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‘Programming the Beautiful’

Informatic Color and Aesthetic Transformations in Early Computer Art

Carolyn L. Kane

Abstract

Color has long been at home in the domains of classical art and aesthetics. However, with the introduction of computer art in Germany in the early 1960s, a new ‘rational theory’ of art, media and color emerged. Many believed this new ‘science’ of art would generate computer algorithms which would enable new media aesthetic ‘principles to be formulated mathematically’ – thus ending the lofty mystifications that have, for too long, been associated with Romantic notions about artwork and art-making. Although, as German computer artist Herbert Franke noted, ‘Traditional aesthetic modes of expression are of little avail to the artist who works with technical systems, particularly computers’, I argue herein that the shifts in aesthetic theory brought about by the introduction of computer art are more complex than a clear-cut subsumption to mathematics, information theory or cybernetics. While the ‘Programming the Beautiful’ project that began in Europe in the 1960s – the three-fold rationalization of the artist, the artwork and color – has been largely realized, nonetheless, today we find ourselves seeped in the neo-Romanticization of new media art, the re-glorification of the role of the artist, and new digital color – ironically, the exact opposite of what the project for rational art initially sought.

Key words

color ■ computer art ■ cybernetics ■ information aesthetics ■ new media history

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> Color shines and only wants to shine. When we analyze it in rational terms by measuring its wavelengths, it is gone. (Martin Heidegger, 1993)

> The control unit of the drawing machine interpreted the coded commands so that the step-engines moved the drawing head with its pens according to the speeds currently requested. A single line element could be as short as 1/16 mm (this corresponds to the resolution). . . . So the computation only knew there is color no. 1 and color no. 2. It had no idea of what these colors looked like . . . (Frieder Nake, referring to 1966, in 2008a)[1]

CONTRARY TO the conventional notions of uniqueness and originality that have surrounded art practices for centuries, the advent of computer art in Germany in the 1960s effectively accomplished a 'Programming of the Beautiful' – resulting in a scientific and mathematical rationalization of art-making, the role of the artist and color phenomena. These rationalizations problematize the continuity of creative practices in the new media arts, and thus demand further scrutiny.

The project to 'Program the Beautiful' first emerged in the fourth volume of German mathematician Max Bense's *Aesthetica* (1965a), a five-volume book project in rational aesthetic theory – an endeavor to quantify art and aesthetics as a mathematical science. The provocative series took its title from Alexander Baumgarten's 1750 *Aesthetica*, a text which, 200 years earlier, introduced the term aesthetics into philosophical discourse and argued that the field of aesthetics merited the status of a science. For today's scholars, one must contextualize Bense's project both within the philosophical tradition of aesthetics as also as a challenge to it – by marrying computation and creative thought.

Scholars within the qualitative humanities met Baumgarten's claims with fear and rejection. Immanuel Kant, the first to voice resistance to Baumgarten's claims, argues in his *Critique of Pure Reason*:

> The Germans are the only people who currently make use of the word 'aesthetic'.. . . Baumgarten, that admirable analytic thinker, [brought] the critical treatment of the beautiful under rational principles, and so [sought] to raise its rules to the rank of a science. But such endeavors are fruitless. (1965 [1781]: 66)

One may wonder how Kant might have reacted, two centuries later, when Max Bense also proposed a science of art, without even the benefit of empirical observation. Some of Martin Heidegger's early protests suggest Kant's likely position. Heidegger worked in the tradition of the humanities that, since Kant, had extracted all mathematics and science from philosophy. Even Hegel's subsequent systematic theory of colors, contemporary German media theorist Friedrich Kittler has noted, 'could do no more than repeat and deepen what natural languages said about colours in the first place' (2006: 41). Heidegger, following Edmund Husserl, kept colors safe in the sacred 'life-world', holding on to Romantic notions that color was 'pure' and 'shines' only from its mysterious core.

When Bense's project for programmable art brought together mathematics and aesthetics, it effectively assaulted this entire Romantic philosophical tradition – a tradition which still informs cultural theory, social science, and art history and criticism today. These two polemics form the ongoing debate between art and science – or instead, between the humanities and quantitative analysis that C.P. Snow (1959) has identified as the 'two cultures' divide. Today, this polemic endures in such paradoxical terms as 'new media art' and in the challenges of discussing machine-generated color using aesthetic terms. This article navigates this challenging terrain by following the historical contextualization of selected early European, largely German (Figure 1), and American computer art of the post-Second World War period and the different appropriations of cybernetics, systems theory and information theory that bolstered them. The last section of the article analyzes the neo-Romantic backlash that these projects encountered.

