The Computer: A Tool for Thought-Experiments

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Abstract: Trajectories into the future of art are projected by investigating the basic question: How does computer art differ from traditional art? The author proposes that the computer as a symbol-processing machine is capable of simulating mental acts similar to the creative activity that is embodied in a work of traditional art. Therefore, the computer artist becomes empowered not only to craft a particular art object with the computer but rather to design another art subject in the form of a machine that is autonomously able to perform artistic activities and create art objects itself.

I. PHYSICAL - SENSUAL - MENTAL

"While in the process of making a work the artist might be said to 'experiment' with his own sensibilities" [1]. Twenty years ago, Frank Malina summarized his artistic credo in this statement. The astronautic scientist Malina transposed the principles of experiments into the sphere of art and maintained that they are valid operations in art as well as in science. Malina considered art and science equally as testing grounds for the unknown, differing only in their subject matters. Whereas he viewed science to be concerned with knowledge, for him art occupied the realm of the senses. Malina's interest was primarily to investigate kinetic art as a way of dynamically changing visually perceivable phenomena. In kinetic art, the physical arrangement of a specific contraption is moving and thus constantly prompts the senses of the viewer to adapt to altered perceptions of the object's states determined by its physicality even if it is as intangible as light. By contrast, in computer art the physical boundaries of the architecture of the machine are bypassed by the fact that it is a symbol processing system.

The processing of symbols, understood here as formal tokens, constitutes the computer as a dynamic system of a very different type; what is being moved and changed by a digital computer is the particular organization of these binary tokens - elsewhere I define them as 'data particles' to emphasize their ontological status as the urform of informational matter [2] - as well as their representational function. The dynamic and non-physical change of the symbols' syntactic and representational structure, has repercussions for their cognitive value. Let me then expand on Malina's notion by including 'mentalities' into his concept of experiments in the arts. After an apparently innocent transformation, his statement reads: While in the process of making a work the artist might be said to 'experiment' with his or her own mentalities.

The computer's potential for symbol processing causes a significant reversal from the physical to the mental and vice versa by visualizing the structural state of the symbols. The act of transposing the internals of the machine into the sensual domain of humans is called, in today's jargon, simulation, if it follows rules found in reality and derived out of the lawful relation between physical objects. On one hand, the repercussions of digital simulations are an ever-increasing dematerialization of, among others, aesthetic activities and objects. On the other hand, they provide sensuously apprehendable simulations in situations where scientists previously felt compelled to check theories with thought-experiments because the instrumentarium used to conduct and measure physical experiments was inadequate to provide measurable data. With Malina I acknowledge experimentation to be a fundamental method in science and in art. This includes the legitimate appropriation of any technology for artistic purposes and the application of suitable procedures to experiment with these technologies in order to find visually meaningful expressions. But, being a child of today's proliferation of computers in all scientific and social domains, I shall stress the meaning of experiment in terms of simulation of the unknown.

Especially in the early times of quantum physics, thought-experiments were frequently used as a potent heuristic strategy whenever a new theory tried to explain results obtained with inadequate measuring instruments. "A thought-experiment is a mental exercise. It has the advantage of requiring no apparatus other than the mind, which frees it from the practical limitations of laboratory experiments" [3]. Thus, theoretical assumptions could be tested for their logical consistency. By the same token, and possibly more important, thought-experiments enabled physicists to use their imaginations freely as a methodical means to invent new hypotheses to guide future experimental designs. Imagination often was brought to bear in form of the visualization of properties that could not be grasped in reality but only contemplated in the mind [4, 5].

Digital simulation carries a similar heuristic principle: it makes sensuously apprehendable something that does not really exist. The kind of real, but simulated objects and their behavior as a computer simulation could be dubbed 'aesthetic reality', a term coined by the philosopher Max Bense [6]. Bense used this term to refer to works of Concrete Art and to identify their ontological being as aesthetical, i.e. they are made 'concrete' for and consumed by the senses; their physical reality exists only for this singular purpose. In conjunction with computer simulations, I use 'aesthetic reality' in the very literal sense of the words: simulations exist only as aesthetic objects and do not possess any concrete reality. In short, though simulations are not corporeal. nevertheless they are sensually existent.

Writing this essay, I am conducting a thought-experiment in the sense that I am envisioning and mentally testing my theories in regard to the question, How does computer art differ from traditional art? Challenged to write this article in the context of *the future of art*, I began to perceive that what was called for was a scrutinizing look at the very fundamentals of art, mind and machines. Only by revealing them, I think, can we attempt to venture beyond the surface criteria that seem to dominate much of the contemporary discussion about computer art. The 'look and feel' of computer generated imagery is less interesting to me than projecting extrapolation from known basic digital-symbolic functions into the future potential of this new medium. Acknowledging the generative power of computers, I consciously limit myself here to only the productive aspect of computer art, even though I am aware that this art form also poses new questions in regard to the completion of the aesthetic communication cycle, particularily in terms of symbolic meaning and understanding by humans and machines. So please, follow me through this thought-experiment - designed as a 'guided tour' rather than a 'Brownian walk' - with an open and critical mind. You are welcome to question my reasoning along the way, but you should be self-reflective and continuously examine the basis and consequences of your own opinions. If we leave this experiment with new insight into the potentials and limitations of computers in future art, we both will have benefitted.

