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Behind the Canvas: an Algorithmic Space

Reflections on Digital Art

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The great conservative friend of art and architecture, Sir Ernst H. Gombrich, in his popular *Story of Art*, has no more than one line to spend on the great Marcel Duchamp, the artist now often considered to be one of the most influential artists of the twentieth century.[1]

What Gombrich mentions in that line is Duchamp's invention of a new kind of object that he presented as possibly an object of art or, at least, as an object to be exhibited alongside with works considered to be works of art. Duchamp gave the name *readymade* to the newcomer. Art lovers know some of those, and certainly the most scandalous: the urinal, bought from a hardware store in New York, given the title *Fountain*, and conspicuously signed by an *R. Mutt 1917*.

The Tate's series of treatises, *Essential Artists*, dedicates popularly written books to individual artists whose work has contributed more to the history of art than that of others. The introduction to the Duchamp book in this series begins by claiming: ‘Well before the end of the twentieth century, the reputation and work of Marcel Duchamp (1887-1968) had surpassed those of Picasso in the eyes of art historians, artists and Duchamp's admirers alike, [...]’.[2]

To the hero of twentieth century art, Pablo Picasso (1881-1973), so surpassed by his younger contemporary Duchamp, Gombrich dedicates several of the precious pages of his book, plus some representations of works. He celebrates the Spaniard’s work and explains the cubists’ many versions of their favourite subject, the guitar, as constructions rather than representations. In order to make their works understood by the ordinary spectator, Gombrich tells us, the cubists had to choose simple and familiar objects from everyday life like guitars, bottles, or fruit-bowls. ’Not all people enjoy this game, and there is no reason why they should. But there is every reason why they should not misunderstand the artist’s purpose.’[3]

It seems as if to Gombrich Picasso’s art was traditional enough to demand from the spectator a serious effort at understanding intention and motivation of the artist, even if the result of this creative intention was incomprehensible to the spectator. We may only speculate that Duchamp's intention, on the other hand, was obviously not of this kind for Sir Ernst.

A piece of art, everyone will most likely agree, must first be an artifact, an artificial product, some sort of thing made by a human. The work, as a finished product, is the result of work spent as an ongoing process and eventually stopped. The kind of work that we are ready to call a work of art is assumed to be the result of an individual's skilled and innovative labour. But the skilled and innovative labourer, Marcel Duchamp in our case, successfully tried to escape this ubiquitous relation of work and artist. In the year 1913, he asked himself if it was possible to *create* works without necessarily producing works *of art*.[4]

Duchamp, in order to avoid intention and intuition, played with randomness. Processes that were obviously not directly influenced by a human should be considered as powerful in generating patterns, arrangements, or compositions as a human's work would be. It is well known that Duchamp's next step, after having come to this conclusion, was to go to a bicycle store where he bought a bicycle front wheel which he mounted on a simple kitchen stool. So the bicycle-wheel became the first of Duchamp's readymades, even *avant la lettre*. The term *readymade* itself appeared in Duchamp's terminology only two years later.

Visual Space and the Space of Art

Why write about the readymade, when our topic is digital art? Do I suggest parallels? Do I see an element of similarity or analogy between Duchamp and the digital? Do I want to draw a line from the 1910s to the 1960s, when digital art was first shown in galleries?

In a way the answer is: yes – I would like to draw a comparison. Have a look at Fig. 1. It shows a computer-generated drawing by Georg Nees, usually dated 1968/70.[5] This drawing, though it is not from 1965 (the year when computer art first appeared in public) has become one of the better known from that world (or space) of algorithmic art. Its creator, Georg Nees, is credited with having mounted the first exhibition ever of this kind of work. It opened on the 5th of February, 1965, at the *Studiengalerie* of TH Stuttgart (later called University of Stuttgart).

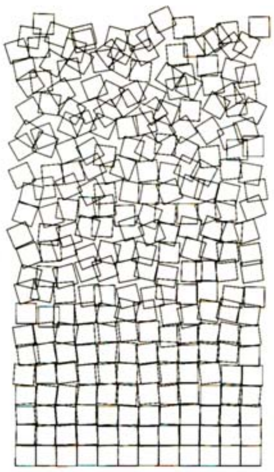

Fig. 1. Georg Nees, *Schotter*. Computer-generated drawing 1968-1970. Original size unknown, subsequently issued as silk-screen print 90 x 69 cm. By permission of the artist.

