HUMAN VS. MACHINE: ALGORITHMIC METHODS IN THE REALM OF ARTISTIC PRODUCTION

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Algorithms primarily belong to the fields of mathematics and computer science. Certainly, the best-known application of algorithms is computer programming. However, algorithmic methods—in the sense of instruction to follow certain rules—have been also used as creative artistic instruments, for example, in modern art movements, such as Fluxus, Conceptual Art or Happening. With this background in mind, this paper aims to explore how algorithmic logic can be implemented in the realm of artistic production by both computer and analog artists. Artists chosen for this investigation include Manfred Mohr, Sol LeWitt, and Hans Arp. Based on the analysis of their works, this paper attempts to establish differences in dealing with algorithms within artificial and human creativity.

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1 INTRODUCTION

With the emergence of computers, many artists began employing these media for the creation of artworks. The main operating principle behind computer programming is the algorithmic approach, since all computer programs are based on algorithms. An algorithm can be described in broad terms as a set of instructions developed to solve a problem or accomplish a given task in a finite number of steps (Barth 2013, 4).

However, an algorithm must not be executed solely by computers. As Peter Weibel (2005, 2008) notices, algorithmic methods had been used long before computers were invented. For example, in the form of “instructions for use and action”, algorithmic principles had been already applied in traditional arts as manuals or musical scores since centuries. In this context, Leon Batista 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) were written as manuals for artists, giving instructions for making buildings, paintings and sculptures (Weibel 2005, 3). In modern art, Weibel distinguishes between two applications of algorithms: an intuitive and an exact application. The art historian points out that the intuitive use of algorithms happened in such art movements as Fluxus, Conceptual Art or Happening where one should act according to given instructions.

On a related note, Conceptual artists formulated conceptual schemas to create their artworks (Taylor 2014, 47). One of the most influential artists of this movement, Sol LeWitt, outlined his methodology as the selection of “basic form and rules that would govern the solution to the problem” (LeWitt 1967), what reflects the main principle of an algorithmic procedure. The artist developed his concepts based on strictly formulated rules, so that “arbitrary or chance decisions would be kept to a minimum, while caprice, taste, and other whimsies would be eliminated from the making of the art”, instead “the plan would design the work” (LeWitt, 1967). This principle is best demonstrated in his *Wall Drawings* (see Fig. 1) that represent explicit instructions for execution of several geometric shapes. Sol LeWitt hired his assistants to carry out these drawings by following the given rules, such as “vertical lines, not straight, not touching”. In doing so, it was possible to execute several variations of these workpieces.

Fig. 1. Sol LeWitt (1971), *Lines long, not straight, not touching* (Details of Wall Drawings), black pencil on wall, Guggenheim Museum, New York [Source: Legg 1978, 110].

While Conceptual Art explores the idea of instructions-based art following the logic of algorithmic procedures intuitively, computer-aided art is based on the exact application of algorithms

(Weibel 2005, 3-4). In computer art, an algorithm is firstly developed by an artist, then executed by a computer, and, finally, displayed on an output device, such as a computer monitor or plotter.

The following paper aims to explore in case study approach how algorithmic logic can be implemented in the realm of artistic production by both computer and analog artists. The first artist chosen for this investigation is Manfred Mohr—one of the most influential computer-art pioneers—as he makes his art through the exploration of computer algorithms. Mohr's works will be analyzed in a comparative perspective with Conceptual Art and Dadaism. It is necessary to introduce the main artistic principles of these art movements in the current discussion, since they—following Weibel's exploration of algorithms—similarly to computer-generated works, are based on the underlined algorithmic logic. Through this comparison, the paper attempts to figure out differences between "intuitive" and "exact" algorithmic approaches.

2 CASE STUDIES

Manfred Mohr is one of the most influential computer artists. However, he 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, mathematician, and semiotician Max Bense, developed in the 1950-60s (Von Mengen 2007).