Our experiment will travel a route that takes us back to basic definitions of art, definitions that were drastically revised after the introduction of machines that could produce images. After a brief look at how some painters responded to this change by emphasizing the mental properties of the creative act, we turn to three prototypes of computer art to illustrate how programmable machines can be used to experiment with our mentalities. The trajectories from this discussion finally result in my suggestion that the digital artist is not limited to making art *objects* , but can create dynamic art *subjects* , machines that can themselves become autonomous devices capable of creating art. My suggestion is not unique - at least two pioneering computer artists, Robert Mallary and Hiroshi Kawano, anticipated similar ideas; both envision the computer as an independent 'organism' or as an 'art-computer' that makes the art [7,8].

II. ART OBJECTS AND THE THINKING CONSCIOUSNESS

Obvious and inherent contradictions have marked the entire history of art because it has a 'thingy' nature and simultaneously speaks directly to human emotion and mind. Hegel tried to mediate this contradiction by distiguishing the art object from the natural object. Whereas nature simply is, the art object is and also exists for ourselves; thus art serves as a means for the human consciousness to reduplicate itself. Art is then a method of mirroring the thinking consciousness by externalizing its content. And by becoming an external object that presents itself to the mind, art becomes the manifestation and origin of other mental activities. Therefore, the creation of art and its perception can be understood as a dialectical act of becoming conscious of ourselves. We are raising our own consciousness about ourselves to a new level by reflecting it in the form of an external object and by reflecting in turn on this object itself.

In the following discussion, I quote comprehensively from Hegel's *Ästhetik* since I am convinced that his dialectic between art object and thinking consciousness is useful for our thought-experiment, even if we cannot consider the Hegelian system in its entirety here. Hegel says:

> The universal and absolute need out of which art, on its formal side, arises, has its source in the fact that man is a *thinking* consciousness, i.e. that he draws out of himself, and makes explicit *for himself*, that which he is, and, generally, whatever is. The things of nature are only

> *immediate and single*, but man as mind *reduplicates* himself, inasmuch as prima facie he *is* like the things of nature, but in the second place just as he really is *for* himself, perceives himself, has ideas of himself, thinks himself, and only thus is active self-realizedness [9]. [emphasis, here and in all other quotes, in the original]

He then goes on to say:

> The work of art then, of course, presents itself to sensuous apprehension. It is addressed to sensuous feeling, outer or inner, to sensuous perception and imagination, just as is the nature that surrounds us without, or our own sensitive nature within. Even a speech, for instance, may be addressed to sensuous imagination and feeling. Notwithstanding, the work of art is not only for the *sensuous* apprehension as sensuous object, but its position is of such a kind that as sensuous it is at the same time essentially addressed to the *mind*, that the mind is meant to be affected by it, and to find some sort of satisfaction in it. ... For the sensuous aspect of the work of art has a right to existence only in as far as it exists for man's mind, but not in as far as qua sensuous thing it has separate existence by itself [10].

The more the artwork, as a spatially extended object, is contemplated in its compositional unity, the more it loses its raw physical character. The more the formal, compositional unity of the artwork and the objects it represents are reflected upon, the more it consequently becomes a unified object in reflection, i.e. in the mind. Contemplation of the artwork 'dematerializes' the thingy, sensory element of the work, assimilating its unities of reflection into thinking. By thus reflectively bringing the reflexive and compositional unity of the artwork to its fulfillment, the artwork is allowed in the mind to open up or disclose multifarious strands of reflection in the process of the mind itself. Thus, by being assimilated into the mind's reflexivity, the art work evinces dimensions of pure thought which constitute its dialectical 'subjectivation'. The reflective subjectivation of the art object is equivalent to its 'spiritualization': that is, through its assimilation by thought, both reflections and feelings, previously viewed as being in the external work itself, are activated in thought, becoming one with it.

I claim that Hegel's dialectic between art object and the thinking consciousness can be made productive for the contemplation of contemporary art as well as computer art, for the fundamental meaning of art has not changed, even if its topics and methods have undergone significant revolutions. A major change that art has undergone, in particular since the turn of this century, concerns the representational faculties used to model consciousness. From the 'narrative' methods (whether symbolical-allegorical, classical or romantic) known in Hegel's time that were built on top of illusionary depictions of the 'real' world, we have moved to physical-painterly methods that attempt directly to embody mental states without reference to meanings suggested by, but outside, the art object itself. But this change, as dramatic as it may seem, does not affect the fundamental purpose of art itself: to be the tool for self-reflection of the human consciousness.

The British philosopher Richard Wollheim attests to the predominant shift toward the physical in the work of art.

> For the mainstream of modern art, we can postulate a theory that emphasizes the material character of art, a theory according to which a work of art is importantly or significantly, and not just peripherally, a physical object. . . . Within the concept of art under which most of the finest, certainly most of the boldest, works of our age have been made, the connotation of physicality moves to the fore [11].

Wollheim's notion of the physicality of the work of art acknowledges the rejection of representing some aspect of reality in an illusionary manner. The artist, rather, creates a new aesthetic reality with the work which embodies in it the mental properties of the artist. By foregrounding the physical object, we have not surrendered the dialectical claim that the art object represents human consciousness in order to speak to it and be reflected by it. It might be said that modern art models with precision consciousness by following one of two approaches. In the next section we will look more closely at the approach where the art object vanishes in comparison to the mental conceptualization of it. Here, I only want to take note of the other approach whose epitome might be earthworks which, in a very literal sense, use the soil of the earth as the most physical material imaginable. Robert Smithson, a pioneering artist of earthworks, discussed his intentions in an article that characterized his art projects as "a sedimentation of the mind [12]." His remark reminds us that even the most physical art works of today are conceived of as mental representations. So there is no contradiction between conceptualists and earth artists, at least in this sense; both try to model mental events but choose extremely different material in which to craft their thoughts.