The *Studiengalerie* was located in the seminar room of Max Bense´s philosophical institute. He used the room to invite artists to participate in experimental shows of mainly concrete and constructivist art.

For the occasion of the not very comprehensive exhibition – only about a dozen drawings of small size were on display – a small brochure was published by *edition rot*, a series of experimental texts on aesthetics, concrete art and literature, and semiotics.[6] The brochure contained a short text by Bense under the title, *Projekte generativer Ästhetik*, and half a dozen of Nees's drawings together with short indications (in plain language) of the algorithms used to generate the graphics.[7]

The word *art* was carefully avoided by Bense and Nees. Nees had to do this because his employer, Siemens AG, did not want to be connected with the term when the subject matter, from their point of view, was computers. Incidentally, something similar happened to artists working for the Bell Laboratories in Murray Hills, perhaps in their case only on a larger scale.[8] Bense, of course, did not as a professor suffer such restrictions. He preferred to talk about *aesthetics* as a scientific endeavour, whereas *art* was a subjective value judgment. So he avoided the term almost entirely. However, he coined the term, *artificial art,* to distinguish works that came out of a computer from those that had never seen one.

Returning to the drawing by Nees (Fig. 1), we see a composition whose elements are squares of equal size located more or less regularly across the paper format in 22 rows of 12 squares each, adding up to a total of 264 squares. The closer we get to the top, the more those squares seem to be leaving their original position on a regular grid. At the same time they are rotated by apparently increasing random angles. Whereas the bottom line displays its dozen squares very regularly on a grid of exactly the size of the square with only a tiny variation, the second line already shows some small rotations.

The variations gradually increase up to line 7 (from the bottom), when the first larger overlaps occur which, in the sequel, become wilder and wilder. The regular structure near the bottom dissolves. In fact, we may interpret the drawing as a screenshot of an arrangement of 22 x 12 squares permanently shivering, twisting, and dancing. The further away from their stable and conservative origins they are situated, the more freedom they seem to have for their movements, or they allow themselves to conquer.

Intention, intuition, and randomness were three important terms in our brief account of Duchamp's readymades. With these three terms, we can now establish a bridge from the genius of Marcel Duchamp to the sober engineers of early digital art.[9]

Duchamp wanted to detach himself from his own intention and intuition as the driving forces behind the artist's creative activities. Therefore, he embraced randomness as a source and means for the decisions an artist or designer is constantly required to make during his creative process. If challenged hard enough, he would still have to admit that somewhere along the chain of actions he must obey his deliberate decisions, and through them follow his own interest, purpose, intention, intuition, or whatever word he would choose for this kind of influence. Whenever we do something, be it of the most trivial or of the most unknown kind, there is always some kind of intention involved, or else we don't even start.

Let us assume someone begins the activity of painting. Why did he start it, instead of doing nothing, or doing something completely different? He may not be able to identify a reason, or refuse to do so. But before he started, he went to get the materials and arranged them in a way favourable for his next activities. Even if he was forced under torture to do what he would not want to do, his motive for doing it would, nevertheless, be the intention to hopefully escape from even heavier pain.

Once a person is getting ready to start an activity of some sort, such as a series of steps involving simpler actions and operations, what would cause him or her to start with exactly this operation, and not its opposite or some other alternative? Numerous reasons may be given, but whatever they are, decisions must be made and thus intentions are involved.

There is, however, an important difference between Duchamp in the early twentieth century and the programmer, some fifty-five years later. The programmer is describing operations that a machine – the computer – is later supposed to carry out. The programmer is *thinking* of operations, whereas the (traditional) artist is actually *carrying* them *out*. For the programmer, these operations must necessarily become more explicit. In fact, they must become as explicit as they could possibly become. A machine is the ultimate test for the correctness, or validity, of the description. If the machine's execution of the description (called the 'program') does not lead to a result of the kind the programmer had expected or hoped for, the description was not clear, or precise, or unambiguous enough.

Even worse, whatever the machine does, and however much the results of the machine's operations may differ from the expectations or non-expectations of the programmer, the results are what was implicit in the description.

