Algorithmic Art and Its Art-Historical Relationships

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ABSTRACT

This paper aims to discuss algorithmic art (also known as computer-generated or generative art) in a comparative perspective with artistic practices generated by means of non-computer-based methods. More precisely, it seeks to trace art-historical relationships between algorithmic art and certain examples from modern art movements. The artist whose works are chosen as the starting point for this investigation is the German artist Manfred Mohr. The investigation will firstly attempt to identify key features of algorithmic art based on its formal visual properties as well as production techniques involved. In the second step, it will discuss these observed characteristics in a comparative perspective with historical precedents and contemporary practices from non-computer art. By comparing aesthetic principles and techniques used by selected artists, the paper seeks to contribute towards a growing awareness that it is necessary to consider algorithmic art within the broader historical context of its relationships with non-digital art forms.

KEYWORDS

Algorithms; Aesthetics; Manfred Mohr; Modern Art Movements; Art-Historical Relationships.

1 | INTRODUCTION

The era of computer-generated art began in the 1960s [1]. This form of artistic practice was born after the emergence of computer technology during the Cold War. During that time, two rivals, the Soviet Union and the USA, had been forwarding the development of computer technology in order to demonstrate their military and technical achievements. In this context, many practitioners from computer science began making visual experiments to implement their artistic ideas. For example, researchers at the Bell Laboratories in New Jersey, A. Michael Noll and Béla Julesz, were encouraged through their professional activity to create computer-generated works for aesthetic aims (Taylor, 2014, pp. 27-39).

Many traditionally trained artists were also affected by new computer technologies and began challenging this device within their creative concepts. They often conducted visual research in collaboration with scientists, forming worldwide several computing research groups and other pioneering movements in this new field. In France, for example, there was the *Groupe de Recherhe d'Art Visual*, also called *GRAV*, with one of the most eminent computer art pioneers

Vera Molnár as a co-founder. In Germany, the Stuttgart school was founded around Max Bense, one of the founders of Information Aesthetics. In Zagreb, the former Yugoslavia, science-oriented artists formed the *New Tendency* movement. Artists who established all these groups commonly intended to conduct visual research on computers in order to create artistic objects.

However, due to its origins in scientific and technical purposes, the majority of the fine arts community initially took a rather skeptical view of computer-generated art and separated it from traditional art history, allocating it rather in a pure technical domain. First practitioners of computer art themselves, such as Herbert W. Franke, A. Michael Noll or Frieder Nake, did not try to position their works within 20th century art history either. Moreover, when writing about their works, pioneers of computer art usually concentrated only on the technical aspect of the production (Taylor, 2014, pp. 3-10, 257-258). In doing so, as Piehler (2002, pp. 62-63) believes, they were not yet aware that they were growing against the background of contemporary art practices.

Indeed, there are many reasons to believe that prevailing cultural environments also influenced the emergence of computer-generated art. Already at the beginning of the 20th century, constructivists and suprematists had demonstrated a close relationship with science, relying on mathematical methods in art production (King, 2002, pp. 90-94). Likewise, Bauhaus decided in favor of science, promoting learning and teaching methods based on the integration of art and technology (Klütsch, 2012, p. 81). These assumptions were maintained some decades later in several art movements that emerged shortly after the World War II, such as Minimalism, Conceptual Art or Fluxus, which also aimed to employ mathematical principles (King, 2002, pp. 90-94).

In recent years, there has been a growing awareness that computer-generated art should be also seen within the broader historical context of its relationships with non-digital art forms. For example, Galanter (2003, 2008) argues that the roots of generative computer art can be already found in ancient Islamic decoration. According to Galanter, the placement of individual elements within these motifs was made by means of manually executed symmetry-based algorithms. Similarly, Weibel (2005) contributes towards a growing awareness of these kinds of art-historical relationships, pointing out that algorithms – in the sense of following predefined rules – had been already applied in traditional arts as manuals or musical scores for centuries. In this context, he remembers Leon Battista Alberti's architectural tractate *De re aedificatoria* (1452), Piero della Francesca's script on perspective in painting De prospectiva pingendi (1474) and Albrecht Dürer's book on geometry *Underweysung der Messung* (1525) that were written as manuals for artists, giving instructions for making buildings, paintings and sculptures.

