A FEW THOUGHTS ON POLYMORPHISM IN DIGITAL SCORES

Georg Hajdu, Konstanina Orlandatou, James Tsz Him Cheung
Hochschule für Musik und Theater
Hamburg, Germany
{georg.hajdu,konstantina.orlandatou,tsz.him.cheung}@hfmt-hamburg.de

ABSTRACT

This paper is motivated by the phenomenon of polymorphism in graphic notation, a notion introduced to the discourse of graphical composition by Greek composer Anestis Logothetis. It refers to the reading of a graphic score in which alternative paths can be taken by a performer. The reading can either be synthetic /global or analytical/local with intermediary levels. We are contrasting Logothetis' concept of polymorphism with analogous phenomena in molecular biology and look at the paradigm shift leveraged by digital technologies where machine and hybrid readings ought to be taken into consideration. Examples of current practices are given for live, extended reality and hybrid scenarios. The paper finishes with an outlook on how AI might eventually become another game changer.

1. INTRODUCTION

We would like start by quoting Logothetis: "What fundamentally differentiates graphic notation from traditional notation is the afore mentioned polymorphism, which clearly enables all performers to retain their subjective reaction times. The composer takes into consideration the divergences of the different performers in composing and expects a certain degree of surprise through the new formalization of musical form in every performance" [1].

The application of the term polymorphism to graphic notation is attributed to Anestis Logothetis (1921-1988) [2]. Inspired by works of Cage and Brown, he established a graphic notation system which was to "was to broaden the musical script/code and not to provide a score with illustrative elements" [3]. To this aim Logothetis distinguished three categories of symbols: 1. pitch symbols, 2. association factors and 3. action signals, a concept put forth in his main essay *Zeichen als Aggregatzustand der Musik* [1].

Much of his work is based on the idea that different readings (German *Lesarten*) of the same text are conceivable. We can see this at a basic level in his text compositions in which Logothetis creates subtexts by overlapping and slicing words into syllables and phonemes. In *Sisyphos – Stein* [4] for instance, he used a passage from Plato's dialog Kratylos for a reading that includes multiple languages as well as the semiotics of shapes (see Figure 1). As Hartmut Krones points out in the introduction of his book [1], the word ἄνθρωπος (man) can also be interpreted as ἄ = ah! (exclamation), θρω = droh! (threat) and πο = po! (the human behind in German) where ω also graphically represents the shape of the body part in question. Logothetis thus used a fragmentation technique to allow for alternative readings, and thereby establishing polyphormism on the level of the rendering of literary texts.

Vickery, co-author of the Decibel ScorePlayer, developed a similar concept which he refers to as *rhizomatic*. Based on the ideas by Deleuze and Guatarri, he explored "the development of rhizomatic musical scores that are arranged cartographically with nodal points allowing for alternate pathways to be traversed" [5].

2. THE MORPHOME

The English translation of title of Logothetis' essay is "Signs as Aggregate State of Music". As Logothetis clearly makes a reference to physics and the natural sciences, one wonders whether this also has a discursive aspect directed at his countryman Xenakis who since the 1950s was fascinated by translating the statistics of molecular (Brownian) motion into music and described much of that in his seminal book *Formalized Music* [6].

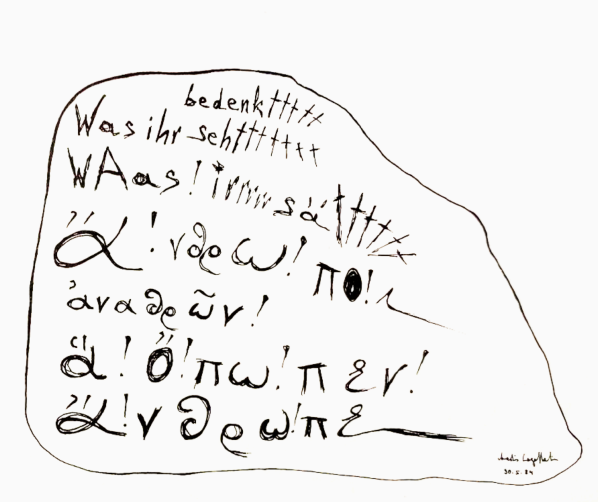

Figure 1. Score of Sisyphos – Stein by Anestis Logothetis.