Dewey nicely expressed the interplay between matter and thought that constitutes in his eyes the creative act:

> The artist has his problems and thinks as he works. But his thought is more immediately embodied in the object. Because of the comparative remoteness of his end, the scientific worker operates with symbols, words and mathematical signs. The artist does his thinking in the very qualitative media he works in, and the terms lie so close to the object that they merge directly into it [13].

Interestingly enough, in contrast to artistic material, Dewey mentions symbols which he correlates with scientific operations. He could not foresee that the advent of the computer as an aesthetic engine is precisely rooted in the artist's capability of crafting imagery with symbolic 'matter' alone. This symbolizing ability of the digital machine is, in my mind, what distinguishes the computer from any other physical material and is at the same time the condition for the machine's potential to simulate mental activities and to externalize them, just as an artist does in making art.

III. BACKPAGES OF THE FUTURE

The art of the twentieth century is distinguished by a continuous and two-fold struggle of artists to account for the emergence of visual media such as photography, film, television, etc. On the one hand, they attempt to consciously integrate these media and to use them alongside more traditional means. But on the other hand, artists feel challenged to reflect on and to redefine artistic and creative endeavors because new optico-chemical and electronic media are significantly changing what visual representations and the processes of their creation are all about. Many of those most sensitive to the 'machine age' [14] feel threatend by a tendency that Siegfried Giedion's feliticious phrase 'mechanization takes command' expresses [15]. Technological development in conjunction with the uncovering of the unconscious strongly influenced artists' quest to go beyond the pictorial imitation of reality. It is symptomatic that Kandinsky inaugurated a wave of non-representational painting at the beginning of this century by probing into 'the spiritual in art' [16].

Let us first consider, in a cursory and incomplete overview, how the Futurists - vocal champions of the machine age, admirers of the machine's power, energy and speed - responded to the machine's intrusion into the arts. Giacomo Balla, for instance, demanded:

> It is imperative therefore not to halt and contemplate the corpse of tradition, but to renew ourselves by creating art that no machine can imitate, that only the artistic Creative Genius can conceive [17].

Since machines such as photo and film cameras can create images, Balla advocated an art form that 'no machine can imitate'. Such art required in his view, the intervention of the 'Creative Genius'. Clearly, Balla reserved mental capacities for the human species and stipulated special powers as emanating from the artist. Moreover, he emphasized that creativity was the main ingredient ensuring that human-made art remained superior to any machine-generated images. Implicitly, he rejected any form of trompe l'oeil painting, since this was precisely the type of visual representation machines could easily reproduce. The significance of this rejection needs to be seen in light of the fact that techniques to produce an illusionary naturalism were the grand achievements of Western painting and remained valid for several centuries. All of a sudden, what had been the hallmark of visual representation is retired in favor of the immaterial capacities of the artist; the Creative Genius becomes the last bastion against the onslaught of increased machine performance. Having established a position that supposedly guarantees human superiority, the Futurists readily embraced the additional power gained with machines that were firmly, so they believed, under their control.

While Balla nonchalantly posited human superiority in the competition with the machine, Moholy-Nagy, the art experimenter per se, pragmatically practiced a division of labor similar to and incorporating industrial production. For Moholy-Nagy, the only determining factor for a work of art was the 'inventive mental process' involved in its genesis. For its actual production, any available method could be commanded.

> In comparison with the inventive *mental* process of the genesis of the work, the manner - whether personal or by assignment of labor, whether manual or mechanical - is irrelevant [18].

Like Balla, Moholy-Nagy put a premium on the mental capacities of the artist; but whereas Balla poetically insisted on the 'Creative Genius', thus reclaiming some of the lost aura of the work of art for the artist, Moholy-Nagy plainly referred to 'inventive mental processes', using a terminology that would be quite acceptable for today's cognitive scientists. Since the cognitive engagement of the artist is responsible for the genesis of the work, the execution of its realization, whether manual or mechanical, becomes irrelevant. This move enabled Moholy-Nagy to freely take advantage of new materials and production processes. He could even propose and practice, for the first time in the history of art, a division of labor that resembled the division of labor in modern industry, while keeping alive the special status of art.

It should be noted that industrial production is quite different from the apprentice's work within a manufactury so common in medieval times. Not only are machines directly employed, the intimate personal relationship between master and apprentice is replaced by an anonymous business deal between artist and machinist. A second important principle of art has been given up: the craftsmanship of the artist. Previously, craftmanship was the precondition of the artist's intimate and skilled handling of the material; only through this kind of manual expertise could the material be crafted into its expressive form. Now, this handiwork is considered even to be limiting in face of various industrial materials that can better be worked on by a new type of professional with industrial machines. The artist is divorced from materiality and becomes a professional inventor.

More recently, the conceptual artist Sol LeWitt moved beyond Moholy-Nagy's understanding of what constitutes art by claiming that not only is the mental process more important than the physical execution of the work, it is the only condition necessary to actually create the work. The artistic idea alone is sufficient and needs no physical embodiment.