This paper aims to discuss algorithmic art in relation to so-called "natural" art. In doing so, it seeks to analyze its key features in a comparative perspective with its historical precedents and contemporary practices that have been created without any help from a computer or digital technology. The artist whose works are chosen as the starting point for this investigation is the German-born artist Manfred Mohr. He is one of the pioneers of computer-generated art, and is also considered one of the most influential artists in this area. The selection of artworks for a comparative analysis is limited to pieces dating from the 20th century. In this context, the main aesthetic principles and techniques used in non-computer art during this period will be compared with Mohr's artistic practice.

2 I ALGORITHMIC WORKS BY MANFRED MOHR

Manfred Mohr began his career as a jazz musician and abstract expressionist, but later turned from traditional painting to computer-generated art (Mohr 2002, 111). In doing so, he was strongly influenced by the theories of the German philosopher and semiotician Max Bense, developed in the 1950-60s (Von Mengen, 2007).

Bense attempted to establish an objective scientific approach in the realm of aesthetics. His main purpose was to construct a theoretical platform that would enable a rational evaluation and creation of artworks, as opposed to traditional theories oriented to subjective and emotional interpretation. The most influential area of Bense's theories is the concept of Generative Aesthetics. Bense formulated it as follows:

> *"Generative aesthetics […] implies a combination of all operations, rules and theorems which can be used deliberately to produce aesthetic states […] when applied to a set of material elements. […] Generative aesthetics is an 'aesthetic of production', which makes possible the methodological production of aesthetic states, by dividing this process into a finite number of distinct and separate states which are capable of formulation"* (Bense, 1971, pp. 57-58).

Generally speaking, Bense believed it is possible to generate aesthetic objects according to exactly formulated rules. For Bense (1965, p. 151), Generative Aesthetics proceeds in three steps. Firstly, the artist defines the elements of the repertoire that will serve to generate a work of art. For example, the repertoire of a literary work consists of a certain vocabulary, the repertoire of a musical work – of the quantity of notes, the repertoire of a painting – of individual forms and colors. In a second step, the artist formulates the rules for connecting the elements of the defined repertoire to a complex composition. For example, in a literary work, the words are combined to sentences and phrases according to grammatical and stylistic rules; notes in a musical composition are governed by the rules of harmony; in art, such rules are determined by an artist or a group of artists. Finally, the artist selects certain elements from the repertoire and combines them to a composition according to predefined rules. Nevertheless, as Bense noted, despite the existing rules, an artist often makes decisions unpredictably. This depends, for example, on his health condition or mood during the act of creation. According to Max Bense, when an artist begins to create his work, he has only a general concept, and does not know exactly what all the details will look like until his work is completely finished. Thus, the creative process is for Bense closely linked to random intuitive decisions (1965).

In the late 1960s, Mohr started exploring computer algorithms for the creation of his computer-generated works based on Bense's scientific aesthetics. The geometrical form of a cube is the primary motive of Mohr's computer-based works since then. Mohr introduced the cube into his works, as its structure is based on a mathematical logic, and therefore can be well adapted to a computable configuration. Nonetheless, Mohr never aimed to visualize mathematical properties of the cube. Instead, his research is rather focused on the exploration of new visual and aesthetic expressions that result from abstract relations between structural elements of a cube (Maiocchi, 1994, p. 35).