But Logothetis might have as well turned to the then budding field of genetics as he could have discovered both there: signs and a molecular structure that enables

life via transcription and translation of genetic code. In genetics, the analogy goes even deeper. We find a precise sequence of nucleotides (the basic building blocks of DNA and RNA) akin to his pitch notation, a molecular machinery operating on sequences analogous to his action signals and finally a complex system modulating the expression of code comparable to association factors. We also encounter polymorphism. For instance, for the major histocompatibility complex (MHC) more than 32000 variants, called alleles, are known[1]. It resembles also a phenomenon called *gene overlap* where a sequence can be read in various ways[2] (Figure 2).

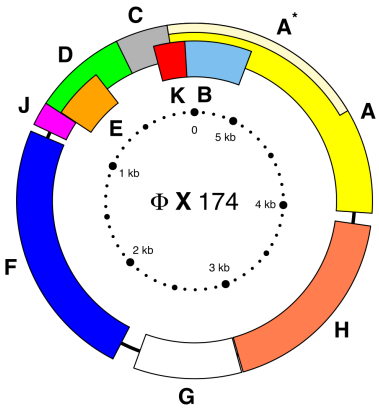

Figure 2. The genetic code of the bacteriophage ϕX 174 exhibiting gene overlap. © Emmanuel Douzery

Extreme cases can be found in out-of-phase overlap where alternative readings can be shifted by one or two nucleotides, leading to a different gene product, or in sense-antisense gene overlap where the usually silent antisense DNA (the complementary DNA strand that doesn't get translated into proteins) also encodes a protein [6].

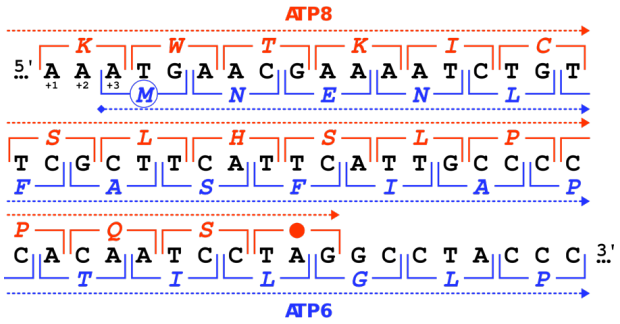

Figure 3. Out-of-phase overlap in DNA transcription resembling Logothetis concept of polymorphism. © Emmanuel Douzery

Reading in two directions is also a requirement in Logothetis' composition Dynapolis [8] which actually is inspired by the layout of a city (Figure 4) yet bears similarities to the aforementioned cellular mechanisms of transcribing and translating genetic code. In analogy to its definition in biology (mapping and classification all the morphological features of species), we are proposing *morphome* as a term referring to *the totality of all possible readings of a score.*

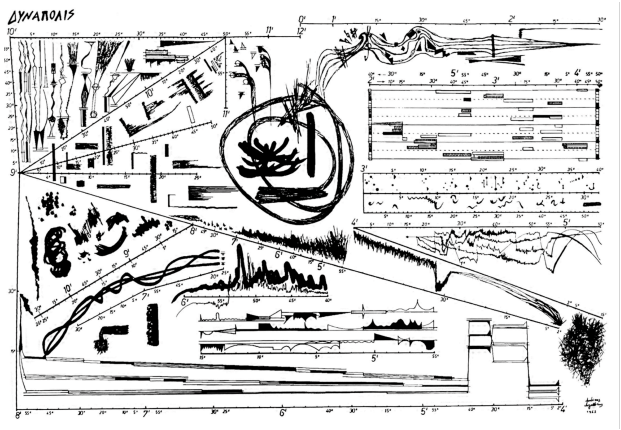

Figure 4. Score of Dynapolis by Anestis Logothetis.

