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Information Aesthetics: An heroic experiment

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Information Aesthetics was a short-lived but influential attempt to establish a mathematically rigorous aesthetic theory without subjective elements. It was based on information theory, semiotics and communication theory. It was mainly developed in Germany and France during the 1960s. It not only gained some influence among designers and artists, but also among teachers of art. Its concepts turned out to be reductionist and schematic, which we argue led to its eventual disappearance, if not failure. We provide a retrospective of its assumptions and results, and draw conclusions for current attempts at algorithmically evaluating the aesthetic merits of a work of art.

Keywords: Information Aesthetics; aesthetic measure; objective aesthetics; Max Bense; Abraham Moles; Stuttgart School; generative aesthetics

AMS Subject Classifications: 00A66; 01A60; 68-03; 68U99

1. Introduction

Information Aesthetics was a radical approach in Europe of the 1960s to establish a rational and objective theory of aesthetics. Its daring idea was to use the concept of statistical information as developed by Shannon [25] as the mathematical basis of an objective measure of aesthetics.

An objective aesthetics should be like the thermometer we use to measure the temperature in a closed room. If in winter someone enters a room from the freezing cold outside, he may feel the air is overheated even though those who had been inside for some time may feel a bit chilly. These contradicting and conflicting judgements are based on subjective feelings. The objective statement according to the thermometer would indiscriminately be '21°C'. Who is right?

Information Aesthetics attracted artists, designers, architects, writers, composers, philosophers, teachers, mathematicians, psychologists, critics and generally young intellectuals. It ventured into the threatening realm of totally objectified methods of evaluating aesthetic objects. This attempt was exciting and provocative. But it did not gain much recognition and ended by silently disappearing.

The term 'Information Aesthetics' has recently come into use again, but with a completely different meaning. The same is true for related terms such as generative aesthetics, generative art, generative design, generative music, generative architecture and more. 'Information Aesthetics' today is about the display of huge quantities of data (erroneously called 'information'), and 'generative design' is now about running a program on a computer with complex parameter settings. This fact may lend added interest to the retrospective presented here.

The movement of Information Aesthetics had two centres. One was the Institute of Philosophy and Theory of Knowledge at the University of Stuttgart, West Germany, whose well-known head was Max Bense. The other, not quite as influential, was at the Université de Strasbourg in France. Its leading figure was Abraham A. Moles, a fervent speaker and sharp thinker with doctoral degrees in physics and psychology.

Max Bense was one of the most radical thinkers and prolific writers of post-war Germany. Besides philosophy, his roots were in mathematics and physics, which gave him a head start towards a kind of extreme rational thinking that, for a decade or so, attracted a large and creative crowd of young intellectuals and artists of the region in the 1960s to study his essays and attend his lectures. They knew this privilege placed them in a group unparalleled elsewhere.

The excitement brought about by Bense's way of doing philosophy came from his total presence and absolute immersion in the process of thinking. Aided only by some scribbles on the back of a package of cigarettes, he lived and demonstrated the mind in action. Things and ideas were all happening right here and now. Everything was authentic and exciting, and

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even if students did not understand a single argument, they knew they had witnessed philosophy as performance. At a time when C.P. Snow's *Two Cultures* [26] were still stirring up controversy, Bense was demonstrating that you could almost single-handedly bridge the gap between mathematics and poetry. You did not need much more for this than your own dedication plus semiotics and information theory.

In this article, I will recapitulate the basic assumptions and results of Information Aesthetics. In particular, the formulae for aesthetic measure will be defined and discussed. I will also introduce the concept of generative aesthetics as defined by Bense and discuss an early computer program capable of generating patterns of images according to prescribed aesthetic measures. I will then offer a critique of the approach by Bense and his disciples. I will hint at the reasons why, in retrospect, I believe the approach failed. My conclusion will connect our deliberations with the current revival of terms like Information Aesthetics, generative design and generative art.

The original publications of Information Aesthetics were in German or French and very few have been translated into English. I therefore apologize to the reader that most of my references are not in English (see, however, Claudia Gianetti's recent summary and critique online [16]).

2. Information Aesthetics

Aesthetics is not an art, and the subject matter of aesthetics is not restricted to art or to beauty or the beautiful. But works of art may be subject matter of aesthetics: in descriptive, evaluative or interpretive modes.