One bridge between Duchamp and the programmer-artist one or two generations later thus is the bridge of voluntarily giving up some control. Instead of acting and operating himself in order to change the state of some material, the artist-become-programmer is only describing what could possibly be done. Whether or not this gets done, is a different issue.

We could interpret Duchamp's final step in his career of turning his back to the canvas in favour of the chess board as his melancholic declaration of an end of painting *as* painting. Perhaps he entered a waiting loop waiting for those who would come to sit next to his table, with no canvas, no paint brush, no paint in sight or smell, but busy writing strange hieroglyphs on their sketchpads of which nobody else could make sense.

Duchamp had alienated many when he took mass produced things and offered them, through his particular arrangement, to be considered as aesthetic objects.[10] The readymade, through such an act of transformation, loses its intended use in the world of commodities. It is deliberately turned into a useless state, or into a state where its newly intended use leads to fun or near-catastrophe.[11] The readymade, in its new context, gains a different reality, one beyond its ordinary reality. That is exactly what art is about. The urinal remains a product of work; it indicates a possible use in everyday life of which it now has become a sign; but it also belongs to the space of art, where it acquires another sort of interpretation.

Across the river, on the other side of the bridge, the artist-programmer is waiting to turn another readymade, the huge machine of mental labour (the computer), into a source of aesthetic objects (works of art, if you like). All that this revolutionary step took, in the middle of the 1960s, was the decision to draw without drawing, to paint without painting, and to sculpt or shoot movies without sculpting or taking pictures.[12]

Intuition stands, perhaps, for the not so conscious decisions during a generative process. An idea springs up like a spark, a surprise, an unexpected flash of no particularly logical train of thought. We often think of intuition as leading to good, secure, and convincing creative elements and structures. We may from hindsight explain why it worked, but we cannot explain how and why it occurred, and the explanation *a posteriori* is always a weak one.

We call such influences on our activities *intuition* because we do not know better. They are obviously close to another sort of influence on events and happenings around us: randomness. Randomness is a second bridge from Duchamp to algorithmic art.

When you write a program to generate drawings, it does not make much sense if your program is capable of generating exactly one and only one drawing, and not a second and third one of a similar kind, yet clearly different. The effort – and often drudgery – of writing a program makes sense only if you think of an infinite (or very large) class of drawings. The program is great design insofar as it stands for infinitely many drawings (or other results of processes) that share some features but are different in others. As algorithmic (programmed) art, art has entered a totally new era. It is a sort of conceptual art but different from conceptual art because concepts have been made machine executable. Machinic concepts, or algorithms.

Historically, each of the three artists to first exhibit computer art – A. Michael Noll, Georg Nees, and Frieder Nake – to a large extent used random number generators. Unknowingly, they became Duchamp's sons when they replaced intuition by random number generators. Nake repeatedly wrote about this idea.[13]

Much of the (visual) art of the twentieth century appears as journeys and explorations into a general visual space. Artists showed and told us of so many different ways of looking at things, that seeing and observing became a permanent feast. The particular visual space we seek and find in museums – the space delimited by canvases, prints, sculptures and videos – is no longer all that can be detected and admired. Those tangible pieces define the trivial aspects: the visible surfaces of visual space and its subspaces.

But artists told us of deeper and hidden layers that, they claimed, are more essential. Space is a much richer concept than the naked box of mathematical space. Space is stories, events, lives, theories and practices, success and failure, happiness and despair. The visual artist contributes to the construction and structure of visual space by establishing painted canvases as boundaries and, thus, challenges. Cultural processes, like spiders, build their webs around the paintings and through them. In controlled and, at the same time, uncontrollable ways, they take the *artist's work* and transform it into a *work of art*. The artist is occupied by his *work*, only society lets it become *art*.

This societal interaction seems to be a sort of process we will never fully understand. We understand a lot about it, and each epoch creates a new way of understanding. But in the end, we are left with eyes wide open. Marcel Duchamp must have understood a lot of this.

Algorithmic Space and Algorithmic Sign

We may interpret the traditional visual space of art as an ensemble of painted canvases, sculptures, video screens, and prints meeting in a cognitively and culturally determined space. We may do so in spite of repeated re-evaluation, re-description and re-organisation like a permanent reshuffling of the growing inventory of art works. Their space remains rather stable and static. Artists know and feel this, and are always on the alert to change things.