As DNA serves as a sequence of codons which carry meaning, the field of semiotics has been expanded to also include genetics. While it's outside the scope of this presentation we would like to refer to the article "The Linguistics of DNA" by David B. Searls[3].

3. HUMAN SCORE READING

In the context of creating his classification, Logothetis extensively studied the nature of reading graphic notation [1]:

"It was the time when I was intensively occupied with problems of musical recordings and realized that graphic elements can be grasped in three ways if one wants to use them for musical purposes: They can symbolize a thing by signifying it. Then they can evoke associations, and finally they can signal commands."

As with any form of reading as a cognitive activity, the process of decoding of text (I use text in a broader sense) is hierarchical. Different brain regions (nodes) are in charge of the decoding of it [9]. This division of work allows for the anticipation of meaning and providing robustness in case of error. We all know *exmaples wehre chactres r swtichd nd omittd* without affecting the intelligibility of the sentence. Such processing of hierarchically arranged information of has been captured by Schenkerian analysis and is also at work when reading Logothetis' scores.

In analogy to gestalt perception of tones which are referred to as analytical (resolution of individual partials) and synthetic (focus on the fundamental) I shall call the reading focussing on the graphics as a whole (and primarily being used to create associations for an

[1] https://en.wikipedia.org/wiki/Gene_polymorphism

[2] Gene overlap was first discovered in the bacteriophage (a virus targeting bacteria) ϕX 174. Its genome being a little larger than 5000 nucleotides codes for 11 genes (A through K), eight of which overlap with other genes by at least one nucleotide.

[3] https://www.jstor.org/stable/29774782?seq=13#metadata_info_tab_contents

improvisatory approach) *global* and *synthetic*, whereas the fine-grain resolution of a pitch symbol or association factor is rather *local* and *analytical*. In this context, it may be useful to distinguish between the interpretation of a score (synthetic) and execution of it (analytic).

Baveli and Georgaki have developed a taxonomy that reflects this hierarchy which also includes an intermediary stage representing a synthetic reading on a local level, as in the case of action signs which aren't fixed on a temporal level [3].

Local resolution (in terms of speed and accuracy) of course isn't a quality per se and depends on familiarity with the terrain in question as hinted in the following distorted image of a passage from Scriabin's piano piece *Vers la flame* op. 72 (Figure 5).

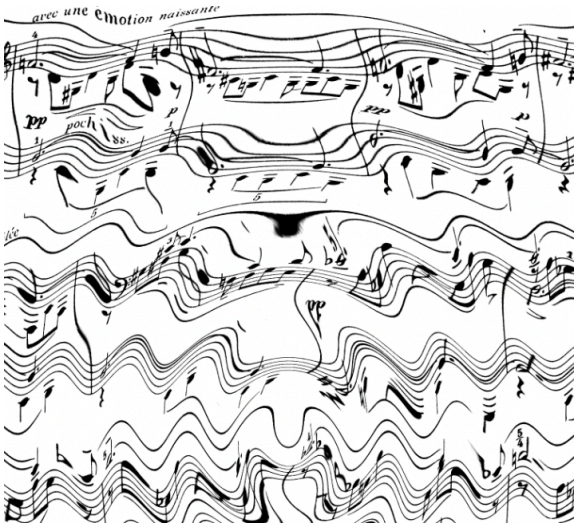

Figure 5. A page from a piano piece by A. Scriabin with distortion applied spurring a different reading and agency in comparison to the original score.

Due to impaired local resolution caused by the distortion, performers are more likely to fall back into an associative behavior and focus on the interpretation of the contorted lines rather than trying to accurately execute the musical events encoded in the score.

