots requires some involvement. The third type of graphics is action or instructive signals. These graphics or often single words or texts are precise instructions that trigger a specific action and usually describe exactly what to do, e.g. 'knock on the piano twice' or 'diminuendo'.

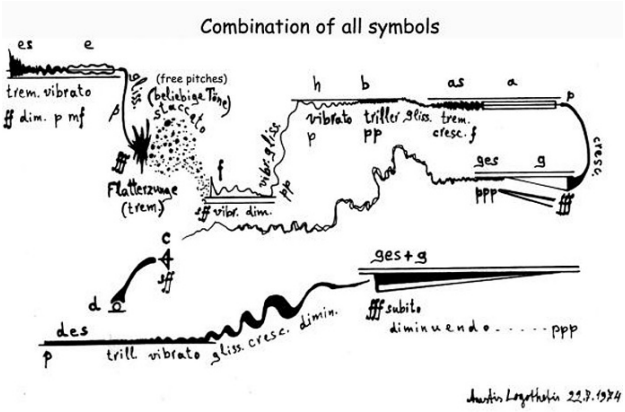

Figure 02. A graphic notation by A. Logothetis from 1974 (Logothetis 1999)

Logothetis often uses a combination of these symbols. They appear in a circular sequence, a wavy line or a symmetrical pattern all over the paper and thereby build a graphic notation with a certain aesthetic value. Depending on the tempo of the performer and his ability and willingness to profoundly read and work with the notation, the performance quality of the piece might vary drastically. Time especially is very often not determined. Friedrich Cerha very vividly describes the evolution of Logothetis' pieces while rehearsing and performing them. He states that graphic notations are much more in need of an elaborate examination than a regular score (Logothetis 1999). Performers are not used to graphic notations and the indicated music of the score has to be decrypted first.

Pianist David Tudor analysed John Cage's scores intensively and 'translated' them into a more practicable form for himself (Thomas 1965). This practice, however, should not be necessary when using Motion Graphic Notation.

Implications for electro-acoustic music

In live electronic music technical devices, regardless of being analogue or digital, are facilitated to create fundamentally new connections and approaches to the organisation of our sonic world (Truax 2000). As mentioned before, there are a lot of ways to merge the sonic and visual domains. It ranges from music video to spectrograms (Roads 1996). However, electro-acoustic music does not seem to have a need for a visual representation, in the sense of music notation. This kind of music already has its manifestation on the hard drive. It is meant to be listened to, not watched. Why do we need a music notation that is able to represent abstract and concrete sounds?

Electronic music in general (I am excluding the electronic music played in clubs) faces some issues when performed live (Collins 2007). Live spatialisation of electro-acoustic music on a multi-channel loudspeaker system using a mixer is not necessarily regarded as a performance. Additionally electro-acoustic music itself is often recorded music and therefore replayed (Collins 2007). Live electronic music usually has the 'human touch' due to the use of acoustic instruments or haptic interfaces (Dourish 2001). There are actually performers playing an instrument. However, compared to a 'classical' concert performance, the audience experiences a lack of certain attributes. Computer musicians sometimes seem to hide behind their technical instruments. Furthermore expressiveness is tough to convey through a mouse, touchpad or computer keyboard. Even the devoutly turning of nobs on a MIDI device mediates neither the actual compositional effort nor the sonic result. Performance and music lack coherence. This results in a disconnection between audience and performers and simply lowers enjoyment (Collins 2007).

The lack of expressiveness and coherence goes along with another problem. Experience tells us what sonic result to expect, when a drummer is about to take a big swing to hit the snare drum. Physical action and sonic result can be easily related (Dourish 2001). With electronic music it is different. Its genesis is hidden in technical devices. Therefore, it is important to make the performance and generation of sounds more transparent in live computer music. And there are very profound approaches like the introduction of physical interaction and new instruments in the works of Michel Waisvisz at STEIM (Roads 1996). Still the connection of motion and sound is sometimes difficult to grasp especially when manipulation or processing of sounds take place within the computer and parameters of sound like pitch, time, filtering or effects are connected to physical movement in D space. Another example is live coding performances that emphasise the process of combining algorithmic composition with improvisation. The audience can follow on screen what a computer musician is typing and can hear the result immediately. However the longer the process and the more complicated the coding gets, it might again be impossible for viewers to follow what is actually being done on stage (Collins 2007).