Rationalization of Color, Culture and the Role of the Artist

In classical antiquity Greek philosophers debased the status of the artist. For Plato, *techné* is defined as both skilled craft and art – but *techné* as craft is superior to *techné* as art. Plato posits that artwork (poetry and other arts) advances false claims about reality because artists can fabricate illusions; whereas a craft, such as carpentry, constitutes only the practical application of a science. Superior to both of these is the abstract, immaterial realm of ideal mathematical Forms. The painter is dangerous, Plato argues, because he does not accept the concept of an ideal bed, and paints instead any physical bed. Painters especially 'deceive with color' and may incite wild, irrational emotions in audiences that could threaten the rational state. Under this logic, artists were banned from the Republic (1968: 601a–602b).[2]

Beginning in the modern age (roughly 1500), empiricism and scientific positivism paved the way for industrialization and, eventually, mechanical reproduction. Machines relieved the artist from performing craft-work's mundane labors; artisans were 'freed' to create analytic structures that could be precisely manufactured by technical devices. Industrialization thus provided the precondition for the rise of the Romantic notions of pure artistic 'intentionality' and the analytic genius-author. This shift helped glorify the concepts of originality and the insight of the isolated-yet-gifted mind of the artist, while repetitive manual labor became monotonous.

American art critic Nelson Goodman's notion of the autographic and allographic in art builds upon this understanding of the new elevation of analytic art-making. Goodman explains that an artist creates an autographic artwork in a singular act of creation, whereas the creation of the allographic artwork is two-tiered. In an allographic art form, such as music, a written score or notation system forms the first stage of production and the performance of the music forms the second stage of production: the end-product

(Goodman, 1976: 114). In computational terms, the allographic artwork requires initial preparation – or programming – with the execution of this notation constituting the performance of the final work.

For some, the freedom from monotonous labor actually elevated automated notation systems to the ideal status of Plato's Forms. When, as the German computer artist Herbert Franke recalls, for the first time, art made using computers was deemed to be completely calculable, many people were excited by the prospect that the 'computer can now find the regularities, patterns, evaluations, [and] speeds . . . of works'. With the computer, humans could finally achieve a 'scientific theory of art' (Franke, 1985: 157). Walter Benjamin also celebrated the potential freedom and liberation from the constraints of tradition brought about by such notational systems. Machine-made art, he suggests in his most well-known essay, could disarm the lofty pretensions of Romantic cult value, or hermeneutic art criticism, which held that the art object was mystically cloaked in a dark veil of secrecy, a shell that could rarely be penetrated or understood. While critical of the potential political abuses of mechanically reproducible art, Benjamin nonetheless declared that art had finally been taken 'out of the wrapper' (1968: 238). Paradoxically, what began as the celebration of the artist's freedom from physical labor and de-mystification of art eventually led to 'freedom' from critical thought as well.

Others kept the visions of technological utopia in check. Ironically, the late Heidegger offers a more nuanced and systematic approach in 'The Question Concerning Technology' (1977). The early Heidegger had mourned the loss of color that only 'shows itself when it remains undisclosed and unexplained' (1993: 172); yet according to Kittler (who today plays the provocative role that Max Bense did a generation ago), by the 1950s, Heidegger had presented an ur-model of cybernetic ontology.[3] The late Heidegger became interested in new technical systems and was intrigued by Bense and his projects – especially in 1955, when Bense brought Norbert Wiener, the father of cybernetics, from the United States to Stuttgart and Ulm in Germany (Hoerl, 2008). Kittler draws out the cybernetic language in Heidegger's later writings on technology. Quoting Heidegger, Kittler writes: '"the energy concealed in nature is unlocked, what is unlocked is transformed, what is transformed is stored up, what is stored up is distributed, and what is distributed is switched about ever anew" (Heidegger, 1993: 322). . . . Heidegger, as if he had just invented the closed circuit, concludes that "unlocking, transforming, storing, distributing, and switching are ways of revealing" (1993: 322)' – the same terminology used to describe the processes of selecting, storing, and transmitting data in Wiener's cybernetics (Kittler, 2006: 49). For Heidegger, however, this was no call for celebration as rational aesthetics purported. Rather, this 'setting forth' constituted the supreme danger of 'enframing' (*gestell*). Enframing blocks humans and human experience, physically *and* epistemologically, from the frame itself. It blocks color from shining forth in-itself. Strangely, because this view posits that technology does in fact 'build a way' – albeit a way that blocks – it *is* somewhat in line with Kittler's technical and mathematical views of technology.

By the mid-20th century, the industrial research spawned by the Second World War, the newly globalized commodity production, and the proliferation of modern communications systems had a similar rationalizing effect on Western culture as did the rationalization of the artist. Alan Turing's theory of automata (1936) had established that any process that could be specified in a 'finite number of logical operations' could be computed. Both Von Neumann's Game Theory (1944) and John Nash's 'Nash Equilibrium' (1950) had demonstrated that a rational player, by employing appropriate rational strategies, could obtain maximal gains with minimal losses. Claude Shannon and Warren Weaver's *Mathematical Theory of Communication* (1949) had announced the quantitative breakdown of communication systems, and Wiener's *Cybernetics* (1948) had theorized the control of the animal and machine through the phenomenon of feedback – giving birth to self-generating, automated and 'intelligent' systems. In 1968, Ludwig von Bertalanffy's *General System Theory* marked yet another shift away from the mechanistic world view of the classical sciences inaugurated by Newton and the move towards theories of connectivity, systems and circuits.