This friction of local vs. global, analytical vs. synthetic is what makes Logothetis' approach to graphic notation so enticing: On the one hand, we encounter action signals which carry an immediate meaning appealing to the embodied cognition of the interpreter and on the other hand, we find precise quantifiable pitch notation which can be further subjected to music-theoretical taxonomies.

4. MACHINE AND HYBRID SCORE READING

Zeichen als Aggregatzustand der Musik was published in 1974 (perhaps as a counter draft - in German "Gegenentwurf" - to Xenakis' Formalized Music) when Logothetis was already 53 years old and computer composition was still in its infancy. Xenakis, an engineer by training, was at the avant-garde of computer-based composition and instigated the development of the UPIC system, completed in 1977. It allowed composers to draw partial tracks on a digitizing tablet, to be sonically rendered by the associated software and hardware. But not all composers of this generation were willing or in the position of following on this path as it also meant to leave the safe boundaries of paper, pencil and (if at all) pocket-calculator and to embark on a journey with potentially questionable results. In his essay *Die Geschenke meiner Umgebung anhand der Frage "was denn nun Musik sei"* (the gift from my environment vis-à-vis the question "what's music after all"), Logothetis expresses his dissatisfaction, a bit circuitously though, with the way musical structures were represented graphically by software at the time [10].

"Many of these devices today register their sound derivatives in various graphic ways, including that of the 5-line staff, and print what is registered, but this leads to an obscuring of the compositional notation concept. The text appearance, which invites to produce sounds, becomes an inventory through the recording of already produced sounds, and the notation activating the musical practice becomes a programmed automatism which can also be triggered randomly by pressing keys and does not presuppose any compositional intellectual work. The sound image is no longer necessary for composing, at most for control purposes. This state of affairs can lead to great perceptual complications in the evaluation of musical recordings and necessitates the emergence of new competencies."

He was most likely referring to piano roll and standard notation representation of MIDI events afforded by 1980s software such as *Notator* by C-LAB or *Cubase* by Steinberg and bemoaning the cognitive divide between the text appearance (*Schriftbild* in German), its reading as a programmed automatism and the sonic outcome, while at the same time mandating the development of new competencies to overcome this very divide. In computer music during the last decades of the 20th century, *reading* has become somewhat synonymous with *sequencing* where in most cases, a linear score either in standard Western or piano roll notation is played back while a play head is moving across the screen, or the score itself moves under a static play head. Here, every note represents a MIDI command to be executed at a particular time defined by its position in the score and a few accessory elements. Logothetis passed away before computers and software applications became powerful enough to offer anything close—in the graphic domain—to what he had already achieved with traditional means. And obviouosly, using a computer only makes sense if there is an added value. This value can be found in the notion of *computer reading* and this ought to be substantially more than just reading a graphic score off a screen created with a mouse on a screen instead of being drawn on paper with a pencil or using a piano roll or 5-line representation of MIDI events. One of the first applications that broke with this paradigm is IanniX [11], a non-linear sequencer whose name is an unequivocal reference to Xenakis and his UPIC system [12].

To achieve the kind of polymorphism that Logothetis would have expected from a digital score, we also need to first define how the score reading is supposed to take

place when performed by the machine alone. Here we can differentiate between three levels concerning the encoding of a score:

- bit map
- vector graphics
- graphical representation of an underlying musical data set

In the first case, pixels are commonly mapped to time and pitch such in a left-to-right linear reading such as in some pieces by Clarence Barlow and the partial tracks created with the UPIC (see section 6 for a brief discussion of more complex mapping facilitated by AI). The second case requires a semantic mapping between graphic commands and music events and forms the basis of the Symbolist software by Rama Gottfried where left-to-right linear reading is also standard [12]. The third case is typical for applications such as InScore [13] where readings can be either linear or non-linear but can also be achieved by gradually moving up the three levels by applying pre-defined rules while progressing from bit map to the musical data set.