Bense attempted to establish 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 (Taylor 2014, 88-89). 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, 57-58)

Generally speaking, Bense believed it is possible to generate aesthetic objects according to exactly formulated rules. For Bense (1965, 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, but he does not know exactly how all details will look like until his work is completely finished. Thus, the creative process is for Bense closely linked to random intuitive decisions (Bense 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 motif 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, 35).

Using the cube as his primary motif, Mohr created series of computer-generated works. His black-and-white plotter drawing *P-154-C* (see Fig. 2) 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 of all edges. Mohr removed a number of contour lines by 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 removed edges by each cube, however, gradually increases, until the figures of the upper rows possess only one or two edges. These cubes are

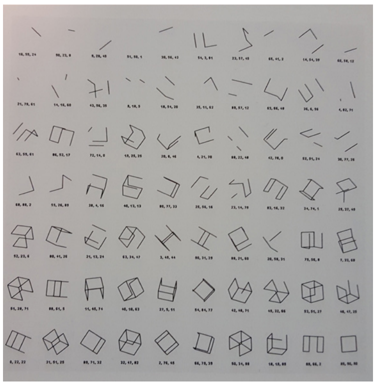

Fig. 2. Manfred Mohr (1973), *P-154-C*, plotter drawing/ink on paper, artist's own collection [Source: Keiner et. al. 1994, 72].

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 never been seen previously. Concretely, by removing the edges of the cube, Mohr breaks the illusion of three-dimensionality, forming instead new two-dimensional structures (Mohr 1975).

Mohr (2002, 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 a random number generators that program chance in the selection of certain parameters based on Probability Theory[1]. In *P-154-C*, random numbers decided which edges exactly must be removed (Von Mengen 2007). The use of random decisions guaranteed here 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-C* 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 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 generation of different combinatorial possibilities of structures emerged through the removing edges of a cube is only possible if the program constantly begins with a new random number. In *P-154-C*, to avoid the same random number and, therefore, the same output, each random number was calculated by computer so that the same occurrence was

1. 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, 1-2).

excluded. In doing so, the algorithm generated a fixed sequence of different numbers. Each time the program ran, the sequence repeated itself, guaranteeing thus the non-repeatability of numbers. 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 rather to be applied here (Klütsch 2007, 116). The sole use of random number generators would lead to chaos. Due to the fact that random was partly controlled, the complete arbitrariness was avoided, and the chaos was escaped. 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 emerged from the removing 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, exactly determining how each individual figure will look like, without involving any random numbers. However, such algorithm would not create a class of figures. A strongly deterministic program would rather 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 $((n) \times (n\text{-}1) \ldots (n\text{-}m\text{+}1))/m$ 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-combinations (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.

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 the three-dimensional cube. 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 its sides. Similarly to Mohr, Sol 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 side eliminated (the last possible variation of an incomplete open cube) (Lee2001, 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 removed edges (see Fig. 3). Based on this drawing, LeWitt created large series of wooden sculptures that show some of identified variations (see Fig. 4).

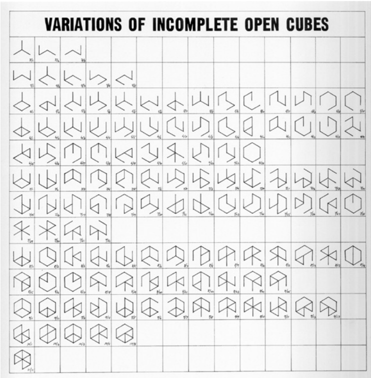

Fig. 3. Sol LeWitt (1974), Schematic Drawing for *Variation of Incomplete Open Cubes*, ink/pencil on paper, Museum of American Art, New York [Source: Baume 2001a, 13].