In the 1960s, progressive social theorists in the United States appropriated systems theory and cybernetics. Gregory Bateson applied the new cybernetic science to human ecological systems by mixing the worlds of the man and the machine, while American film scholar Gene Youngblood's *Expanded Cinema*, and the electrified prophecies of Canadian visionary Marshall McLuhan, argued that systems theory and computers would expand and transform the social consciousness. In 1968, curator Jack Burnham observed that the new art 'does not reside in material entities, but relations'. In other words, art had become a system in which audiences and machines could be synchronized. This ecological and humanistic appropriation of computers was, for the most part, absent in Europe. Significantly, many German computer artists and theoreticians regarded computing machines in literal, material terms, thus gleaning insights the Americans missed. The unique styles of early computer art produced in Germany and the United States reveal these differences.

In Europe, the ideas of information theory and cybernetics had already been circulating for at least a decade prior to their circulation in the United States; these early developments led to the formation of information aesthetics. 'From the late 1950s through the 1960s . . . [this] term had a very precise and . . . formal meaning . . . the application of information theory to issues of aesthetics' (Nake, 2008a).[4] Working separately, Max Bense, in post-war Germany, and Abraham André Moles, in post-war France, founded information aesthetics. While Bense's role in the development of information aesthetics and the 'Programming of the Beautiful' is the focus of the current discussion, Moles has made significant contributions in the French context. Moles argued that since the advent of the printing press, communication had become 'material'. In other words, the sheer quantity of the symbols that were produced could now be subjected to quantitative analysis like other empirical phenomena. Material signs could then be measured, arranged and composed regardless of their ideational content, similar to Goodman's description of allographic art (1976: 192–3).

Rooted in the semiotics of Charles Morris and Charles Peirce, yet also strongly influenced by the American mathematician George David Birkhoff, Bense aimed to standardize formulas for the systematic interpretation of the 'signs' of computer art. Around 1933, Birkhoff attempted to standardize aesthetic perception through numbers. Informed by 19th-century experimental scientists such as Hermann von Helmholtz and Gustav Theodor Fechner, who quantified perception by measuring human physiological responses, Birkhoff claimed to have found a 'reliable, objective . . . [set] of rules for the aesthetic evaluation of works of art' (1933: 27). Concepts such as 'meaning' or 'purpose' normally discussed in traditional aesthetic theories became 'units of measure'. Similarly, Shannon and Weaver's 1949 publication also quantified the data within a communication system in such a way that the link between meaning and content was radically severed. For Shannon and Weaver, information 'must not be confused with meaning. . . . In fact, two messages, one of which is heavily loaded with meaning and the other of which is pure nonsense, can be exactly equivalent' (Shannon and Weaver, 1963: 8). Similarly, for Birkhoff: 'the quantity of information indicated the complexity of a message' and, thus, the value of a work of art, irrespective of semiotic notations (1933: 28).

Birkhoff's formula argues that order (O) stands in direct relation to aesthetic pleasure (M), where C represents the complexity of the art object. The equation: $M = O/C$ denotes that the 'most beautiful of a class is that which exhibits as much order and as little complexity as possible' (1933: 28). His theory of optical perception constructs a formalized economy of optical stimulation and response, in order to achieve the 'happy feeling of associative cognition' (Pias, 2008: 116). For Birkhoff, beauty is constitutive of the subject's perceptual *efficiency* in capturing and processing the information transmitted.

Bense took Birkhoff's formula, discarded the concern with subject perception, and combined it with Shannon's theory of information. Where Birkhoff's aesthetic measure is 'a function of order and complexity, Bense replace[d] the complexity C with information H of the selected signs and replace[d] order O with redundancy R' (Bense, 1969: 118). Redundancy is a repetition of the same, but originality and innovation come from a rupture in a pattern: new information in, or disorder within, the system. The measure of creativity is equivalent to the amount of disorder, whereas the amount of effective communication is equivalent to the amount of redundancy. Although these formulas may, to some, appear to bring a certain kind of order to aesthetic judgments, the equations ignore the ethical and practical problems to quantifying art and poetic thought.

Quantifying Computer Art

Bense began lecturing on information aesthetics at the Stuttgart Technological University in 1957. Information aesthetics is also appropriately referred to as ‘generative art’: art that is composed and produced through computation. Frieder Nake, a pioneering computer artist and former student of Max Bense, recalls that during these lectures Bense would ‘regularly use the seminar room to put up exhibitions of concrete and constructivist art and poetry, typography, and generally experimental works’ (Figure 2). On 5 February 1965, a visitor to the class, Georg Nees, displayed some of his computer art on the walls of the lecture hall. Two of the works, *Andreaskreuz* and *23-Ecke*, were composed using ALGOL 60, on Konrad Zuse’s Graphomat Z64, his last commercial product (Nake, 2008b; see Figure 3). One of Bense’s students, an artist, reacted:

> ‘Tell me, Mr. Nees, can you make your machine draw like an artist’s flow?’ Nees ponders for a moment. He is a calm, patient, friendly mathematician of about 35 years of age. Then he says, ‘Yes, I can. If you can tell me precisely how to define your way of drawing.’ (Nake, 2008b)

The student’s response is emblematic of a wider reaction to this work. The advent of automated computer art suggested that the genius artist could be tinned in a can. Bense responded to his student’s anxiety by assuring him, ‘It is only *artificial* art’ (Bense in Nake, 2008b).