A computer-based system needs to imbue a graphic element with some meaning pertaining to the environment in which the reading is to take place and turned into machine agency. A beautiful example for a polymorphic score with is *Cube with Ribbons* by Simon Katan which has a cursor travelling down a line to which various events are attached like ribbons until it encounters a junction allowing it to take an alternative path (Figure 6).

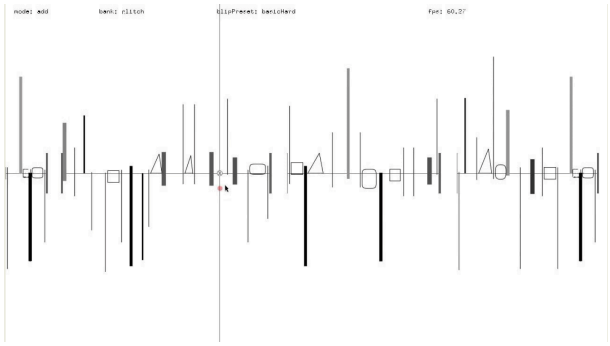

Figure 6. Screenshot of *Cube with Ribbons* by Simon Katan.

As one can see in the video on Vimeo[4], user intervention can change the likelihood for such things to happen. Like in a score by Logethetis, such an approach implies that certain constellations may never sound or at least not in a particular rendering of the score. The score, therefore, is a field of possibilities rather than just an unambiguous linear text. We have already referred to this as the *morphome*. Such fields can be either hard coded in the score in terms of alternative routes to be chosen by the performer or the basis for real-time notation in which the computer makes those choices, ideally in response to the performer [15].

[4] https://vimeo.com/36888504#_=_

If we factor in human reading, we end up with a hybrid scenario where the digital score is executed by the machine and interpreted by the human at the same time. A hybrid of a simultaneous human and computer reading can therefore be achieved, for instance, when the computer deals with the necessary local and analytical reading of details such as the exact pitch or sample to be played, while the human user can focus on the global and synthetic interpretations concerning the more associative aspects of the piece, about when and how these signs should be triggered as interface elements.

5. UMIS: UNIFIED MUSICAL INSTRUMENT SURFACES

The Decibel ScorePlayer [16] is a piece of software which the typical right-to-left linear scrolling paradigm but also has a mode that allows non-linear reading by employing moving shapes to highlight areas of a score. A performer can thus *react* directly to the score, either scrolled or presented page-wise (which is preferable presentation mode when the screen needs to be touched). However, when *interaction* is required, a graphic element needs to function as a GUI element. For instance, in MaxScore, a package for standard Western, microtonal and graphic notation co-authored by Hajdu and Didkovsky, any element created with its Picster drawing tool can be associated with an expression to be executed and interpreted by the Max and/or Ableton Live host environments [17].

An expression thus forms a sign in which the element takes on the role of the signifier and the expression that of the signified. This can either be a linear relationship where a curve gets interpreted as a trajectory and translated into a breakpoint function or an abstract one where the element becomes a graphical representation of some parameter settings. In MaxScore, these signs can then be executed according to their temporal order or serve as interface elements to be manipulated by an interpreter at his or her own will. Elements can be left out and non-linear, rhizomatic routes taken.

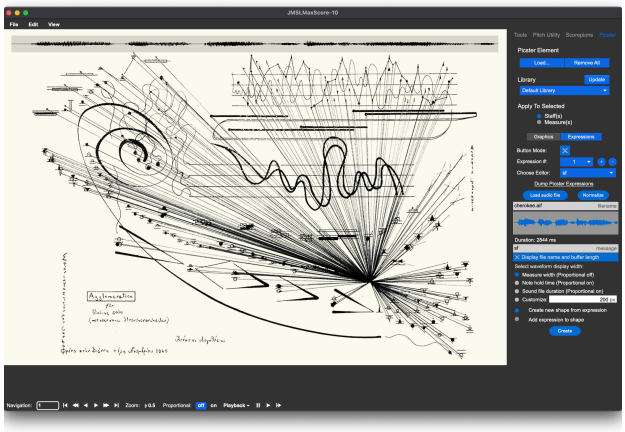

Figure 7. A score by Logothetis rendered in the MaxScore editor with an additional waveform added as

an example of how an existing graphic score can be supplemented with additional expressions.