> In conceptual art the idea or concept is the most important aspect of the work. When an artist uses a conceptual form of art, it means that all of the planning and decisions are made beforehand and the execution is a performatory affair: The idea becomes a machine that makes art [19].

Once an idea is considered to be a legitimate work of art, all previous notions about the art object vanish. No longer does it consist of physical material; no longer has an artist or anybody to spend physical energy to manipulate and form the material; no longer has the beholder anything to hold onto. How the idea - the constituting element of the work of art - is communicated is secondary to its very existence as an idea. Actually, as insinuated by Lucy Lippard, the realization contaminates the purity of the original idea [20]. Once made for real, the art 'work' loses its lucidity to convey mental concepts. Here we see the radical ramifications of the ongoing trend toward the mental in art: The object itself dissolves into a transcendental being; what has been the goal in creating art has been completely replaced by the mental process that thinks the art.

This admittedly cursory flashback into the history of twentieth century art demonstrates that artists have consciously severed their ties to physical activity to a point where the result of artistic work does not necessarily need to be embodied in a physically existent art object. The shift from the physical to the mental has been prompted by the arrival of machines that can produce the physical portion of imagery; the artist is still privileged to create the imagination.

Let me then finish this overview with a quote by the Russian painter Kasimir Malevich that reveals his utopian imagination.

> My research has led to the conclusion that Suprematism contains the idea of a new machine, in other words of a new organic engine without wheels, and without power derived from either steam or gasoline [21].

Malevich had recognized the very material of painting as the basis for his aesthetic constructions. He ultimately reduced the image to a single geometric object, the square, painted in the most basic colors, all black or all white. His paintings Black Square andWhite on White are bold painterly metaphors to mark the closing chapter of former representational painting and to open it to the 'non-objective world of pure feeling'. In this speculative-theoretical statement, Malevich remained true to himself when he used the metaphor of an 'organic engine' to describe his dreams of a future painting device. It should be noted that Malevich conceived of this machine as quite different from known mechanical devices by calling it *organic* . Even if he was unable to further qualify his vision, it is clear that he had in mind something that could rival the human organism. His dream machine, too, was to overcome its mere physicality by not being powered by material energy such as steam or gasoline.

Next, we will see how the advent of the digital engine pushes the concept of the artwork and the process of its creations into the non-objective, or more precisely, non-material world of symbols.

IV. THREE CASE STUDIES

In tune with my thesis of the ongoing dematerialization of the art object, I find the most interesting projects to be those that cast a shadow forward by experimenting mentally with the capabilitites of the computer. Such experiments do not fall into the mainstream of computer graphics which currently is occupied by attempts either to render superrealistic representations, i.e. to simulate photorealistic representations, or to act as a substitute for traditional artistic media such as painting. It is obvious that, at least in the short run, such surrogates will gain widespread acceptance because of their economical feasibility, inviting accessibility and immediate practicality. Nevertheless, a few radically different approaches are being explored that promise to alter common standards of creation and perception. Prototypes of this kind will exert their impact in the future and will change the relationships between artist, art and audience more profoundly than the modest ambitions of the realist persuasion could ever predict.

Machine Vision: Looking Through Machine Eyes

From the outset of working with the brand-new medium of video, Woody Vasulka, a Czechoslovakian-born film maker who now resids in the United States, was drawn to its material and basic qualities: the electrons that scan the image in a constant, regular pattern. Charged with different voltages, these electrons contain information about color intensities with which they strike the phosphor of the screen momentarily, only to be consumed a few nanoseconds later by the next electronic wave. Woody and his wife and collaborator, a former musician, Steina, soon became obsessed with time/energy as the material for electronic imaging; they started using, then devising and building, special machines to explicitly influence and control the waveforms, the ephemeral substance of the video image. Even though they continued to use the camera for capturing 'real' images that later could be modified and deformed, they also devoted many of their experiments to working exclusively with internally generated oscillations that, after various processing steps, appeared on the picture screen transformed into visual energy. Woody Vasulka recalls: "Our goal was to create reality, a certain reality that would testify to its own electronic complexities" [22].

Given this attitude that tries to do justice to the imaging properties of electronic machines, it is no surprise that Vasulka strongly advocates a systematic experimentation with all the parameters involved, without constraining them beforehand by our cultural conditioning of what constitutes a meaningful and thus legitimate image. He actually goes so far as to consciously challenge conventional image making by bypassing techniques that are based on the common perspective projection. He states quite rebelliously:

> I can at least unleash some attack against the tradition of imaging, which I see mostly as camera-obscura bound, or as pinhole-principle defined. This tradition has shaped our visual perception not only through the camera obscura, but it's been reinforced, especially through the cinema and through television. It's a dictatorship of the pinhole effect, as ironic and stupid as it sounds to call it that [23].

After having divorced himself from the highly limiting concept of photo-realism, Vasulka felt free to enter a period of experimentation with the Rutt-Etra video synthesizer, a device that uses intensity information to deflect the scanning beam of the cathode ray tube (CRT). In essence, in place of the 'empty' regularity of the scanning rhythm, originally set up simply to move the beam across the screen plane, is now charged with image properties; this, of course, disturbs the scanning pattern and simultaneously deforms the video image itself. What we see is, in Johanna Gill's words, " a topographical map of the brightness of an image" [24]. [see figure 1] These are unfamiliar images indeed, images that no longer valorize the conventions of 'reality'; instead they allow novel perceptions of well-known objects, extract new meanings from them and press us to question the previously unquestionable, the validity of our own sensual-perceptual mechanisms.