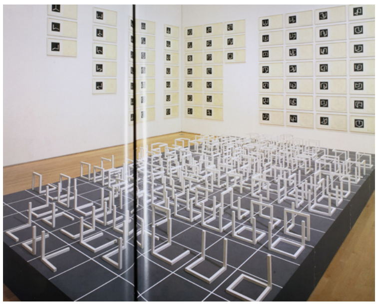

Fig. 4. Sol LeWitt (1974), *Incomplete Open Cubes*, installation, painted wooden structures, Museum of American Art, San Francisco [Source: Garrels 2000].

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 Manfred Mohr and Sol LeWitt used the cube as the primary motif of their workpieces. Furthermore, both applied to equal methods of art production, namely, repetition, seriality, mechanical rationalism and algorithmic logic. Finally, both aimed to show potential infinite different states emerged 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, 48-49).

Nevertheless, there are also essential differences between them. Although both artists are focused on the investigation of the cube, they treated this geometrical form from different perspectives. While Sol LeWitt was 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 Sol LeWitt, similarly to 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, 24). In contrast, Mohr applied to 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,

Fig. 5. Hans Arp (1932), *Constellation with Five White Forms and Two Black, Variation 3*, oil on wood, Guggenheim Museum, New York. [Source: Waldman 1993, 134].

Fig. 6. Hans Arp (1932), *Constellation with Five White Forms and Two Black, Variation 2*, oil on wood, the Sidney and Harriet Janis Collection [Source: http://www.moma.org/collection/works/81609?locale=fr].

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 deliberately making such a choice, since a production of an installation without horizontal structures would be rather unstable (Baum 2001, 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 rule-based works. Nonetheless, he applied to random mechanism differently from computer artists. On a related note, Arp created series of compositions with the title: O*bjects Arranged According to the Laws of Chance*. 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 (see Fig. 5,6). When creating these works, Arp's rule was to produce the required number of the forms, then randomly, without thought,drop them onto a flat surface, and finally attach each of them wherever it fall (Glimcher 2005, 56). This means that Arp used chance in its pure form, as opposed to Manfred Mohr's computer art that refers to the mechanical random which is incapable of creating a true chance.

3 CONCLUSION

Based on a case studies approach, this paper has provided insights into how algorithmic logic—simply understood as instruction to follow certain rules—can be implemented in both computer and analog art. Artists chosen for this investigation included Manfred Mohr, Sol LeWitt, and Hans Arp.

The analysis started with the exploration of Manfred Mohr's computer-generated work. This investigation has demonstrated that Mohr attempted to achieve aesthetic results on computers through a combination of strictly planned logic and mathematical chance within computer programs. That is, the artist firstly predetermined rules that defined the general composition of his graphic. The local structures of the graphic, however, were constituted by random number generator. In doing so, it was possible to create the whole class of works where graphical outputs have common ground characteristics but are different in their details. Moreover, this method of image-generation allowed Mohr to produce unpredictable works, without repeating twice the same figure. Concluding, it can be said that all steps within Mohr's process of creation are mathematical operations.

Although Conceptual art is similar to computer-generated art mathematically oriented, it shares, as Grant D. Taylor (2014, p. 65) observes, only a "spiritual relationship" to mathematics. In one of his theoretical works, Sol LeWitt confirmed that Conceptual Art does not have "much to do with mathematics, philosophy, or any other mental discipline" (LeWitt, 1967). Moreover, LeWitt maintained that Conceptual Art does not necessarily proceed in a logical order. In this context, he pointed out that conceptual artists are "mystics rather than rationalists. They leap to conclusions that logic cannot reach" (LeWitt, 1967). 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 Dadaism refers to a pure chance, random numbers of early computer works are used in terms of computational logic, namely in the sense of so-called pseudorandom, where the chance is partially controlled.

Concluding, it can be, therefore, outlined that the use of algorithmic procedures in Mohr's computer art is clearly grounded on a scientific base, while algorithmic approach within Conceptual Art and Dadaism is to be considered rather pseudoscientific.

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