A score hence functions as a controller in addition to being a graphic gestalt. In MaxScore, this type of interaction is toggled by the "buttonmode" message which allows arbitrary Picster elements to act as buttons. Figure 8 shows an example for a GUI element auto generated from parameter settings aiming to control the real-time generative program DJster [18].

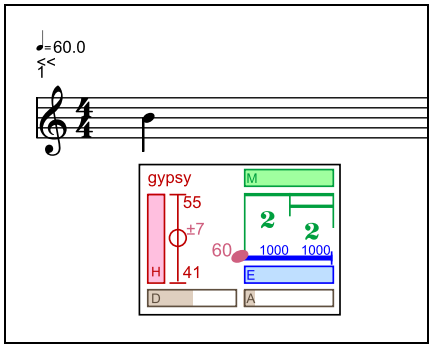

Figure 8. An example for an Picster expression, auto generated from DJster parameter settings. The code for this was created by Cheung.

By integrating a camera and projector into the body of the instrument, Sello [19] has converted a timpani and a tom-tom into hybrid instruments he named Hexenkessel and Hexenkesselchen, resp. (Figure 9) where the membrane serves both as (a) a score display and (b) a touch-sensitive controller in addition to being playable by mallets (c). Sello and Hajdu coined the term UMIS (short for *unified musical instrument surface*) to capture the triple nature of such hybrid instruments. Using OpenGL texture mapping, scores can be bent into a circular area to be projected onto the membrane of the instrument.

To achieve this in MaxScore, we connect the matrix outlet of the maxscore.bcanvas abstraction (containing the JavaScript object jit.pane.js, capable of rendering a score directly to a Jitter matrix) to a jit.gl.texture object and apply the texture to the circle via jit.gl.gridshape (Figure 10).

Figure 9. The Hexenkesselchen. © Jacob Sello

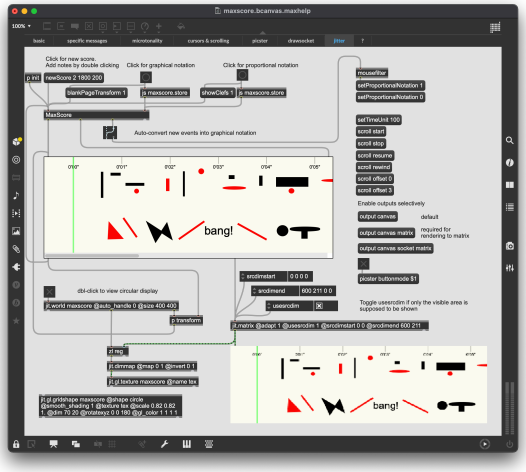

Figure 10. The Max patch in charge of generating and processing the Jitter matrix.

The score to be projected onto the membrane of the percussion instrument (Figure 11) can be played by tracking the position of the mallet and sending this information over the network to the computer serving the score. Due to their bending, a geometric transformation must be applied to calculate its Cartesian coordinates in order to identify the touched shape and trigger its expression.