Once we have seen, that is, have sensuously experienced, alternative visions, our perceptual convictions can never remain innocent; by their mere existence, these machine visions expand the scope of how the world can be looked at, and simultaneously they enrich the expressive means of artists such as the Vasulkas. For, once artists have encountered the spectrum of potential transformations which at first might come unsuspected and by surprise, they can catalogue them and make them part of their visual vocabulary. Woody Vasulka calls such results of their visual investigations 'artifacts'. These visual signs are artifacts in that they could not have been premeditated by the artist and then simply realized; rather, these artifacts emerged from the artist's dialogue with the machine or, put even more strongly, they are manifestations of the machine's structural architecture as it dynamically processes visual information. The physicality of such artifacts is subsequently transmuted into symbols capable of triggering cognitive events by the reflective labor of the artist, a reflection that endows the purely formal utterances of the machine with meaning and makes sense of them.

This is how Woody Vasulka judges the dialectical process between the machine and himself: "By artifacts, I mean that I have to share the creative process with the machine. It is responsible for too many elements in this work. These images come to you as they came to me - in a spirit of exploration" [25]. In another interview Vasulka considers the machine to be a device for the amplification of his fantasy:

> What intrigues me about computer and video are mostly the changes between time and other problems ... that cannot be foreseen or fantasized through the best fantasy synthesizer, which is the human brain. ... This untapped wealth is the pool of unmatched fantasy, fantasy that cannot be produced by plainly human fantasy, confined in a pictorial tradition [26].

Here we see an admission of human finiteness in conjunction with an understanding of a machine's unique contributions to image making. Note how much this statement differs from Balla's arrogant insistence on human superiority when he tried to confine a machine's capacities to rudimentary forms of imitation and anxiously reserved all potential for creation to the Creative Genius. Vasulka already approaches his interaction with the machine as a symbiosis in which no participant is privileged *a priori.*

For the Vasulkas, it was a consistent development to start using digital computers once their price had dropped enough to make them accessible to individual artists and their power had increased sufficiently to make them suitable for video imaging. During the mid seventies, the Vasulkas with the help of the digital designer Jeff Schier, built an 'image articulator', a digital video machine that contained up to eight frames of image memory, analog-to-digital and digital-to-analog converters, and an arithmetic logic unit (ALU). The converters are important initially to digitize a holistic video image into discrete binary particles and then, at the end of the pipeline, to make the digital information accessible again to the human viewer in the form of a video image. The machine was optimized to operate in 'real-time', video-time that is, processing full video frames at 1/30th of a second. The Vasulkas had to trade off spatial and depth (color) resolution in order to achieve such high processing speeds, which they were quite willing to do, if only the pressing demands of the video-timing could be met. Out of the myriad of novel visual representations, that the Vasulkas were able to create with the image articulator, I will select only one example for discussion.

While experimenting with the arithmetic logical compositing of two images that were concurrently stored in two of the image buffers, Woody Vasulka came upon a strange phenomenon - logical motion. The initial set-up was as follows: Vasulka had two image sources. One came from a camera monitoring a simple object made out of white styrofoam, a ball. The other was an internally generated, abstract but well-structured computer image. The video image was digitized and the values of both images stored in a bitmap (4 bits deep for a total of 16 shades of grey or colors). Vasulka wanted to create a visual table that contained as entries all the combinatorial possibilities of compositing these two images, using Boolean algebra to combine their numeric values pixel-by-pixel. Some of these calculations yield visual results that are commonly used in television production. For instance, an addition is the equivalent of a superimposition of two image sources. The majority of Boolean operations (they include AND, NAND, OR, NOR, EXOR and inversions of the original images) result in composites that can be achieved only by these digital methods and have no analogue equivalent. This is the reason they have been non-existent before and are not charged with visual meaning, at least not yet. [see figure 2]

The 'logical motion' effect occurred when Vasulka replaced the regular shape of the computer-generated image with a random pattern. He combined this image containing an arbitrary distribution of grey values with the video image of the ball. He fed the video image into the framebuffer not only once but continuously and calculated new values by merging the incoming image with the stored previous one. To his surprise, he saw a disc on the screen the pixels within the perimeter of the disk were percolating at high speeds, whereas outside the disc the pixels remained motionless. Vasulka was amazed that completely static images (the ball was not moving) could somehow create this motion. When he stopped feeding this static image of the ball into the computer, the motion vanished; all that remained visible was an unstructured, random picture. (Out of obvious reasons this effect cannot be shown in a static medium such as this journal. Please refer to Woody Vasulka's videotape 'Artifacts' [27].)

After some reflection, he resolved the mystery: what he was seeing when the ball's image was continuously fed into the computer and composited with the random image was the difference of light intensities between the white ball and the black background. This difference had been translated into higher or lower binary numbers by the digitization process. Pixels within the disk were changing their values faster than those outside it because they represented the white ball's higher light intensity. The pixels representing the black background accumulated, on the average, higher values only gradually and, as a consequence, did not change as fast. Therefore, a high contrast was created between pixels in the two image areas, a contrast that depended on the different rates of change rather than on noticeable differences in distinctly separate colored areas. Due to the random image, the entire image plane was unstructured; therefore, all that became visible was the 'logical motion' which immediately stopped once the feed with the ball's image was interrupted.