A third major issue in live electronic music is the interaction of performers. The performance of acoustic instrument and computer musician depends on agreements invisible for the listener. A stopwatch, score following techniques or other forms of hidden communication have their inherent drawbacks. Many musicians refuse to use a stopwatch as it limits the possibilities of decoration and interpretation known from working with regular scores. Score following techniques have become very sophisticated and precise in recent years (Collins 2007). However, the action is hidden from the audience again. It is usually not clearly perceivable that the computer is triggered when an acoustic instrument plays a specific pitch.

Compared to abstract arts, abstract music is still leading a rather miserable existence. Francis Dhomont evokes classicism for electro-acoustic music to improve the issue of pure attendance in concerts (Daniels / Naumann 2009). Simplified, he claims the audience cannot keep pace with innovation. The development of technical equipment and computational power has a great influence on electro-acoustic music composition and performance, where "novelty sometimes seems to be the only criterion of worthiness" (Daniels / Naumann 2009). This is surely one aspect. However, the sheer opacity of electro-acoustic music, especially regarding its genesis and compositional process, secondly, the question about what is actually performed live and finally the interaction of performers are further issues that need to be considered.

Motion Graphic Notation

Graphic notation had its peak about 50 years ago. Ever since graphics have been used within staff notation or as standalone scores. However, graphic notation did not become a common practice. After reviewing and comparing static graphic and motion graphic approaches and illustrating the problems of live electronic performance practice, I propose a concept called Motion Graphic Notation (MGN). The main objective is the enhancement of live electronic music performance

practice by creating traceability and transparency of actions for performers and audience. Thereby MGN uses actual techniques to ensure the full utilisation of computational possibilities and to support the following five conditions:

1. universal validity: MGN and the resulting score need to work for every performer, acoustic instrument as well as computer musician. Only then is it able to enhance contemporary performance practice and to support communication and interaction of performers of live electronic music.
2. time-based media: MGN focuses on time-based media like film, video, animation or motion graphics to ensure the synchronisation and the development of concrete and determined musical structure over time.
3. comprehensibility: MGN is based on a simple paradigm that can be applied intuitively. It tries to utilise already learned and commonly known features, like the Cartesian coordinate system with pitch indication on y-axes and time indication on x-axes.
4. usability: MGN provides an optimised interface regarding performance practice and the needs of musicians.
5. sustainability and definiteness: MGN seeks a definite, recognisable and reproducible way of communicating musical form and structure to be able to store musical ideas.

To apply the above-stated conditions, expertise in graphic design, media design and interface design is needed. However, they are not equally important. Graphic design is first. The prudent use of colour, shape and motion is vital for understanding graphic scores. Usability and aesthetic value of moving images are secondary. Thereby it is crucial to understand that Motion Graphic Notation tries by no means to take over from regular staff notation. It is a tool that extends composition and notation practice, especially for live electronic music. Motion graphic forms of notation offer new possibilities and have the following advantages that derive out of the used medium and the previously mentioned five conditions. Moving graphics allow displaying very slow and subtle movements over a long time span or complex morphing of interwoven structures. Secondly using time-based media naturally allows exact timing. Structuring of events and the duration can be fixed. Third, Motion Graphic Notation is computerised notation. Therefore, it utilises computational power and possibilities of interaction and interconnection. A fourth major advantage is the use of graphics that can convey different meaning than staff notation symbols.

The basic principle of MGN is that the profound analysis of the motion graphic score will lead to a comparable acoustic result regardless of the individual interpretation of the specific graphic. The overall structure of musical events over time is clearly defined. In MGN it is not important whether a violinist plucks a string or if he hits it with a stick as long as the small short graphic in the score is represented acoustically and the performers decision is easily comprehensible for the audience. On the other hand there are countless possibilities to display one specific sound visually. This allows the composer to design the score in the most individual way. And the overall appearance of the score will surely have an impact on the interpretation. Nevertheless, MGN is not a way to store exact pitches. Erhard Karkoschka gets to the heart when stating: it is not about notes, it is about sounds (Karkoschka 1966).

Sketchbook – a case study

'Sketchbook' is the first implementation of MGN. A 36-minute score for harpsichord and live electronics divided into 4 sketches ('Vari', 'Reflexion', 'Thr8e', 'Goldener Schnitt') and 3 short interludes ('symbolic', 'associative', 'instructive'). Every sketch focuses on the display of different sonic features. The harpsichord was chosen due to its sonic characteristics' especially short sustain and rather small dynamic range and because of its seldom use in live electronic music. Furthermore, the performer of the analysed concert was a specialist in early music. She had no experience in contemporary music practice. She was chosen to be able to analyse the intuitiveness and usability of the score. Score and interface were programmed in Adobe Flash (see figure 03).