In aesthetics, we consider objects of any kind from the perspective of sensual perception and with the goal of sensual cognition. This view of aesthetics is based in the modern foundation of the field as a separate philosophical discipline by Alexander Gottlieb Baumgarten in 1750/1758 [1]. He considered aesthetics as the discipline dual to logic insofar as both are concerned with human cognition. There is a division of labour between logic and aesthetics. Although logic studies discursive and rational cognition, aesthetics concentrates on holistic and sensual cognition (*cognitio sensitiva*).

This view of aesthetics does not place at the centre the question of whether a given work is, or is not, beautiful. Value judgement is not avoided, but it can sensibly be raised only after it has become clear what the basis is for a judgement. That basis lies in cognition as we experience and practice it through our senses. Baumgarten suggests that besides the mind's *logical* cognition, there is also a mode of *sensual* cognition that is equally important but instead tied to our physical capacities and experience.

2.1. *The assumptions of Information Aesthetics*

As Maser [21] makes very clear, the basic assumption of information aesthetics is that there are general and objective features that characterize an object as an aesthetic object. Such an assumption is necessary for otherwise the search for aesthetic measures would be in vain. A feature is general if it can be detected in all objects irrespective of its particularities. Compare this to the fact that temperature can be measured for all physical objects.

A feature is objective if it does not change when another observer is judging it. The basic assumption and goal of Information Aesthetics is that objects are material carriers of aesthetic state, and such aesthetic states are independent of subjective observers. Information Aesthetics is an aesthetics of the object.

The second pillar on which Information Aesthetics is founded is the idea that a particular kind of information is conveyed by the aesthetic state of the object (or process). This information is called aesthetic information insofar as it is contingent with the physical reality of the object, which it transcends. Aesthetic reality is *co-reality*, a mode of reality that comes with the material aspects of the object (or process). It functions in communicative processes and is realized by processes of selection.

The aesthetic object depends on a repertoire of elementary signs arranged as a complex supersign. Its elementary signs constitute the level on which the statistical information (in the sense of Shannon) is measured.

Shannon (and Weaver) assume for their definition of the information content of a message that a source is selecting signs (better: signals) from a given repertoire of elementary signs according to given probabilities. If the repertoire is $\Omega = \{\sigma_1, \sigma_2, \ldots, \sigma_r\}$, and the probability of σ_i being selected is p_i, where $0 \le p_i \le 1$ and $\sum p_i = 1$, then the average information of a message sent by the source is

$$H = -\sum_{i=1}^{r} p_i \lg p_i,$$

where lg denotes the logarithm to base 2.

A third and last precondition is borrowed from Birkhoff [7]. In the 1930s, Birkhoff studied a number of artefacts such as planar polygons or rotationally symmetric vases for their aesthetic merits. His general approach for defining an objective aesthetic measure

was to take the degree of *order* relative to the degree of *complexity* in an object.

If a class of objects was given, the task therefore consisted of defining order (O) and complexity (C) as numeric quantities. The aesthetic measure according to Birkhoff was then given by

$$M = O/C.$$

Birkhoff extensively tested his method on a large set of polygons (with questionable results). We must keep in mind that this was an objective measure that said nothing about the subjective judgement by a given observer.

The mathematicians Frank [12] and later Gunzenhäuser [17] wrote Ph.D. theses in which they interpreted, in different ways, Birkhoff's formula of order-in-complexity by transforming it into information-theoretic terms.

The simpler of the two ways, and a purely objective one, was Gunzenhäuser's suggestion to equate complexity with the average statistical information H, and order with the so-called relative code redundancy

$$R = (H_{\max} - H)/H_{\max}.$$

The information content is maximal when all probabilities are equal, i.e., $p_i = 1/r$. We then formulate the aesthetic measure as

$$m = R/H = (1 - H/H_{\max})/H = 1/H - 1/\lg r.$$

2.2. *Results from Information Aesthetics*

Bense [2,3] distinguishes two phases of the existence of the work (of art): the first phase being the generation of the artwork and the second phase being its evaluation. Phase one is more or less the artist's activity, phase two is more or less the critic's activity.

In real life, these two phases cannot be treated separately because the artist, during his or her productive activity, is judging the current state of the work, and the critic, during his or her evaluative activity, is judging the current state of the critique. Besides, even if we assume the artist is working in isolation (an assumption not so often true anymore), the critical dimension is to a large extent a public event. All sorts of activities, events, productions, distributions and communications take place as part of the critical appreciation [6]. It is safe to say that the artist generates the work (only), whereas society may transform it into a work of art.