Figure 1 ‘Artists, critics, general audience in Werkstatt Breitenbrunn, Austria, 1966, at a discussion on computer art. . . . This picture shows how computer art was accepted in Europe early on’ (Nake, 2008a). Courtesy of Frieder Nake.

Figure 2 Frieder Nake in Stuttgart, 1966, holding up his computer art at an auction to raise funds against the war in Vietnam: 'I am moderately successful' (Nake, 2008a). Courtesy of Frieder Nake.

Figure 3 Konrad Zuse's Graphomat Z64 at the Computing Centre, University of Stuttgart, in 1966. Courtesy of Frieder Nake.

The idea of artificiality only intensified the controversies then forming in response to computer technologies in art. The threat of artificial art, Nake explains, is that it 'questioned the much-cherished retreat: the artist's intuition and creativity' (2008b). Second, the term intentionally invoked the then current, and equally contentious, artificial intelligence research being conducted in government and military agencies, which purported that the computer could be programmed to think and act just as a human could, if not better. Third, these computer images reintroduced the polemical question 'What is art?' Even Nake, in 2006, does not refer to his work as 'art' but as 'algorithmic images accepted as art'. However, Bense's belief regarding what constitutes art aligns with Goodman's definition of the allographic artwork: 'a set of drawings that had been produced by an automatic drawing machine controlled by a program run on a digital computer' (Nake, 2008a). According to Bense's theory of information aesthetics, computers rationalize both art and the art-making process – in short, they accomplish a 'Programming of the Beautiful'.

After the Second World War, Germany faced a new intellectual abyss that Bense aimed to fill. Like Martin Heidegger, he saw the new world of technological rationality, ordering and the economization of every sphere of existence. While both held different attitudes towards technology, they nonetheless both recognized the brute fact that technological rationalism had pervaded cultural consciousness. Bense's provocative move was to target the effects of this rationalization in the last stronghold of classical aesthetics and philosophical humanities: the concept of the artistic genius. These provocations, like Kittler's do today, functioned indirectly, as a critical performance. Bense believed that the 'moral lesson to learn from the Nazi past [was that] anything that was not accessible to rationality, not stochastically objective, was ideologically suspicious' (Pias, 2008: 115). While on the one hand, his project constituted a critical mimesis of the Nazi's distorted glorification of rationality and science, on the other, his project for a rational aesthetics was also a genuine attempt to 'demystify' computer art and to 'get rid of all the terrible ideology and to prepare for a world with as little ideology as possible' (Nake, 2008a). In this second sense, which offsets the first, the performance attains its critical edge as it shores up the absurdity of rational autonomy by placing it at the center of art-making. Nonetheless, such subtle ambivalences continue to plague Bense's and Kittler's discourse(s) today.

The 'Programming of the Beautiful' must be understood both as an indirect critical discourse of rational society and as a way of integrating traditional aesthetics with new technologies – just as Benjamin had earlier celebrated the possibility of mechanically reproducible art. 'Rational aesthetics', Nake explains, was designed to 'draw a line to a non-rational aesthetics'. He expands:

> . . . [I]n the early 1960s . . . in Europe, aesthetics was to a large extent a discipline of interpretation . . . the freely and intuitively wandering mind that

> allowed itself any freedom to say this and that . . . and soon would be talking about god and the world, and claiming this was all about the aesthetics. . .. So the starting point for rational aesthetics was a discontent or even discomfort with an approach to painting that was more interested in the history and psychology behind the work than with the actual appearance in terms of material, form, color etc. of that work. (2008a)

The project disfigured the sacred intuition of aesthetics and art-making, laying it out to dry as an allographic act of selecting within a 'given repertoire' of choices that the 'computer simulated . . . from pseudo-random numbers'. Second, Bense's program required one to question the new ways in which social subjectivity was now produced through numbers and rationalized thought. Statistics, Bense acutely observed in the 1960s, are 'the only way to approach a new being' who is increasingly dissolved into an extended 'sphere of technical being' (Bense in Pias, 2008: 115). The ongoing resistance, denial and dismissal of Bense's (and Kittler's) ideas confirm that we are still invested in the Romantic beliefs that human originality, intentionality and autonomy distinguish us from animals and machines. The provocations of 'Programming the Beautiful' – the claims that human genius can be quantified and art calculated – function to expose these values in full detail.

Bense was not alone in his anti-Romantic forays into technological aesthetics. Rul Gunzenhäuser, a German theorist of information aesthetics, also followed Birkhoff's approach, arguing that children's rhymes have a higher aesthetic value than the 'poetry of Poe, Coleridge, or Goethe', and that stars versus irregular shapes are superior and more 'beautiful' (Pias, 2008: 117). German computer artist Herbert Franke also explains that, because the human brain retains '16 bits of information per second with a storage limit of 10 seconds', computer artwork must balance the amount of information transmitted. '[T]oo much order leads to boredom or alienation, while too much innovation is noise or disorder.' Thus, he argues, the amount of innovation in art may be 'measured with the help of the concept of *statistical information*' (1985: 154). These claims at once wrest the term 'innovation' from its roots in the Romantic tradition, transplanting it into a new system of signification for the rationalized world. The Germans had found a way to quantify both art and aesthetic perception; the dawn of computer art proved that automated measurements and statistics could finally achieve a 'Programming of the Beautiful' – efficiently and effectively organizing, sorting and distributing electronic signals and noise.