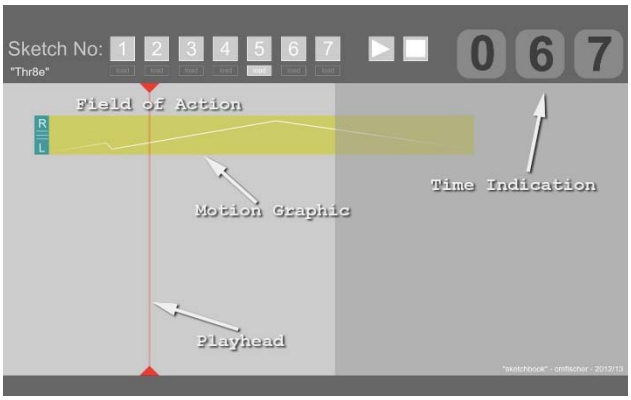

Figure 03. Sketchbook interface

The interface consists of a small dark grey header display indicating the sketch or interlude number and the time played. Below is the field of action. It is divided into two parts. A grey area on the right with 50% opacity shows the graphics to come next, while the light grey area on the left shows the actual graphic. A thin red line that can be considered as a static playhead indicates when a graphic needs to be played. In practice, graphics 'fly' from the right to left over the field of action and are played whenever they touch the red playhead. Thereby the performer is able to 'look ahead', meaning observing which graphics come next. Finally there is a small, dark grey footer on the bottom on the display to margin the field of action.

Empirical analysis

Rehearsal recordings, interviews with the performer and the premier concert of 'Sketchbook' are the bases of this analysis. The following descriptions cannot be pinned exclusively to one sketch or interlude. They appear in mixed forms all over the work. Simplified examples are given to illustrate the specific topic. The main focus is on characteristic features of MGN.

Pitch and time. In all sketches and interludes the display of relative pitch on the y-axes and time on the x-axes was easily adopted by the performer, as it is similar to regular staff notation. Relative pitch is indicated by the position of a graphic on the y- axes. The height of the field of action is related to the ambitus of the harpsichord and in some sketches for the live electronics as well. Relative pitch correlates with the position of other graphics. This means whether three dots that pass the red line at the same time are to be played as a cluster or a dissonant chord may be not accurately indicated by their position on the y-axes. There are however various other possibilities like colour, shape or written indications to set parameters like this that are discussed later. However, it is clearly perceivable that one graphic is higher than another on the screen and therefore needs to be played at a higher pitch. While rehearsing these relations became quite clear and even the smallest distances of graphics were observed and played accordingly.

Within MGN we encounter time in three different ways. First there is the duration of the score. Once the start button is hit, the clip, containing animated graphics, plays for a predefined time span. Thus the length of a piece can be determined exactly. Second, there is the time a graphic needs to pass the red playhead. This refers to the length or sustain of a sound or to the length of an entire sequence, for instance when a graphic triggers improvisation. The different times the graphics need to pass the playhead and the time in between two graphics describe what is known as tempo in regular staff notation. Third there is the time a graphic needs to fly over the field of action from right to left until reaching the playhead. In some sketches, like 'Vari' this speed of graphics remained constant for all the appearing graphics to support the performer. In other sketches graphics move with different speeds and even decelerate when touching the red line. Thereby time and motion convey information about the overall sonic expression of the sketch. Ten small red dots that appear with various speed and fly in a chaotic way until they reach the playhead are of course perceived differently than ten blue squares moving accurately with the same speed. The sonic result will be significantly different, even when the red dots and the blue squares will have exactly the same positions and motion after reaching the playhead. 'Red chaos' looks inherently different than 'blue conformity'. The general visual appearance of a sequence of events before they need to be played has therefore an important impact on the play of the performer.