The upshot of this experimentation is a remapping of visual information originally derived from a 'realistic' into a qualitatively different kind of representation. In this case, a representation of light intensities, our common way of using optical means to project light rays onto a picture plane is interpreted as rate of change. And only this change is what remains visible, since any differences in intensity have been randomized throughout the process. As understood by Vasulka, we get to see the 'collision of code' that produces this remarkable motion. Since we have never seen digital code in action, it is no wonder that we initially have difficulties making sense of it. But I agree with the Vasulkas that once we have grown familiar with such visual structures, suggested and produced by the digital machine, we will start to utilize them to understand computers and to convey meaning among ourselves. The Vasulkas have been using techniques found in these experiments in their later video pieces by incorporating such images in an artistic compositional manner. We too will learn to see the world with a machine's eyes.

Digital Dada: The Representation of Visual/Binary Symbols

Hubert Hohn, originally a photographer, produced a mind-boggling piece entitled *Binary Data Dump* in 1984 . (see figure 3) It consists of 256 sheets of computer printout, a floppy disc containing the print program and a list of assorted alternative titles for the piece. The printed image represents the state of the memory of an APPLE II personal computer that contains the program to produce this particular print-out. With this multifold assemblage, Hohn immediately presents a number of questions about the character of computer imaging and art to the viewer. The first questions concern the artwork itself: Where is it? Is it the printout, the floppy disk or the program on the floppy disk? It seems to me as if Hohn wants the entirety of different pieces replete with the long list of optional titles to be considered the artwork. By presenting it as this complex multi-media collage, he indicates that for him the computer and works produced with it encompass many different levels of signification that refer to each other in a circular, self-referential fashion.

In an accompanying statement, Hohn describes *Binary Data Dump* as an attempt

> to locate ourselves within the nature of the digital processs and see what we become. The digital computer is a symbol processor. 256 discrete patterns of signals are available for definitions and manipulation as symbols. Everything here consists of symbols created through the transformation of symbols by yet other symbols. There are no original thingy sort of things. The territory consists entirely of maps which refer to no territory but to other maps. What I do is on floppy disks, and what the computer does is on paper printouts. My work exists only as binary magnetic code, and means nothing except during its execution, which is done by the computer. . . . Multiple titles are used to encourage the viewer to be conscious of the work in a variety of ways, thus allowing it to exist in more than one state. My intent is to enliven the concepts while being fully consistent with the discipline of computing, for a world of multistate hardware and multireferent symbols is nothing if not a world of optional meanings [27].

If we look at the printouts at face value, we see that Hohn's program renders visible the invisible. He directly puts before our eyes the content of a memory of the computer, information that we normally cannot see and, to be sure, do not want to see, because our interest is usually not in how the computer stores information but rather in the information itself. For instance, nobody would ordinarily be interested in the arrangement of binary numbers that represents this text internally in the word processor. But that is precisely what we are confronted with in Hohn's piece. With a conspicuous completeness, he presents the informational internals in front of us, as they are, in their basic form of binary values. His program prints out the 'data particles', those last and only remnants of physicality that reside in the machine. By printing the values of these particles which actually are tiny electro-magnetic charges rather than the numbers 0 and 1 that we see, he arrests their fleeing ontological status. Finally someone captured that which is constantly changing, under steady revision and always switching from its current to its opposite value. In this regard, this is thus a traditional picture: the symbols in it refer to realities outside of it, and they do so by relying on conventions that rule the relationship between picture and depicted.

But what is really on display? Hohn says this a 'self-portrait' made by the computer and jokingly claims that its 'self-consciousness' is located in the memory locations made visible by the print program. Of course, he knows that this machine does not have any self-awareness of its actions; but literally speaking, he is correct, since the image we see is the code of the program that prints itself. Not only does this raise the question of machine consciousness but also the problem of the original. Is there a digital original, and if so, where is it? I submit there is a digital original, but it cannot be located as a physical entity. Neither the printout nor the floppy disk containing the program nor the program loaded in a particular computer can claim the status of an authentic, i.e. non-reproducible original. Not only can any of the above be exactly copied (this is one fundamental phenomenon of the data particle), the data particle itself is not authentic but only referential. Here we arrive at the heart of digital simulation where the transduction from the physical to the symbolic and vice versa takes place. And here is precisely the reason computers can simulate physical reality by processing a material which externalizes mental states: symbols.

Let me then approach this riddle by first explaining where the digital original can be found. Only one answer is possible: it is the particular pattern of binary symbols. To use Nelson Goodman's term, the original is the notation describing a singular succession of symbolic events [28]. The unalterable definition of a chain of symbols is the original, whether it is a musical score or - and this is important - a binary description of a picture. (A binary description of a single image or a binary description of a production rule of a picture are equivalent as notations.) But Goodman did not see or did not consider that, with the existence of digital machines and digital symbols, images can be described, and therefore copied, with the help of a notational system. Moreover, the existence of a notational system for digital imagery is the basic reason that image making can be divorced from the physical conditions it was subjected to before. The physical task of placing visual marks can now be delegated to a machine if this machine is capable of performing the score, i.e. if it is capable of processing the symbols. At the same time, such notational symbols can not only be executed but generated by the digital computer. This creation of symbolic objects is, at least potentially, linked to cognitive capacities. In the next example we will meet such a machine that autonomously functions as an art-making system.