Numerical Color in German Computer Art

Ideas about color underwent the same process of rationalization that transformed the notions of post-war society and the role of the artist in the post-mechanical age. For the entire traditions of philosophy, aesthetics and art-making, color was purely subjective, transcendental and even spiritual – it could not be quantified or calculated. But in early computing, color always arrived to the artist as a number before it could be seen as a visual color. This posed a problem for artists who wanted to continue using color in traditional ways. The treatment of color as number in early German computer art helps to recapture this lineage and with understanding how the treatment of color as number impacts today's computing practices and assumptions.

Frieder Nake began making computer art in 1963. In 1967, he created *Matrix Multiplication*, one of the few uses of color in computer art from this early period (Figure 4). Divided into four sections of a grid, each sector 'reflected the translation of a matrix [that] was multiplied successively by itself. . .. Each number was assigned a visual sign with a particular form and color' (Nake, 2008a). He placed these value-signs in a raster according to the numeric values of the matrix. Nake computed them on an AEC/Telefunken TR4 programmed in ALGOL 60 and plotted them with the Graphomat (Dietrich, 1986: 161). He describes the process of producing color in detail:

> . . . the computer, under the control of my programs determined all the necessary movements of the drawing machine later on. Its output was a paper tape. It contained an exact coding of each and every detail of the drawing. This coding typically consisted of commands of the following

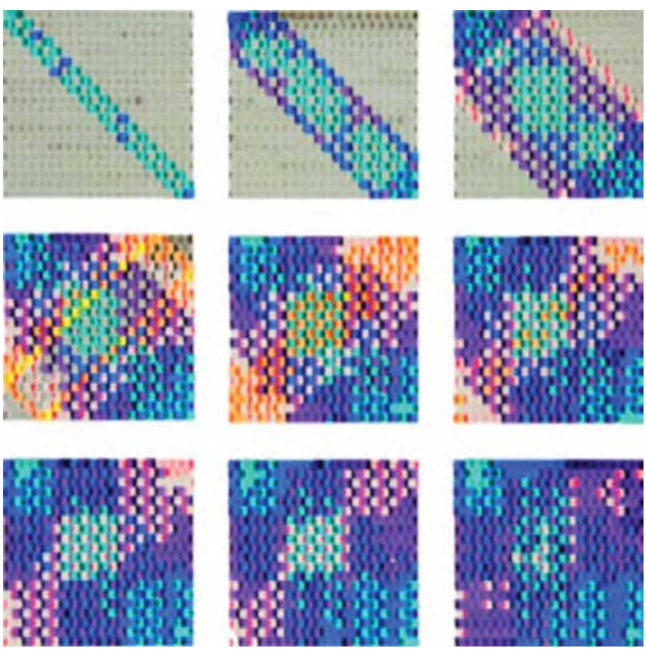

Figure 4 Frieder Nake, *Matrix Multiplication series 34* (1968); computer-generated drawing, ink on paper, 50 × 50 cm (paper). Courtesy of Frieder Nake.

> simple type: move to (x, y); pen p down; pen q up; stop. The paper tape was then taken to the drawing machine where it became the input. The control unit of the drawing machine interpreted the coded commands so that the step-engines moved the drawing head with its pens according to the speeds currently requested. A single line element could be as short as 1/16 mm (this corresponds to the resolution). . .. So the computation only knew there is color no. 1 and color no. 2. It had no idea of what these colors looked like . . . (2008a)

Color was programmed into the system from the start. Yet what was actually programmed was not color, but number. Arbitrary, abstract and non-visual – these numbers were placeholders for any color or variable: the algorithm had no real connection to the actual output color. Nake notes that the process could also 'result in a different choice of the color set now and tomorrow'. When reprogramming *Multiple Matrix* in 1970, he recalls, 'instead of short strokes in color', he used 'certain elementary symbols as output [which] encoded grey values'. This use of symbols echoes the work of 1968: 'signs were arranged . . . as symbols chosen from the typewriter. A code would say that * was red, + was yellow, # was blue etc' (2008a). Computer color, at this early stage, was limited to the algorithmic code in the initial stage of conceptualization. Nake's innovation was to use color in computer art when color was not yet attended to in the programs' data or processes. While the condition of color as number is still the condition of computers in general, today, an artist, or any user, selects colors visually; Nake, however, selected colors analytically – through mathematical programming. This work is an important predecessor in the pre-history of digital color – it constitutes the inverse of what has become the fully automated, digital color picker – where the fact of color as number has become naturalized and rendered invisible, ironically, by the visual appearance of the interface.