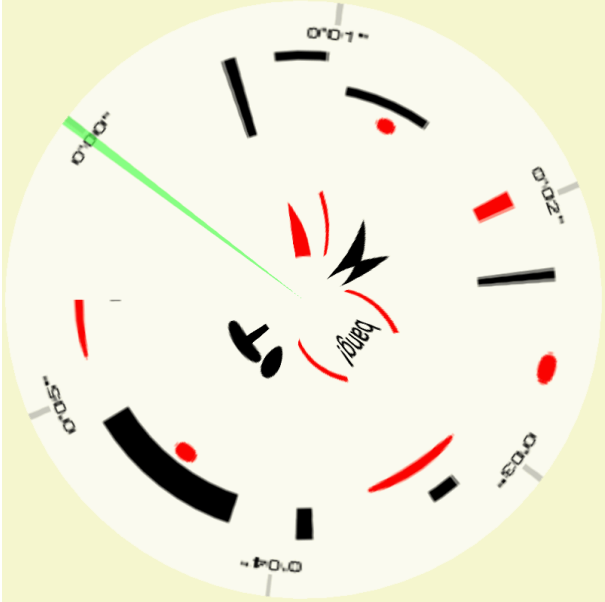

Figure 11. Circular score to be projected onto the surface of the Hexenkesselchen. This score can either be scrolled circularly or presented as a static page with its elements functioning as buttons to be struck by the player at will without necessarily following the given temporal order.

6. AUGMENTED AND VIRTUAL REALITY

We can easily imagine a scenario in which a performer or a conductor wearing augmented reality glasses can guide a performance without fixing a computer screen or a tablet. As a proof of concept, we have used Hololens 2 mixed reality glasses to interact with a score rendered in its browser via Drawsocket [20], which serves the score over the local network. The user interacts with the

graphical elements in buttonmode through the virtual laser beam and thus executes the Picster expressions associated with them (Figure 12). While this approach is confined to a 2-dimensional plane, we can also conceive of a score as a three-dimensional arrangement of objects.

Figure 12. An ensemble can be directed by a conductor wearing Hololens 2 mixed reality glasses. In practice, the browser window is more transparent than it appears on the screenshot.

In her project Moving Sound Pictures, Konstantina Orlandatou deals with the question, whether it could be possible to consider art works of the 20th century - especially those of the abstract painters - as polymorphic graphic scores in Logothetis' sense? To this end, she turns paintings by famous artists such Wassily Kandinsky, Piet Mondrian or Kazimir Malevich into 3-dimensional spaces where the graphical elements of the painting become tangible objects. These objects emit sound upon tactile interaction. With the usage of controllers and a head-mounted display (VR), the user is able to grab these objects and generate music with his/her gestures. The user thus becomes the musician who interacts with a graphic score, but the score is the painting itself (Figure 13).

The way Orlandatou interprets the objects into musical elements align with Logothetis description of reading musical scores in the broader sense of polymorphism. Firstly, graphical elements become symbols of sounds. Every element has its own sonic characteristics based on its form. For instance, a triangle sounds edgy, but a circle may sound smooth. Secondly, the graphical elements as objects positioned in space can elicit associations. Their form or even colour can arouse emotional state or can resemble an object of daily routine. Finally, graphic elements become symbols of actions and commands. The interaction with the object is the action needed for making the object audible.

The potential of implementing graphic scores 3-dimensionally in a virtual reality environment is barely explored. A space, where the score is not only a linear text that has to be read in a specific timeline, opens a new path for creating holistic perceptual experiences in which the musician can directly interact with the graphic score.

Figure 13. Screenshot of a Moving Sound Picture project (Kazimir Malevich: Suprematism).

7. OUTLOOK: AI

Where we going to take this from here? There is a lot of talk about machine aesthetics and machine appreciation of art in the context of AI, but some of the current results are seriously wanting as the completion of Beethoven 10th symphony has shown[5]. Still, we foresee fascinating applications of AI in the context of machine reading of scores. Networks could be trained (e.g. by using eye-tracking data) to a corpus of graphic scores and learn how to interpret them. Once again, the local vs. global paradigm can be useful to define what the networks ought to be capable of.

Yet, we believe that for the foreseeable future, machine reading of graphic scores alone won't be the golden grail. Instead, hybrid readings which include both the human factor as well as the machine (be it as generators or interpreters) will be the most likely scenario, until a machine reading machine-generated scores while entertaining another one with machine music becomes a reality and an evolutionary advantage. Logethetis probably would have had some thoughts on this as well.

Acknowledgments

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