Using the cube as his primary motive, Mohr created a series of computer-generated works. His black-and-white plotter drawing *P-154-C1* (Figure 1) belongs to his early work phase *Cubic Limit I* (1972-1975). This computer-generated work shows a sequence of three-dimensional cubes. These figures are evenly distributed over the image surface 10 across by 7 down, forming straight rows. There is however no cube with all its edges. Mohr removed a number of contour lines from each of them. In the lower part of the picture, cubes are missing only one or two edges, so that the three-dimensional shape of the cubes is still recognizable. From the bottom to the top of the picture, the number of edges removed from each cube gradually increases, until the figures of the upper rows possess only one or two edges. These cubes are no longer identifiable as such. Mohr deliberately aims at disturbing the symmetrical balance of the cubes. In this way, he seeks to create a visual tension. His main goal is to create new aesthetic forms with the visual language that has not been seen previously. Concretely, by removing the edges of the cube, Mohr breaks the illusion of three-dimensionality, forming

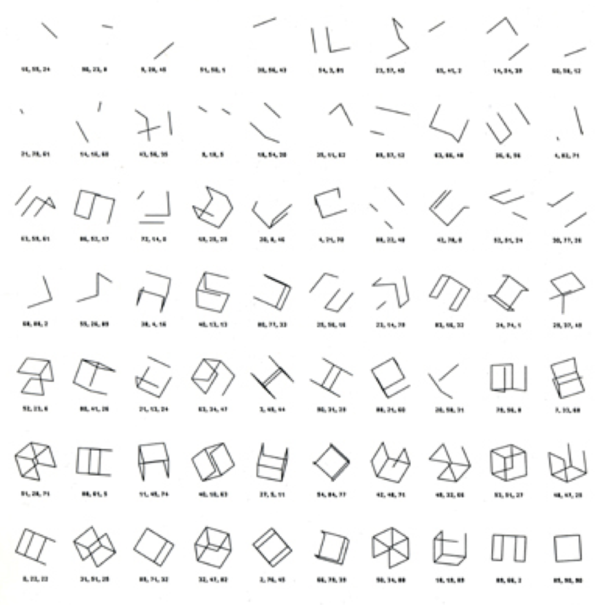

Figure 1 | Manfred Mohr, *P-154-C1*, 1973, Courtesy of the artist.

instead new two-dimensional structures (Mohr, 1975).

Mohr (2002, p. 111) developed the algorithm for this work in accordance with Bense's Generative Aesthetics. In doing so, the artist firstly defined the elements of the repertoire. Geometrically defined, a cube is a three-dimensional form constructed by means of twelve contour lines or edges, respectively. Consequently, Mohr used twelve edges of a three-dimensional cube as a repertoire for creation of his computer-generated piece. More precisely, Mohr's repertoire consists here of straight lines of equal length that can be placed only at an exactly predetermined order, and can appear only once. In a second step, Mohr established the rules that determine the main futures of the graphic: to combine the predefined twelve straight lines into cubes, and to distribute them evenly in the grid. The local structure of each cube was determined by random number generators that program chance in the selection of certain parameters based on Probability Theory [2]. In *P-154-C1*, random numbers decided exactly which edges must be removed (Von Mengen, 2007). The use of random decisions guaranteed the unpredictability of aesthetic production, which Bense regarded as a necessary criterion for being an artwork. In other words, what occurs in artistic-creative processes through intuitive spontaneous decisions in a natural way is simulated here by random number generators. Moreover, the involved chance demonstrates here the innovative character of the production process – which would be impossible in a purely deterministic program, where only a predictable outcome can be produced.

On a related note, the algorithm for *P-154-C1* predefines the amount of straight lines and the instruction to connect them in the way that introduces the form of a three-dimensional cube, while the decisions to eliminate certain edges of the cube is determined by a random generator. The result is a cube, known in advance in its general structure but unpredictable in all its detail.

It is important to notice that it is possible to generate different combinatorial possibilities of structures emerged through the removal of some edges of a cube only if the program begins with a new random number every time. In *P-154-C1*, to avoid the same random number and, therefore, the same output, each random number was calculated by the computer so that the same occurrence was excluded. Consequently, the result here is not truly random; it is only generated by means of randomness, and appears to the observer as being random. For this reason, the term pseudo-random is applied here (Klütsch, 2007, p. 116). The sole use of random number generators would lead to chaos. Due to the fact that the random was partly controlled, the complete arbitrariness was avoided. The result is the perceptible aesthetic information.