With the advent of the computer, however, the situation has changed in unprecedented ways. It took a while before we began to understand just what the changes are. An exhibition at ZKM (Centre for Art and Media) in Karlsruhe, Germany, with the title *The Algorithmic Revolution* was a clear statement to this effect.[14] A revolution had taken place of great impact on all fields of cultural (and thus societal) existence, but hardly anyone had taken notice of it. Now the algorithmic principle, often called the digital, is with us. We cannot avoid it even if we resist.

There had, of course, been many shows and books before that prepared the ground for a new understanding of visual space. Such events include, for example, the shows *Software* and *The Machine as Seen at the End of the Mechanical Age* in New York, 1968. Or, in the same year, *Cybernetic Serendipity* in London and *Computers and Visual Research* in Zagreb.[15]

These shows, among others, developed the first feeling that the canvas, the print, and the sculpture were no longer alone in defining the space of visual art. Op art, kinetic art, concept art, the happening, video art – they all contributed to discoveries in visual space. They prepared the ground for expansions of art, as it was called.[16] Visual space is what expanded. But those art movements often remained essentially where Duchamp had already been.

The new principle created the *algorithmic* space, together with the creature that inhabits algorithmic space: the *algorithmic sign*. What is new about it?

The algorithmic sign is a sign with a double existence. Something is a sign only when an interpreter takes that something as a sign. Any thing, any phenomenon can become a sign when it is used in a process that takes a first to relate to (or to stand for) a second in such a way that an interpreter may generate a meaning from this relation. The process of interpretation itself creates another sign, called the *interpretant*, which is part of the sign. At the same time, the interpretant transcends the original sign situation in a semiosis (sign process) of principally unlimited character.

This concept of the sign as a triadic relation is the work of Charles S. Peirce (1839-1914). He is considered the father of modern semiotics. His concept constitutes the sign as a representamen (the first that signifies), an object (the second that is signified), and an interpretant (the third that is intended or concluded). Peirce's sign is a recursive process without start or end. It is culture happening. All that is solid melts into air.[17]

Now, let us look at computers. They are machines, first of all. Computers are machines to compute the values of computable functions. The computable function was an important definition (invention, really) by several authors in the 1930s, notably by Alan M. Turing. His definition of computability relies on the concept of a paper machine that he described. It is so simple that it is hard to believe that Turing machines can be used to (symbolically) compute everything that can, in an intuitive sense of the word, be computed at all.

Turing, Alonzo Church, and others in the 1930s helped mathematics to escape from a deep crisis of its conceptual basis. They solved the question of what to compute could mean, or what a strictly formal rule could be. The crisis had started with the formulation of some set-theoretic anomalies by Bertrand Russell and Alfred North Whitehead, and a series of unsolved problems by David Hilbert. Five years before the construction of the Turing machine, Kurt Gödel had discovered principal limits of formalisation, and thus of the belief that the world can completely be described mathematically.

The world ever since knows that there are definite limits to the Western belief of continued progress in formal theory. On the other hand, the Western mind also knows *exactly* what it is doing, and how, *when* it is doing something precisely.

This is the point where the computer enters. It takes as input cases of the relations that humans call *signs*. It turns signs into signals, i.e. into signs without meaning that stand for themselves, or that mean what they are. Those signals are usually called *data*. The computer transforms data, and outputs the results of such transformations. The results – which, from the computer's point of view, are data again – upon leaving the computer immediately become signs again if a human is watching. As humans we cannot but interpret. We are, as Felix Hausdorff has said, semiotic animals.[18] The computer, at the other end of the spectrum, turns out to be a semiotic machine.[19]

The computer is a semiotic machine insofar as it is capable of accepting signs, transforming them, thus creating new signs, and generating these in perceivable form. The only problem is that the computer is not really capable of dealing with signs. Only in the form of the grossly reduced signal can the computer be claimed to manipulate signs. It is lacking any capacity for interpretation in the same sense that we interpret. When the computer is engaged in something like a *formal* interpretation, what it is doing boils down to a *determination*. The one and only interpretation the computer is capable of doing is exact and determines what is to be done. There is no interpretative decision in the computer's operation. This incapability is not a flaw, nor a weakness of the computer. The computer is a machine. As a machine, we want to know what it is good for. Its weakness is its strength: when we interpret, it determines. We make up our minds as living beings, it, as a functioning automaton, makes up for our unreliability.