Another early computer artist who worked with color as number is Peter Struycken, born in 1939 at The Hague. Struycken wrote computer programs to calculate color values and usage within architectural spaces; he was involved in many building projects during the 1970s that conceptualized color as a structure in space. For Struycken, calculating color relations became a part of art-making: 'It is my purpose to show that form and color can be correlated mathematically; the result is not only a complete unity, but [to show that] the interrelation of form and color can be calculated as well' (1977). *Metro* (1975) generated a 'periodically changing black and white block structure'; *Ostre* (1975) was a program for electronic music; *Plons* (in English '*Splash*') (1972–4) continually changed color values and automatically generated new images. 'The result was a series of color patterns which have undergone exactly the same changes as the numbers in the computer program' (Struycken, in Leavitt, 1976: 31). At the point where a color change became perceptible, it was allotted a numeric value, and a new color would replace the old color.[5]

These early examples of 'thinking color as number' (Kittler, 2006: 7) in European computer art reinforced Goodman's allographic paradigm. The automation of color closed off access to this notation system and its mathematical reality. One may also view the development of sophisticated color palettes in software today as yet another, wholly distinct notation system – an allographic system that now indexes a visual simulation, and no longer a numerical value. If one views digital color palettes as new notation systems, however, these palettes must also be understood as allographic systems that have been subjected to extensive re-mystification.

Subjective Color in Computer Art: The United States

Color in early computer art in the United States functioned differently from the German computational paradigm. Americans generally believed that color was an aesthetic accessory and a supplementary add-on. At this early stage in American computer art, it seemed that thinking about color *and* numbers was impossible: even the most cutting-edge technological products of the time stopped short of accentuating color's rational nature. Moreover, the use of color reflected the utopian and socially progressive attitudes of Marshall McLuhan, Gregory Bateson and Buckminster Fuller. These intellectuals, as noted above, promoted ideas of symbiotic relations between man and machine, which integrated mind, body and consciousness with the new electronic landscape; and the American computer artists reflected these attitudes in their work. For instance, film critic Gene Youngblood declared that American experimental film-maker John Whitney's computer films created 'patterns, colors and motions dancing before us [which] seem to be addressing the inarticulate consciousness with a new kind of language' (1970: 215). Frieder Nake also confirms that, in contrast to the German approach, the 'American/Canadian approach was without theory. Just play, do your thing, be creative, do something exciting' (2008a).

Experimental film-maker Stan VanDerBeek, in another example, worked with programmer Ken Knowlton of Bell Labs on their *Poemfield* series (1966–9; see Figure 5). These short computer films interwove text, sound (*Poemfield* #7 is performed by John Cage), voiceovers and layered imagery (both computer-generated and photographic). Knowlton recalls that he was not involved with programming color in any of the films: 'The output [was] on Black-and-White 35 mm film by means of computer-written tapes . . . the coloring . . . was arranged by Stan . . . [who hired] persons such as Brown and Olvey' (2008). Robert Brown and Frank Olvey, experimental film-makers at the time, were known for their three-strip color dye separation method, a process that had been developed several decades earlier in the history of color film, and one which has nothing to do with rational numbers.

Another pioneering American computer artist, Ben Laposky, a mathematician and artist from Iowa, turned to color in 1956. Known for producing the first graphic images on the face of the cathode ray tube of an oscilloscope, Laposky did not generate color using electronic signals;

Figure 5 *Poemfields* (1966). In this image Knowlton used alphanumeric characters that VanDerBeek had colorized in post-production. Courtesy of the Estate of Stan VanDerBeek.

instead he used methods that had been developed in much older media platforms such as photography and film. He produced rotating colored filters and placed these in front of the display screen – in other words, *after* the phosphors were shot out of the electron gun, color was added on as accessory and supplement. Certainly this effect was aesthetically pleasing, but, like VanDerBeek's work, had nothing to do with computers and the rational logic computers engendered.

The same was the case with John Whitney, who had worked in the Lockheed Aircraft Factory during the Second World War. At Lockheed, he noticed that the anti-aircraft missile computing systems could also be used to produce lean and distinct geometric lines that could be employed in the arts. When the war ended, Whitney purchased his own M-5 Antiaircraft Gun Director and developed a sophisticated motion control system which he named his 'cam machine' (Morritz, 1997). In 1966, IBM invited him to be an artist-in-residence; while there he made several colorful computer films, including *Arabesque* and *Catalog* (Youngblood, 1970: 107). Like Laposky and VanDerBeek, Whitney added color during post-production, using mechanically rotating color filters. *Catalog* (1961), reproduced for the introductory image sequence made with Saul Bass for Alfred Hitchcock's *Vertigo* (1960), was shot on black-and-white 35mm film and the color was added later, using an optical printer in Whitney's home studio (Youngblood, 1970: 107).

In all of these cases, color functioned as an adjunct – a supplement retaining the qualitative attributes of color. The American approach generally sought new ways of expressing human-mediated desires through computers and traditional coloring methods, while the approach that the Germans developed was concerned with the rational and machine functions of color. While Nake, Struycken and Zajec also added color in post-production, through pens and paint, color existed as a numeric value from the earliest stages of programming. Further, because colors were programmed as numeric place-holders that could control any potential variable, color-data was not specific to color as a sensory phenomenon. Where the American social consciousness maintained a distance from the rational accounts of art, conversely, they brought Romantic ideas about color into the rational world of computing – the precise quality that the Germans sought to prevent. These two schools therefore became counterparts that simultaneously reflected each country's attitude towards the new systems theory, cybernetics and the advent of post-war computer technologies. Each school also suffered from its own backlash.