AARON: World Knowledge and the Logic of Image-Making

AARON has been maturing over the years like a child growing up. AARON is the brainchild of the painter Harold Cohen, who in the midst of a successful career realized that painting was no longer challenging enough for him and, instead of continuing to paint himself, set out to teach a computer how to paint. The results of his efforts are embodied in AARON, a computer program that together with a suitable drawing device, such as a remotely controlled 'turtle' automatically produces endless variations of line drawings. Since its first inception at the beginning of the 1970s, AARON has undergone constant revision, becoming more and more sophisticated, and thus has grown along with the programming and image formalizing expertise of its creator, Harold Cohen.

When Cohen started using computers for making art he asked himself the question, What is an image? In a lucid discussion in an article with the same title [30], he revealed his reasoning and disclosed its results and the actions he took. This article was addressed to an audience of researchers in artificial intelligence, but later Cohen demonstrated that he can explain his concepts equally well to a group of children. The latter discussion is proof that the strategies brought to play within the computer program resemble fairly basic image-making ideas that can easily be taught to children in a sensuous manner. Maybe this is so since children might unconsciously be using similar strategies themselves and therefore are receptive to rationalizations that help them to clarify and make conscious their own drawing activities.

With the development of AARON, Harold Cohen has tried to tackle what he considers "the only question which differentiates the computer *fundamentally* from other tools. It is not, what can you do *with* a program, but, what can the *program* do? For the artist, the essence of the computer is its autonomy" [31]. Such an approach completely rejects using a computer as a painting or modelling device because in both instances the artist has to provide, through suitable interfaces, the data and the commands on which the computer operates. Since I am not able within the scope of this article to discuss the particular qualities of human-machine interaction in detail, I will bypass Cohen's argument and will agree that it is indeed a challenge to program a computer in such a way as to make the machine an independent agent of art-making. Cohen's system AARON achieves certain qualities of this goal, but presently it is at a high price. AARON is not only autonomous in that it can generate without human intervention numerous different drawings in a rather perculiar (not to say, personal) style, it is also completely shut off from the surrounding world - AARON is deaf and blind, it cannot hear and cannot see. These are, if we compare it with the human artist, severe handicaps. AARON is not able to expand its knowledge, cannot check its internal structure against the outside, does not participate in life and cannot learn anything new unless it is spoonfed by Harold Cohen with another routine in the program that might enable it to do a new trick.

Harold Cohen is obviously aware of these limitations and is nevertheless proud that AARON can do what it does and that it has been expanding its drawing capabilities significantly over the years. So what can AARON do well? AARON can draw images all by itself without any intervention. No two drawings are the same. Each drawing exhibits a well-ordered, non-random structure. AARON's drawings are fairly organic in that they are not mathematically prescribed geometric functions. Taken together, these abilities in and of themselves demonstrate a certain accomplishment in the skill of drawing, and the pictures prove it. But there is more to it. AARON has gone through two distinctly different phases of drawing lessons. In the first period, AARON was taught the basic structure of images and image making. In other words, AARON has learned image-making strategies that comprise issues such as simple repetitions, the figure-ground problem, closure and various other related techniques. It also can find out where it currently is drawing, remember what it has done before and locate empty space on the picture plane. All of these techniques have been analyzed by Cohen, formalized into rules and are now embodied within the program.

The program guides AARON's drawing behavior and controls the decision-making process during the course of a drawing event. But the program does not directly determine the outcome of a particular drawing as if it were driven by a notation. Such inevitable determination is given, for instance, in the case of the pianola, where the notation of a piece is engraved in the roll that mechanically controlls the playing of the tune. Similarly, most computer programs are strictly deterministic by executing their inherent commands consecutively. They produce clearly predictable results which only change with different input. In Cohen's case we observe that AARON is a program capable of heuristic searches, i.e. AARON constantly asks itself WHATIF questions and it is only the conditional response to them that effects the next drawing event. For instance, "IF you are about to bump into a figure and what you are doing is a closed shape, THEN find another path to close the shape"[32]. Or, "WHATIF I am going to go off the page? Well, THEN start circling; otherwise, keep going. WHATIF I'm circling, and I'm facing the direction I started from? THEN stop circling and head straight back; otherwise, keep circling" [33]. We see that AARON is not quite blind as I stated previously; AARON is able to orient itself within the little drawing world it is operating. Since this kind of feedback provides answers to the questions it is asking, AARON can construct its decision making around its drawing activities. It can be said that AARON contains rule-based heuristic image-making strategies that are enacted depending on the local situations encountered and the kind of inquiries made.

This first generation of AARON already could serve as an 'evocation generator' by 'sustaining an illusion' of intended meaning. This illusion rests on the clever exploitation of AARON's use of

> cognitive primitives [that] echo the structure of visual experience, which gives the image its plausibility. . . . Like its human counterpart, AARON succeeds in delineating a meaning-space for the viewer, and as in any normal transaction not totally prescribed by prior cultural arrangements, the viewer provides plausible meanings [34].

Having achieved an *illusion* of visual meaning produced by the computer, Cohen took the next step and incorporated world-knowledge into his program. The latest pictures produced by AARON illustrate this newly devised methodology. [see figures 4 and 5] The pictures clearly show trees, plants and human figures. Moreover, these objects are organized within an apparently three-dimensional space, those in the foreground obscure others in the back, those farther away are smaller than those closer to the viewer, etc. Cohen reasoned that

> the human cognitive apparatus develops in the context of the real world: so that in some sense cognition is the way it is because the world is the way it is. The result of considering this proposition is that, where the earlier AARON had been limited to knowledge of image-making strategies, the new AARON is more explicitly concerned with knowledge of the external world and the function of that knowledge in image-making [35].