So the algorithmic sign results when both a human and a computer are 'looking' at a sign. When they do so, they generate new signs and signals. The algorithmic sign creates one interpretant coming from the human, and a second interpretant coming from the computer. The first (human) interpretant may be called *intentional*. The second (machine) interpretant would then be the *causal* interpretant.

The algorithmic sign is in constant motion jumping back and forth between its two interpreters. Better: they operate in parallel and they are, in such algorithmic processes, loosely coupled in the semiotic domain. This is algorithmic space.

Algorithmic Art by Example

In this and the following section, we return to art, but now in algorithmic space. We will indicate by example two kinds of aesthetic production that must be explained in their specifics from the perspective of algorithmic sign. These two art movements are *algorithmic art* and *interactive art*. The first is the historic beginning of digital art; the second is the first non-traditional kind of algorithmic art.

Algorithmic art is art generated by an algorithm. We usually know algorithms in the form of programs running on a computer. The program must have been designed and implemented by a human. We may safely say that a program is the machining realisation of an abstract schema describing an entire class of visual works. Each execution of the program requires the concrete specification of all its input variables. The program describes the operations and the sequence of their application. The input describes the operands the program is applied to. The program says what the transformation is; the input says what is to be transformed.

When we say that there is a difference between algorithm and program, we emphasise the following facts. The algorithm is a rather general, but extremely precise, and abstract description. It can as such not be executed. The algorithm's description is the abstract form common to all its concrete implementations as programs. Each of those programs has an invariant, the algorithm. Algorithms are for us to read, programs are for machines to execute.

Fig. 2. Manfred Mohr: P-707/F. Computer-generated painting 2001.
Endura-Chrome on canvas, 140 x 143 cm. By permission of the artist

Figure 2 shows a work of algorithmic art by New York artist Manfred Mohr. He designed the program that computes this and similar images on a graphic display unit. It is, of course, one in a long sequence of images. Mohr decided to have this particular one realised materially in large size on canvas using digital printing devices of high quality.

The one image chosen here is similar to other realisations of the same program in an abstract sense only. A structure and a process are common to all the images from this program (the artist calls it *P-707*). Let us indicate the structure and the process, and thereby the algorithm.

Consider six-dimensional space: a space of six dimensions (6D).[20] Consider a cube in that space. It possesses $2^6 = 64$ vertices. Mohr's program selects one vertex at random and determines its opposing vertex. The program further creates a 'diagonal path'. This is a path from the first vertex to its opposing vertex. The path consists of six edges because we are in 6D space. Each of those edges brings us closer to the end of the path in one of the six dimensions.

Mohr's program actually chooses four diagonal paths from the set of 180 that are possible between two opposing vertices. Number the paths by I, II, III, and IV. Number the vertices along each of the paths as 1, 2, ..., 6 where 1 is the start and 6 the end. Now connect vertex I.1 with II.1, then on to III.1 and to IV.1, and finally from there back to I.1. You get six such connecting polygons. Together with the four original diagonal paths, the connecting polygons define a set of 24 'areas'.[21] You do not see anything of this: it happens in algorithmic space.

Having described to the program how to create the set of 24 areas, Mohr takes the decisive step – in his mind – before he proceeds to the actual image. He has his program choose at random a colour for each of the 24 areas. The choice is from a larger palette of colours established ahead of time.

We now have, in 6D space, an arrangement of abstractly coloured areas, which are, in some specific way, neighbours of each other. The program takes a final step by projecting the coloured areas down to the flat 2D picture plane. The result appears, finally coloured not only abstractly but visibly on screen. The artist neglects it or selects it for material production.

This sounds like a very simple procedure. You may claim to have no idea what it feels like to be in 6D space. You may also wonder how the program realises random choice. Although this is a simple matter, it will not be explain here.

For our current discussion the only interesting point is related to the algorithmic sign. As long as the generation of picture *P-707/F* progresses, the picture is in the state of an algorithmic sign. It exists twice: it is *visible* on screen and, at the same time, *invisible* in computer storage. The two modes of the one image are related to each other in a one-to-one relation.