An essential feature of this method of image generation is that one can produce a great number of characters using the same program without repeating the same figure twice. In *P-154-C*, there is indeed no figure showing the same combinatorial possibilities of structures emerging from the removal of edges of a cube. This means that such programs do not create individual figures, but rather classes of figures that share common features defined by the algorithm (Nierhoff, 2005).

Certainly, it was also theoretically possible to develop an algorithm for the generation of differently shaped cubes, determining exactly how each individual figure will look, without involving any random numbers. However, such an algorithm would not create a class of figures. Rather, a strongly deterministic program would generate concrete graphical outcomes or, in the case of the graphic *P-154-C*, exactly 70 individual combinatorial possibilities of a three-dimensional cube. A class of figures consists, on the contrary, of endless chains of variations. More precisely, in all, there are ((n) x (n-1) ... (n-m+1))/m combinations possible with the cube edges, where n = the twelve edges of a complete cube, and m = the number of missing lines. Following this mathematical formula, if two lines are removed from a cube, there are (12 x 11)/2 = 66 possible line-combination (Mohr, 1975). This means that Mohr investigated here some of (12 x 11)/1, (12 x 11)/2, (12 x 11)/3 ... - (12 x 11)/11 possible structures. In other words, the graphic *P-154-C* could also display other combinatorial possibilities of a cube.

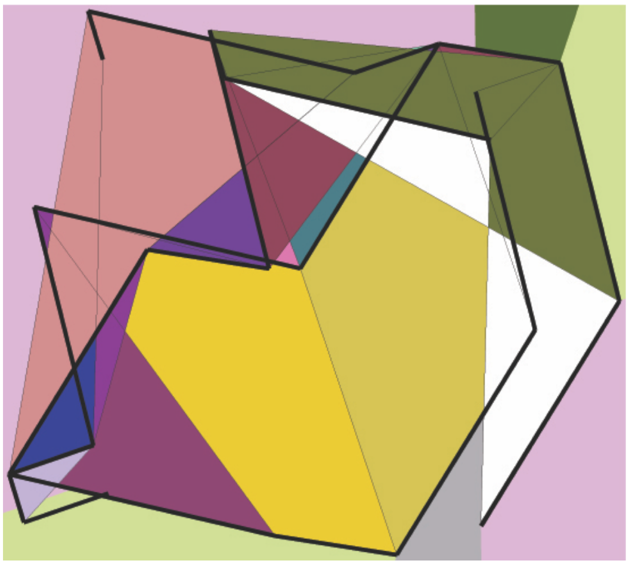

Figure 2 | Manfred Mohr, *P-707-E*, 2000, Courtesy of the artist.

While early algorithmic works by Mohr are exclusively generated as black-and-white drawings, his cubic works created since around the year 2000 are colored (Figure 2). The reason for this is the increasing complexity of his works. Throughout his artistic career, Mohr gradually transfers the cube into higher dimensions, exploring this geometrical form as a four-, six- and even eleven dimensional structures. As Mohr (2002, p. 112) affirms, in order to demonstrate the complexity of these hypercubes in a comprehensible way, he has been forced to reconsider the exclusive use of black and white. On a related note, Mohr started using colors that enable differentiation between quadrilaterals of a cube. The color choices themselves are however not based on any color theory, but rather are to be considered random decisions. The program randomly selects a color from a pallet predefined by the artist.

3 I COMPARATIVE ANALYSIS

The decision to investigate the structure of the cube immediately brings Mohr's works into line with those artists who also aimed at the exploration of this geometrical structure. For example, the cube was an important motif in Conceptual Art. In this context, Sol LeWitt created a cubic work *Variations of Incomplete Open Cubes* – a series of three-dimensional cubes each missing one or more of its sides [3]. Similarly to Mohr, LeWitt also developed rules for the production of his project: to create all possible three-dimensional structures of a cube by systematically removing its edges without repeating identical forms. In his investigation, the artist started with the variations consisting of three edges (the minimum number needed to identify a three-dimensionality), and ended with a cube with one its sides eliminated (the last possible variation of an incomplete open cube) (Lee, 2001, p. 51). Following these rules, LeWitt figured out 122 possible variations of incomplete open cubes, which are illustrated in the schematic drawing, where variations are arranged according to the numbers of edges removed [4]. Based on this drawing, LeWitt created a large series of wooden sculptures that show some of the identified variations.