Rhythm and patterns. The playhead (red line) allowed clear structuring of events over time. Therefore, movement patterns or rhythmical passages could be accurately displayed and played. A usual meter signature was not missed by the performer. When numerous events occurred in a fast sequence, simultaneous playing became quite difficult. To monitor the computer screen as a whole or merely focusing on the vertical area of the playhead seemed to be a task too difficult for the untrained eye. At this point graphic design becomes crucial. Apart from the speed of motion, intelligent use of colour and shape are vital to be able to note all information desired. Another possibility is the use of interlacing that is elaborately described in the section *Interlacing.*

Although offering the possibility to exactly display events and processes, time-wise precision of graphics reaching playhead was sometimes regarded as metronomic and therefore uncomfortable for the performer. While rehearsing the style of playing suffered and in the sketch 'Reflexion' the music became even really static. To avoid this limitation the written indication 'tempo rubato' was added that allowed the performer a certain rhythmical freedom. Repetitions, variations and recurring structures can be made clearly visible. Regarding MGN as an interface, our visual memory is trained much better than our acoustic memory (Dourish 2001). Therefore, the audience especially can follow a musical structure even over a long time-span much more easily if certain structures or patterns go along with a specific colour or style indication. This creates transparency of actions and supports communication between composer and audience.

Dynamics. In 'Sketchbook' dynamics are indicated mainly using colour and opacity. Only seldom size and sound intensity are linked. Size works well as the harpsichord has a small dynamic range. However, size will not work that well anymore with large dynamic range acoustic instruments, as the space of the computer screen is limited. Compared with the display of pitch and time colour and size were not always accurately transposed into sound. If one single graphic features visually various sonic attributes, the performer tends to focus on just one or two. Gradients however worked quite well for dynamic indication. They fade visually out or in. This attribute can be directly transferred into sound. The initial idea of an extra display using a graphical indication (similar to a level meter on a consumer audio device) was not pursued, as it was not possible for the performer to focus on the playhead and an additional visual display. The attributes colour and opacity in all their variations are sufficient for

conveying dynamics. Additionally in the interlude ‘symbolic’ the common indication ‘pianissimo’ was used.

Interlacing. Interlacing in MGN describes the possibility of framing. A group of graphics, graphics and instructions or a pattern can be set within another graphic, usually a rectangle or a circle. This has the following advantages. The performer and the audience comprehend the interlaced graphic as one single piece of information, although it may contain various indications of what and how to play. Thereby more complex structures can be noted and the problem of overstraining the performers visual capabilities can be avoided. Furthermore interlacing allows to degenerate the framed graphics from the overall set of parameters to a certain level. For instance in the interlude 'symbolic', relations of pitch within a framed graphic are transposed to almost the full dynamic range of the instrument, although the graphic is much smaller than the height of the field of action. Framed graphic work as an independent graphic within the system where deviant parameters can be applied. Another option used is applied the sketch 'Reflexion', where a simple grid frames single notes to a more strict indication of pitch. In the sketch 'Thr8e' differently coloured rectangles frame visual instructions about the exact use of hanks of horsehair to draw agains the strings of the harpsichord, meaning when and which direction to pull. The relative height of rectangles indicates relative pitch. Finally interlaced graphics mark precisely the beginning and the end of a passage. Thereby they simplify the understanding of the overall structure of the piece.

Reciprocal Action. The score of ‘Sketchbook’ was composed and designed for harpsichord and live electronics. On the field of action graphics for both performers can be found. Some graphics clearly indicate which instrument they are made for. However, some sketches intentionally included graphic elements that were impossible to be played by the harpsichord. The intention is to create graphics that obviously cannot be played by the acoustic instrument so that the live electronics would have to accommodate. A very simple example is some graphics in the sketch ‘Goldener Schnitt’. Small red dots indicate single notes. However, they are accompanied by a kind of tail consisting of black jittery semicircular decreasing lines (figure 04). A violinist could interpret this tail vaguely as a vibrato or some other kind of alteration of the tone. This is of course inappropriate for harpsichord. Furthermore a vibrato could be indicated much better, for instance using a narrow continuous horizontal sine wave (Augoyard / Torgue 2006). The graphic in ‘Goldener Schnitt’ is more specific, though. The jittery lines are black while the dot is red. Colour and shape indicate two separate elements that belong together as they are closely aligned in space. The lines themselves can be clearly distinguished, they are crooked and decrease in size over time. A reasonable solution is a delay combined with a distortion. Of course other solutions can be found as well. Within MGN decisions are based on reasoning. The interpretation is by no means accidental as long as a comprehensible connection between graphics and acoustics can be made. In the premiere, different colours (red and black) referred to the two instruments. The single lines referred to the delay while their irregular character was reflected using a distortion effect. The harpsichord was recorded and the effects were deployed in real-time using ‘Integra Live’ software. Thereby the delay was adapted for graphics in the most accurate way possible regarding timing. The sonic result was a mix of the live harpsichord and a distorted delay.