The visible mode is for us to view in delight (or despair). The invisible mode exists for the computer processor without any emotion.

The fact of the two modes of existence allows the artist to immediately, in almost no time, change the image. We have designed *device-X* which allows you to interactively move from one rendition of the image to another one (Fig. 3). The software device marvellously helps to view the geometry *and* the topology[22] of one of those Mohr paintings.[23]

With the concept of visible *sur*face and invisible *sub*face, as we call this, we distinguish two modes of the algorithmic sign. The algorithmic image possesses the strange property of carrying inside of itself some aspects, important ones, of its own description. If we may say of the picture realised as a painted canvas that this piece of matter, at first sight, is what it is and nothing else, we can hardly make the same statement of the algorithmic picture.[24]

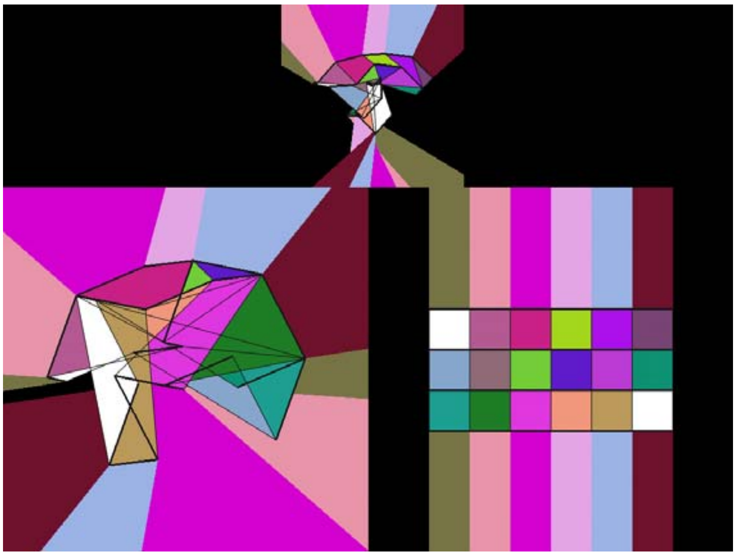

Fig. 3. Matthias Krauß: device-X, applied to a painting by Manfred Mohr.
Software developed in project compArt, Bremen 2004

Traditional art history and theory have relied on descriptions of paintings, and have generated many. Each one of those descriptions is a human's interpretation. The interpretation is a sign produced in consideration of the given work. The painting's description is, of course, totally separate from the painting itself.

The algorithmic sign, however, owing to its very nature of an algorithmic entity, also allows for the computer to manipulate the algorithmic subface that we may know of, but to which we have no access. The algorithmic sign also allows for all the interpretations and utterances that humans produce when they are confronted with a picture.

Interactive Art by Example

Another example of digital art is no longer of the traditional and somewhat boring character typical of the painted canvas, even if it is digitally printed and owes its existence to an algorithmic process. Early computer art was almost exclusively done on paper or photo-paper. It was exhibited the traditional way in galleries. Critics, therefore, often did not pay much attention to those brave but old-fashioned appearances on the walls of galleries. They were right, but only because they did not have much imagination. They essentially did not understand a thing. They were not ready to realise the algorithmic revolution which was hiding undiscovered in those early works of digital art.

Here is our more advanced example, see Fig. 4. It allows a view into a lab. You see a person moving not very decidedly, looking at a white wall onto which something gets projected. Unfortunately, the figure does not yet show much. This is due to the fact that we are reporting here about work in progress. The situation is as follows.

Fig. 4. Kolja Köster's experiment with an interactive installation based on carpet-HB. Part of his thesis work, Bremen 2008.

The visitor steps on a small 'carpet'. As soon as she is doing so, something happens to an image projected onto a wall that she was not aware of before. She develops an interest in the situation between herself and the image. How do her movements change the projection? To experience correlations, she starts moving on the carpet, back and forth, left and right. She observes that pressure affects the appearance of the projected image. Several persons may stand on the ‘carpet’ at the same time.

The image is vaguely reminiscent to Georg Nees's graphic in Fig. 1, consisting of squares of equal size on a regular grid. The presence of persons on the pressure-sensitive ‘carpet’ (serving as an input device with 64 hidden sensors in an 8-by-8 grid) creates a pattern of input signals. They can be interpreted in any of a large number of modes.