Taken together, the two strategies - internal image-making logic and (some) knowledge of the external world - account for even more impressive drawings by Harold Cohen's program. AARON is proof that it is possible to embody a painter's skills in rules within a computer program, to formalize and materialize in a programming language the artist's image-making consciousness, and then to leave it up to the computer that executes this program to do the actual material work and draw the image. This achievement convincingly contradicts many people's understanding of the process of making art. Only by seriously considering the potential of this and similar experiments in computer art will we be able to make reliable predictions about future developments; clinging to opinions that are tainted by emotional judgments about the nature of art clearly will not do.

V. FORECAST FOR TOMORROW

One can appreciate the drama of digital machinery entering the world of art - a world that has always been highly charged with connotations of creativity, spirituality, and the like - by observing the fundamental premises that the French philosopher of perception, Merleau-Ponty, posed in the early 1960s. In his essay, 'Eye and Mind', he makes the following assumption that completely neglects any potential that digital machines might have for image making: "The painter 'takes his body with him,' says Valéry. Indeed we cannot imagine how a *mind* could paint. It is by lending his body to the world that the artist changes the world into paintings" [35]. If Merleau-Ponty could not "imagine how a *mind* could paint" at approximately the same time the first computers were used in the arts, we should not be surprised to still find disbelief and misunderstanding today, even in view of the fact that minds are able to do just that with the help of computers.

By carefully evaluating such extreme antropocentrism as brought forth by Merleau-Ponty's philosophy, we can gain insight into those features that constitute *human art*. This will be most important since any attempt to generate *machine art* will be compared and measured against it. Crucial to Merleau-Ponty's understanding of vision and art is the synthesis which binds body and mind together.

> Everything I see is in principle within my reach, at least within the reach of my sight, and is marked upon the map of the 'I can'. Each of the two maps is complete. The visible world and the world of my motor projects are each part of the same Being. This extraordinary overlapping, which we never think about sufficiently, forbids us to conceive of vision as an operation of thought that would set up before the mind a picture or representation of

the world, a world of immanence and ideality [37].

Like other phenomenologists before him, Merleau-Ponty wants to foreground the 'lived experience' of human beings, and this attempt, for him, entails moving "from thought of seeing to vision in act" [38]. He therefore criticizes Decartes's abstractions which made space an empty entity void of living beings but perfectly suited for geometric computations. (It is ironic that computer graphics technology has developed to a point where Decartes's laws of three-dimensional space are no longer simply computed by algorithmic software but are directly embedded in suitably designed hardware architectures, for instance, the so-called 'Geometry Engines'. Descartes's abstractions are physically embodied by graphics machines. In this regard, geometry is being made 'real' again.) But Merleau-Ponty's insistence on the symbiosis of the body's motor acts and the mind's thinking as necessary for a totality of Being seems to be correct in that it puts thought and the symbolic means of thinking on the solid grounds of primary experience as enacted and lived by the body.

Only when such conjunction and grounding are provided are the signs used in interaction and in making art intelligible and meaningful. This lesson was learned the hard way in early, unsuccessful attempts in artificial intelligence (AI) to model cognition. These ambitious attempts failed mainly because symbols were processed as purely formal tokens. Searle's attack [39] against AI and his skepticism that it could ever create machines that are conscious rest precisely in the formidable difficulty of 'materializing' the content of symbols in form of 'lived experience'. Today's researchers are regrouping to resolve the problem of how to model in a machine a similar dialectic between mental and corporeal which is the cornerstone of human Being and human-made art. Even if this feat could be accomplished satisfactorily, another, almost more severe difficulty is already lurking at the horizon: how can a machine bypass its own physicality and inbred rule systems [40]? The real test of making art is creativity, the ability to overcome outgrown rules and to posit new ones; in short, creativity requires a mind that is free from the world, as Sartre has pointed out: "For a consciousness to be able to imagine it must be able to escape from the world by its very nature, it must be able by its own efforts to withdraw from the world. In a word it must be free" [41].

Although the obstacle of creating creativity lies in front of us, let me conclude as if we had already succeeded in removing it. (We might succeed in the long run; just keep in mind that we have only a few decades' worth of experience in computer simulation behind us and still centuries ahead of us.)

Previously, we had created art objects in which, by reflecting on them, we found echoes of ourselves. Now we are creating another subject, the Other that is not a mechanical contraption, such as in kinetic art, but a dynamic, autonomous entity capable of producing and understanding symbols - a machine capable of communication. This Other is really another subject which we cannot presume to be similar to us even though it can simulate a similarity that can make it indistinguishable from us. This Other manifests itself in a material physicality that is not of our flesh, and it possesses a mind that is not our mind. Still, this machine-Other will be, in a slight modification of Benjamin's words, 'the Computer as Producer' [42]. By building this machine-offspring, humans will have achieved a marvel of artificial creation, and with this achievement the ultimate prerogative of humans, to be creators, will have been transferred onto a machine itself. Will this conclusion of our thought-experiment ever become reality? If it does, what will be the repercussions for a society of humans and machines?

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