V. Neo-Romantic Backlash

The projects for the rationalization of art, the role of the artist and color as number have been haunted by their own ambitions. As Adorno and Horkheimer explain in the *Dialectic of Enlightenment*, Reason has always coexisted within, and against, myth. Myth – here understood as that which is beyond rationality, calculation and, in some sense, cognition – is similar in form to the Romantic and humanistic accounts of color held by Heidegger or Hegel, where color is *poiesis* – a qualitative phenomenon that, because it cannot be measured, rationalized or caught within a technological world, remains a pure, mystical kernel disguised within a shell. In the era of late capitalism, the commodity fetish reflects such a phenomenon: Marx defines the commodity fetish as an object or thing which a person has produced for the market in the attempt to control it, but which turns against the maker (and the consumer), becoming unrecognizable to them and concealing the material conditions of its production. Similarly, in the Enlightenment's pursuit of Pure Reason, the delusions of self-sufficient autonomy and individual capabilities for self-legislation became so severed from material reality that they fell back on themselves. Like the commodity fetish, they became subject to re-mystification and misunderstanding, dooming any attempt to assert a system of reason as either autonomous or self-sufficient, as in the case of the project for a rational aesthetics. Myth and *poiesis* will always return, as they do today in the neo-Romanticization of color, art and contemporary art-making. The aim to master, control and quantify art negates itself at the point where calculations are severed from their aesthetic context and history.

This tension between myth and reason is also articulated through the two-sided paradoxical logic of the supplement. Derrida explains that the 'supplement adds itself, it is a surplus, a plentitude enriching another plentitude, the *fullest measure* of presence'. But once the supplement is taken for granted, it intervenes and 'insinuates itself in the place of; it is as if one fills a void' (1994: 144–5). In turn, reliance on the supplement *produces* the instability and 'emptiness' of the supposedly 'originary' thing it was only meant to accessorize. For example, when computer artists use color today, that color is encoded as a rational number, but one often remains unaware not only of what that number is (unless one uses hexadecimal values), but also the fact that color is only ever a placeholder for a number. One becomes so familiar with the operating system and software that the mathematical logic generating the color falls below the level of awareness.

Current trends in art and design have moved past the visionary days of the 1970s; as a result, they seem to have cast aside Romantic notions of color. Digital color must conform both to the principles of efficient information transmission, as Bense predicted, and to the rationality of the Fechner law of psychophysics, which states that only the smallest amount of (color) information is needed to create a perceptible difference (Fechner, 1966: 36). The less color used, the better the communicative range of the image because it can travel farther, in less time and with the least amount of energy. The rational, economic logic of efficiency and exchange that structures information theory, as Bense and Birkhoff argued, underlies the most 'effective' images today.

At the same time, while rational computers may censor the mythical *poiesis* of color, a world of advertising and commerce ushers it back. The descriptions offered by software and operating systems claim to provide users with 'tools' to access 'unlimited colors', – or, as Photoshop boasts, '16.7 million colors'. In theory it would be possible to use so many colors, but this abundance simply cannot correspond to practical realities. First, human perception is unable to recognize this many colors, even those artists and designers whose training may help them to recognize a few more colors than the general population. Second, even with sophisticated color calibration systems, digital color is notoriously inconsistent and an image on one screen, or on one output medium, may look completely different on another. Third, the efficiency logic of information theory governing digital color ensures that, despite the number of colors one thinks one has selected, rendering algorithms and compression standards, such as rastering, sampling and bitmapping, allow only the smallest fraction of these colors for the actual display.

Like the dangerous supplement, what once began as a poetic add-on and adjunct instead turns into an unrecognizable replacement and dependency. In the United States, electronic artists began working with color by borrowing from elsewhere – from film, printing techniques and traditional aesthetic theories for adding color to artwork. The danger has been not only in forgetting that color is an artifice and add-on, or forgetting its existence as number, but also in failing to acknowledge its supplemental status when it appears as a natural given. As a result, one experiences rational, digital color as one of many fetish objects in modern computing.

The ubiquitous and user-friendly animated widgets and soft luminous colors that one can select with a simple click are certainly irresistible, as were the candy-colored casings once offered in an iMac campaign. Technology is so sophisticated, Kittler posits, that one may use synthetic color to generate a 'life-world' far superior to the natural one. With 'solid-state physics and silicon and lasers . . . chip technology can penetrate miniaturized stones up to a point where they start shining from within' (Kittler, 2006: 46). One need not be nostalgic about the 'natural' earth colors, because modern science and Photoshop can use rational numbers to synthetically generate the Romantic shine (*schein*) more brilliantly and efficiently than any poet or artist ever could. Today, neo-Romanticism appears as the fetishism for automated and rationally produced color objects and palettes, trumping the Heideggerian nostalgia for a color that could only ever shine from within.