The interactive program in this example is waiting for input from the feet of passers-by. When such input signals appear, they cause the selection of a mode for further manipulation. As long as visitors move on the carpet, the mode remains the same. This causes permanent transformation of pressure input patterns into visual appearances. The situation allows for considerable complexity. Our intention is to store a large number of computer art works from 1965 and interact with them through movement.

What, in conclusion, do these two examples demonstrate? They demonstrate that in either case the works of computer art are algorithmic signs: Janus-headed creatures. The examples further show how the subfaces of the algorithmic signs are being treated differently in the two cases. The older algorithmic art example requires a simple input. It can be activated by a set of numbers or choices.

The interactive art example, on the other hand, requires a visitor's presence and continued activity. Input signals from the participant are not discrete signals any more. The visitor is permanently producing them. The subface of the interactive art is, thus, in permanent exchange with visitors. The work is loosely and semiotically coupled with visitors.

This semiotic coupling brings the interactive work of art to the current height of digital media. The work itself is a process in constant flux as long as visitors are active. The work's dynamic behaviour collapses almost immediately when visitors leave.

The interactive work relies in its visual appearance on continued activity by visitors. It thus demonstrates two principles of art of the twentieth century extended into the digital era: first, it is the spectator or the audience who finishes the work; and second, the work remains in a state of unfinish.

The first principle became more and more common over the last century. Marcel Duchamp was, again, among those who early and clearly formulated the active role of the audience. 'All in all, the creative act is not performed by the artist alone; the spectator brings the work in contact with the external world by deciphering and interpreting its inner qualifications and thus adds his contribution to the creative act.'[25]

The second principle of the state of unfinish was formulated by Peter Lunenfeld in his introduction to *The digital dialectic*.[26] The aesthetics of digital media, he suggested, will be an aesthetics of unfinish. The work is no longer interesting in its form as an individual piece on the wall. It has become a process in itself. In the interactive work, the process appears visibly. The subface becomes more and more important for the aesthetics of visible surface. It is the locus of the algorithmic power of a work. The algorithmic power is constituted by the potential built into the invisible part of the work. It is responsible for the incessant changes of the surface, and thus for the kind of universe caught and trapped, as an infinity, in the work.

Behind (and beyond) the canvas we enter a second space. It is an algorithmic space, first. It is further a space of interpretation, the social space of history where the material work, released by the artist and exposed to its critics, is becoming the work of art. The work of art *now* appears as the (permanent or temporary) interface between the visual space and the algorithmic space. Some of our interpretation has migrated to that other space. Mind you – only computable aspects can do this.

Acknowledgements

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Notes

[1] Gombrich, E.H. (1950), *The Story of Art*, London: Phaidon. This is the most widely distributed book on art of all times.
[2] Parkinson, G. (2008), *The Duchamp Book*, London: Tate Publishing, p. 6. – The neglect of Duchamp by Gombrich, mentioned above, was even more radical. The 1950 English edition does not mentions the French artist at all. A single line appears in the German soft-cover edition of 2000 on p. 601.
[3] Gombrich (1950), p. 433.
[4] Tomkins, C. (1997), *Duchamp. A Biography*, London: Chatto & Windus, quoted after the German translation (Munich: Carl Hanser 1999, p. 157).
[5] The drawing was first published in Nees, G. (1969), *Generative Computergraphik*, Ph.D. thesis, Berlin, München: Siemens, p. 242. The thesis was defended in philosophy at the

University of Stuttgart, 1968. It is, in all likelihood, the first doctoral thesis on a topic of computer art. A reprint was published as Nees, G. (2006): *Generative Computergraphik*, hrsg. v. Hans-Christian von Herrmann & Christian Hoffmann as vol. 6 of *Kaleidoskopien*, Berlin: Vice Versa. Georg Nees added a new essay to this edition. For more information about an emerging history of computer art, see Herzogenrath, W., and Nierhoff-Wielk, B. (eds., 2007), *Ex Machina – Frühe Computergrafik bis 1979*. *Die Sammlungen Franke und weitere Stiftungen in der Kunsthalle Bremen. Herbert W. Franke zum 80. Geburtstag* (in German and English), München: Deutscher Kunstverlag, p. 440.