The project *Variations of Incomplete Open Cubes* is linked by formal criterion to Mohr's Cubic Limit series, and particularly to the graphic P-154-C. In fact, both artists Mohr and LeWitt used the cube as the primary motif of their works. Furthermore, both applied to similar methods of art production, namely, repetition, seriality, mechanical rationalism and algorithmic logic. Finally, both aimed to show the potential infinite different states emerging from the construction and deconstruction of the cube. Generally speaking, the aesthetic of both art objects, by a mere observation, appears exceedingly identical (Taylor, 2014, pp. 48-49).

Nevertheless, there are also essential differences between them. Although both artists focused on the investigation of the cube, they treated this geometrical form from different perspectives. While LeWitt primarily concentrated on the three-dimensional realization of the cube, Mohr, in contrast, was mainly interested in a two-dimensional expression of this multidimensional geometrical structure. Moreover, although LeWitt, like Mohr, removed edges of cubes, their structure always remained identifiable as such. In doing so, the artist clearly emphasized the principle of symmetry, whereas Mohr primarily aimed to destroy it (Lähnemann, 2007).

The most significant differences, however, become particularly evident by comparing production methods involved by the artists. Although LeWitt was able to identify the correct number of possible variations, he couldn't figure out a logical way to identify repetitions. In order to verify that there are no repetitions, the artist simply built a three-dimensional model of each structure, and then rotated it (Baume, 2001b, p. 24). In contrast, Mohr applied a mathematical approach – that is, pseudo-random numbers – that guaranteed the non-repeatability of variations. Additionally, due to this method of image-generation, all variations of Mohr's work are to be considered random decisions, while all executed variations of *Incomplete Open Cubes* are chosen deliberately. When looking at LeWitt's wooden sculptures, all of them contain one complete side on the ground. Indeed, LeWitt confirmed to have deliberately made that choice, since an installation without horizontal structures would have been rather unstable (Baume, 2001, p. 25).

Certainly, the use of randomness in the processes of art creation is not the invention of computer artists. For example, Dada artist Hans (Jean) Arp also involved the principles of randomness in his works. Nonetheless, he applied random mechanism differently from Manfred Mohr. On a related note, Arp created a series of compositions with the title: *Objects Arranged According to the Laws of Chance* [5]. In this context, the group of wooden reliefs known as Constellations illustrates different arrangements of five white and two smaller black biomorphic forms on a white ground. When creating these works, Arp produced the required number of forms, then randomly, without thought, dropped them onto a flat surface, and finally attached each of them wherever it fell (Glimcher, 2005, p. 56). This means that Arp used chance in its pure form, as opposed to Manfred Mohr's computer art that refers to the mechanical randomness which is something different from true chance.

Josef Albers's masterpieces also suggest certain parallels to Manfred Mohr's algorithmic art [6]. That is, with their attempts to generate variations, and particularly with their use of differently colored blocks within squares and cubes, the later algorithmic works by Manfred Mohr and the paintings series *Homage to the Square* by Josef Albers looks similar. Although abstract geometrical styles of both artists share common characteristics, however, the artistic objective beyond their works is completely different. More precisely, Albers's aim was to explore different colors within the same format of squares. In his works, the artist attempted to show how effects of certain color and its perception can be changed through its juxtaposition and interaction with other colors (Schmied, 1989). In other words, Albers's main concern was the color of the squares and not the square itself as opposed to Mohr who used color only as a means to explore a complex structure of the hypercube. Moreover, all Albers's decisions regarding the use of color and its placements within squares are made in accordance with color harmonies based on the artist's precise studies, while the choice of color combinations is of secondary importance to Mohr.