The development of higher-level programming languages has given way to the birth of software, or the interface. While this has made computer use substantially easier, it has also produced an obfuscation of the machine. The interface, by definition, hides the technical layer of computer processing. Lev Manovich refers to the interface layer as the 'cultural layer', as opposed to the 'computer layer' – the physical place where all the number crunching and processing occurs (2001: 48). The cultural layer can be located on the surface of the screen, where all the visual, semantic and semiotic meanings reside, making computer use 'easy and accessible' for 'consumers'. The cultural layer, like the commodity fetish, conceals the concrete material processes that went into its own production, just as the generation of color through a series of numbers conceals its originating, pre-programmed algorithms. Thus, through the interface one finds the neo-Romantic vehicle through which new media artists and designers may re-enter the mystical realm of millions of 'pure' colors and seemingly free intuitive choices, and yet they do so without a sense of the actual machine processes, or their problematic histories.

The computing machine is an analog to digital color. Both were initially employed as adjuncts to other aspects of an artwork, yet as the thinking about color and computation evolved into social interfaces and industry standards, their technical status was replaced, concealed and forgotten. This radical degree of 'enframing' cuts off both sensory experience *and* epistemological knowledge, driving home Heidegger's 'supreme danger' of forgetting on an unprecedented level (1977: 29). Computer simulation and the informatic generation of color as number parallels the dangerous possibilities that Plato recognized in the artist using color: the computer replaces and obfuscates the true, original and the real, with fetishized technical re-presentation. Today this impasse has been inverted, and the visual and the empirical have become unremarked adjuncts to the algorithm.

While both color and the computer interface have been elevated to neo-Romantic levels of consumerism, the art market has also re-inflated the programmer with neo-Romantic notions of a tech-savvy genius-creator – the exact opposite of the rationalized role of pixel-pusher that Bense once envisioned. Because certain aspects of computer programming have become so specialized, many people have no idea how a designer made a simple green triangle fade to blue. This mystification feeds the belief that the programmer-artist has access to technical knowledge transcendent of human understanding. Thus, the monotonous and rationalized labor of the computer artist has been re-Romanticized as computer artists (i.e. programmers) are given the analytic esteem once reserved for doctors, lawyers and engineers – people with highly specialized intellectual skills. On top of this, computer artists are also granted poetic and creative genius status. The logic of the interface also contributes to this obfuscation of computer automation and control, but, as Nake explains, 'a successful piece of "algorithmic art" attempts to think like that engine that cannot think' (2008b). In short, the programmer-artist must simulate a computer's code – which cannot think – but make it appear as if the computer code can.

The project for the 'Programming of the Beautiful' – the rationalization of art and the role of the artist that Bense articulated in provocative rhetoric – has been denied the critical attention it merits. Many art critics and historians have simply rejected his seemingly absurd position at the outset. The vested interests in these denials and rejections, as noted, are rooted in Romantic notions of the self and art-making. Furthermore, provocation itself serves as a sophisticated rhetorical and poetic device, not a mechanical or technical one. Bense notes, 'When we talk of provocation it is a matter of the artist creating something . . . which causes a shift in consciousness in society' (in Pias, 2008: 113). In this sense, Bense's project for a rational aesthetics successfully waged a critical encounter, not only because it simulated the cold and economic logic of fascism or an already rationalized social existence, but also because he artfully demonstrated that rationalization, automation and control echo an archaic human dream. Just as Plato invoked the poetic device of allegory at the end of *The Republic* to advocate the systematic rationalization of human experience,[6] Bense used rational aesthetics to illustrate that rationality cannot be isolated from art and myth. This dialectic must be kept in view today, when re-assessing Bense's important interventions, the new school of German media theory led by Friedrich Kittler and historical accounts of early computer art.

The cultural and conceptual complications surrounding digital color remind us that, as Heidegger once noted, 'the question concerning technology is not technological' – rather it is about questioning (1977: 4). Without questioning the way one thinks through, uses and experiences digital media, one has failed to understand the ways in which technology mediates and constitutes social and psychic experiences. Without this crucial critical consciousness, commercial and political-rational institutions that control the development of color in new media, and thus aesthetic practices and experiences, proceed unchecked. The project for a rationalization of art, aesthetics and color succeeded at the point where it began to question the rational computer and its ability to deceive and mystify, but it failed at the point where rationality became myth and fetish – that is, the exact opposite of what was sought.

Notes

1. References to Frieder Nake often invoke personal accounts of his own experiences from this historical period. These accounts nonetheless reclaim unique and valuable fragments otherwise lost to the history of early computer art.

2. The debates about the role of color as a false and secondary illusion would continue, reaching an apex in the Italian Renaissance preference for *disengo* (line) over *colore* (color), and persisting through the aesthetic of high modernism and contemporary design (Pastoureau, 2008: 155).

3. The similarities between Max Bense and Friedrich Kittler's provocative styles, two generations apart, yet both in the context of German media theory, should not go unnoticed. I would like to thank John Durham Peters for pointing this out to me.

4. In this context, information aesthetics is distinguished from the way in which contemporary media theorist Lev Manovich uses the term to refer only to the visual design of a computer interface.

5. Other early European computer artists also worked with the new medium and produced images that directly reflected the rationalized mathematical base of computation. Many of these artists, such as Vera Molnar and Georg Nees, worked in black and white and thus are beyond the scope of the current discussion. While also beyond the scope of this discussion, even the experimental music movement that began in Germany, a decade prior to computer art, approached their compositions with this proclivity for rational aesthetics.

6. An aspect of Plato that has been ignored.

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