[6] Bense, M., and G. Nees (1965), computer-grafik, Stuttgart: *edition rot* no. 19, eds. Max Bense and Elisabeth Walther.

[7] An English translation of this first manifesto of computer art (as I don't hesitate to call it) was published in a special issue of *Studio International*, 1968. The publication coincided with the seminal exhibition, *Cybernetic serendipity* at the ICA (Institute of Contemporary Arts) in London.

[8] A. Michael Noll and Bela Julesz, cf. note 9.

[9] Two more exhibitions took place after the Georg Nees show held between 5 and 9 February, 1965. In the same year, from 6 to 24 April, A. Michael Noll and Bela Julesz from Bell Labs had a show at the avant-garde Howard Wise Gallery in New York. Frieder Nake and Georg Nees exhibited at Galerie Wendelin Niedlich in Suttgart from 5 to 26 November, 1965. – On digital art see also Franke, H.W. (1971), *Computer Graphics – Computer Art*, London: Phaidon; Spalter, A.M. (1999), *The Computer in the Visual Arts*, Reading, MA: Addison-Wesley.

[10] Mind you, the urinal, when it was ennobled to become a piece of art, was a brand new one. It did not show any traces of ever having been put in use. Painters had long lived in peace with their industrialised tubes of paint. Why should sculptors not be allowed to buy things and arrange them in surprising ways.

[11] Duchamp liked fun and irony. He arranged one replica of the original fountain (which got lost) in such a way that, should you use it to urinate, you would get wet shoes (or feet if you didn't wear shoes); cf. Tomkins (1997)

[12] The latter, by the way, was already a machinic process.

[13] Most comprehensively in Nake, F. (1974), *Ästhetik als Informationsverarbeitung*, Wien, New York: Springer Verlag.

[14] ‚The Algorithmic Revolution' was on display from 30 October, 2004, through 31 January, 2008.

[15] Nine Evenings: Experiments in Art and Technology, 69th Regiment Armory in New York City, 13-23 October 1966 – Software, Information Technology: Its New Meaning for Art: Jewish Museum New York City, 1970 – The Machine as Seen at the End of the Mechanical Age: Museum of Modern Art New York, 1968 – Cybernetic Serendipity: ICA London, 2 August to 20 October 1968 – Tendencies 4 & 5, Computers and Visual Research: several symposia, exhibitions, a magazine, from 3 August 1968 to 1 July 1973 with a final symposium on 13-14 October 1978.

[16] To mention only two: Youngblood, G. (1970): *Expanded cinema*, New Yoek: E.P. Dutton 1970. Claus, J. (1970): *Expansion der Kunst*, Reinbek: Rowohlt. Artists as, e.g., Joseph Beuys or Bruce Naumann, in their public actions greatly expanded the meaning of art.

[17] This is a beautiful metaphor from the *Communist Manifesto* by Karl Marx and Frederic Engels.

[18] Hausdorff, F. (P. Mongré) (1897), *Sant' Ilario – Gedanken aus der Landschaft Zarathustras*, Leipzig: C.G.Naumann.

[19] Nadin, M. (undated), Semiotic machine, *Semiotic Encyclopedia Online*, seen on 5 November 2008. – Nöth, W. (2002), Semiotic machines, *Cybernetics and Human Knowing* 9 (1), pp. 5–22.

[20] We deliberately say 'Think six-dimensional space' and not, 'think of six-dimensional space'. Here, the human mind only creates that space mentally. We cannot experience it

differently. In particular, such spaces cannot be visualised. Spaces of higher dimensions are a purely mental concept.

[21] The areas are quadrilaterals in 6D space.

[22] We want to caution the reader. We cannot *see* topology, nor geometry. We can see only visualisations of them.

[23] Mohr calls the series of these images *colour.space*.

[24] Be aware of the formulation 'at first sight'. At first sight, we don't become aware of the subface.

[25] Duchamp, M. (1973), *The Writings of Marcel Duchamp*, ed. by M. Sanouillet and E. Peterson, Oxford University Press.

[26] Lunenfeld, P., ed. (2000), *The Digital Dialectic*, Cambridge, MA: MIT Press.