4 I CONCLUSION

This paper has focused on art-historical lineages that connect algorithmic art and modern art movements. Artists chosen for this investigation included Manfred Mohr, Sol LeWitt, Hans Arp, and Josef Albers. In this context, main aesthetic principles and techniques used by these artists have been compared.

As the analysis has demonstrated, one of these lineages connects Manfred Mohr's algorithmic art with Sol LeWitt's Conceptual art, since the cube became a central concern for both artists. Furthermore, the use of randomness in the processes of art creation is not only an important concept within Mohr's art; it was already evident in the work of Dada artist Hans Arp. Finally, hard-edge abstract paintings by Josef Albers also suggest certain parallels to Mohr's algorithmic works. That is, the motif of differently colored squares plays an important role within both creative practices.

However, the most important consideration regarding such art-historical lineages is that Manfred Mohr's computer-generated works and these selected examples of modernist styles have been created as variations on a theme based on self-imposed rules or restrictions. At the same time, it is important to notice that all steps within Mohr's process of creation are mathematical operations as opposed to LeWitt, Arp, and Albers. That is, as the investigation has demonstrated, Mohr attempted to achieve aesthetic results on computers through combinations of strictly planned logic and mathematical chance within computer programs. Although Conceptual art is also mathematically oriented, it shares, as Taylor (2014, p. 65) observes, only a "spiritual relationship" to mathematics. In fact, as the analysis of Sol LeWitt's work has illustrated, the underlying algorithmic logic of his conceptual schema is far from being a mathematical concept. For example, in order to avoid the repeated execution of the same variation, LeWitt simply verified it by rotating a three-dimensional model of each structure, as opposed to Mohr who created variations based on computational, i.e. mathematical logic. The use of chance within Dada-art is also to be distinguished from random numbers of computer art algorithms. While the chance of Dada refers to a pure chance, random numbers of Mohr's works are used in terms of computational logic, namely in the sense of so-called pseudo-random, where a process only appears to be randomly generated but is not. Finally, when using colors, Manfred Mohr and Josef Albers applied different types of rules. That is, while Albers followed the principles of color theory, Mohr generated his colored works based on precise mathematical laws.

Concluding, it can, therefore, be outlined that the emphasis of concept and instruction-based logic in Mohr's computer art is clearly grounded on a scientific base, while concepts and ideas involved by Sol LeWitt, Hans Arp, and Josef Albers are to be considered rather pseudoscientific.

ENDNOTES

[1] The period around the 1960s has been cited in numerous writings, including Ch. Klütsch 2007, W. Herzogenrath & B. Nierhoff-Wielk 2007, G. D. Taylor 2014 etc., as the beginnings of computer art.

[2] In 1906, A. A. Markov developed the theory of stochastic, or random, processes, also known as Markov chains. This is a mathematical description of a transition process from one state to another. In this context, the probability of the transitions from a state of a randomly changing system depends solely on the current state of the system, but is independent of the previous processes by which the present state reached. In other words, the probability of moving from the state at time t + 1 depends only on the state at time t and on nothing else. In this way, the Markov chains enable to study the probability of an outcome of a random phenomenon (Weibel, 2005, pp.1-2).

[3] A reproduction of Sol LeWitt's work Variations of Incomplete Open Cubes (1974) can be seen in Garrels 2000.

[4] A reproduction of Sol LeWitt's schematic drawing for Incomplete open Cubes can be seen in Baume 2001a, p. 13.

[5] A reproduction of Hans Arp's work can be seen in Waldman 1993, p. 194.

[6] A reproduction of Josef Albers work Homage to the Square can be seen on the website of Guggenheim Museum: https://www.guggenheim.org/artwork/173

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BIOGRAPHICAL INFORMATION

Anna Daudrich (born in Russia) studied Art History and Italian Philology at the University of Erlangen-Nuremberg in Germany. Currently, she is a PhD student in Art History at the same institution, conducting research on aesthetics of algorithmic art.