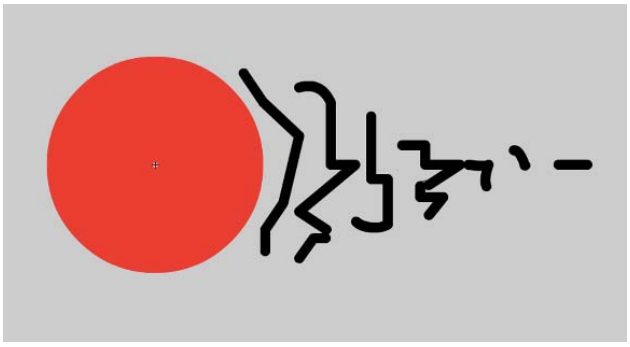

Figure 04. Magnification of one single graphic.

Discussion

The present findings indicate that Motion Graphic Notation is capable of communicating music to performers and audience alike. It improves live electronic music performance practice revealing performers’ actions and the overall structure of a piece. However, MGN is not a closed system, ready to apply. The upcoming task is to design a profound framework grounding on further empirical analysis of concerts, rehearsals and experiments with musicians and composers. This includes the continuous enhancement of graphics in colour, shape, motion and style. Additionally features of acoustic instruments, their sonic qualities and contemporary playing techniques need to be taken more detailed into account. The same holds for abstract and concrete electronic sounds. Furthermore the revision of interaction design and interface design to enhance usability and to lower the boundaries to apply MGN in practice will be considered. This goes along with the improvement of comprehensibility of scores for the audience. Finally the development of algorithms for the synchronisation of multiple scores (e.g. streaming of several synchronised videos using LAN) is a further field of research.

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[Abstract in Korean | 국문 요약]

모션 그래픽 기보: 라이브 전자 음악 연주 향상을 위한 도구

크리스티안 엠 피셔

전자 음악에서 슈토크하우젠의 《습작II》와 같이 기보된 작품의 예는 흔하지 않다. 일반적인 오선 기보법은 합성된 소리나 구체 음악을 표기하기에 전혀 적합하지 않다. 스펙트럼 사진spectrograms처럼 소리를 시각적으로 보여 주는 것은 분석 도구로서는 중요한 역할을 하지만 악보로는 유용하지 못하다. 대부분의 전자음향 작곡가들은 컴퓨터를 통해 미리 생산되고 연주되는 전자음향 음악에 악보가 필요하지 않다고까지 주장하려 한다. 그러나 라이브 전자 음악에서 피아노나 바이올린같이 전자 장치를 활용하지 않는 악기를 사용하는 연주자와 컴퓨터 음악가 사이의 소통은 상호작용과 심원한 연주 실제에 있어 필수적이다. 말로써 합의하거나 시간의 흐름에 따라 가시화하거나 악곡에서 연주되는 부분을 악보에서 쫓도록 하는 기술은 자체적으로 결점을 지니고 있다. 게다가 전자 장치를 활용하지 않는 악기를 사용하는 연주자의 연주는 청중과 함께 호흡하기 쉬운 반면 컴퓨터나 마우스, 키보드를 사용하거나 미디 장치의 손잡이를 돌리는 연주자의 행위와 라이브 전자음악 자체의 자동 생성은 종종 청중들에게 불가사의하게 남기 일쑤이다.

이 글은 이와는 다른 견지에서 그래픽을 다루는 방법에 대해 논의하며, 모든 연주자와 청중에게 연주 행위와 음악적 구성, 연출에 대해 소통할 수 있는 컴퓨터를 도입한 모션 기보 방법을 제안한다. 이 기보법은 음악적 사건을 연속적으로 보여줄 뿐 아니라, 전자 장치가 장착되지 않은 악기의 음높이와 셈여림에 관한 지시와 라이브 일렉트로닉스를 위한 음원, 음질, 소리의 정의에 대한 지시, 그리고 시간의 흐름에 따른 소리의 발전까지도 포함한다. 모션 그래픽 기보법은 소리의 대응부로서 논리적으로 그 의미를 나타내는 동영상 그래픽에 기반한다.