Max Bense points out that in phase one of the genesis of a work of art, the aesthetic object appears as adding to the world of pure being (*reine Seinsvermehrung* [2, p. 37]). In phase two, the aesthetic object leaves the state of pure being and enters a state of pure theory. All aesthetic reality is of the mode of co-reality. That is to say, it 'comes with' and, therefore, is neither independent nor self-contained. Thus the artist's creative act is a first necessity without which the later activities of perception, critique and appreciation cannot take place at all. Aesthetic perception appears as mediating between aesthetic generation and aesthetic appreciation.

As an aesthetics of the object, Information Aesthetics is forced to engage in a process of impossibility. For, if appreciation of an existing, and therefore generated work as possibly a work of art requires perception, a perceiving agent must first be in place. Only to the extent that we allow this agent to be non-human or machinic or algorithmic in nature, can we try, and hope for, an objective evaluation. This was the point of departure for Information Aesthetics.

Abraham A. Moles was the other founder of Information Aesthetics. Unlike the Stuttgart School, whose publications are almost exclusively in German, Moles' main relevant work was translated into English 10 years after its original publication in 1958 [22].

As a physicist and psychologist, Moles did not entirely exclude the observer. Aesthetic information, in his theory, is the counterpart of semantic information. Semantic information is *what* appears in a message. Aesthetic information is *how* it appears. Semantic information is embedded into a universal logic, it can be articulated and translated, and it serves to prepare for action. Aesthetic information, on the other hand, can only be expressed the way it *is* expressed, i.e., it cannot be translated. It creates particular states of the mind and depends on the actual sender and receiver. Semantic information is directed towards action and, therefore, to external goals. Aesthetic information is directed towards states of the mind and, therefore, to internal goals. Semantic information is bound to conventional signs, aesthetic information to individual signs.

A frequent oversight in dealing with evaluation or appreciation of the work of art is mistaking *measure* for *value*, or vice versa. We measure an aspect of a phenomenon, if we have a device, an instrument, a technique, or method that, when applied to the phenomenon, yields a number. The number expresses the location of the chosen aspect of the phenomenon on a numeric scale. The scale, and the way measurements are taken, must be defined precisely. In the case of many of the measures of physics, agreements on the measurement method have been established internationally. Relative to such an agreement, the measure appears as objective even though its origins may be arbitrary.

Abraham Moles draws a clear dividing line between measure and value. Value is based on judgement and is, therefore, depending on situation, context or history, individual. Moles considers value judgement to be outside of scientific aesthetics, whereas information measure is an issue of science [22, p. 160].

In relation to the aesthetic information of an object (measure), Moles envisions the aesthetic judgement (value) to be low at the two extremes of information. That is, when the information is very low, redundancy is high, so we can make predictions about the work, and this should be reflected in a low value ('banal'). But when information is very high, approaching its maximum, redundancy is low, so we cannot predict anything; we then cannot discover any patterns and may feel lost. This should also be reflected in a low value, although for a different reason ('chaotic').

In consequence, value judgement will reach a climax somewhere between banal and chaotic. The German–British psychologist Hans Jürgen Eysenck was one of the earliest authors who questioned Birkhoff's formula, which as noted previously was based on little more than speculation. Eysenck's empirical research [10,11] triggered a large number of experiments, many of which suggested that Birkhoff's O/C formula was wrong [9]. The alternate formula $M = O * C$, as suggested by Moles, was a closer approximation to the behaviour of value [22,23].

Max Bense was the first to use the concept of aesthetic information. (It appeared in print in the first of his four volumes on aesthetics that were published from 1954 to 1960, and later when they were published all together in one volume [2]; see also [5].) Abraham Moles used the term a bit later in 1958. From him it passed to Helmar Frank (1959).

While Gunzenhäuser was working on his interpretation of Birkhoff's formula in terms of information theory [17], Frank went on to define some additional measures based on Shannon's quantitative and statistical theory of communication (and information) [13].

Continuing Moles' conception of aesthetic and semantic information, Frank declared aesthetic information to be what remains in an arrangement of signs when their meaning is already known [13, p. 27]. The statistical information is always calculated relative to a repertoire of signs. The primitive signs constituting a message are, however, not necessarily given explicitly. We can consider them as given in the case of a text, if we identify words or phonemes or morphemes as the elementary repertoire. But even this is a problematic act. The problem is enhanced when the given work is of a continuous character such as a painting or drawing.

A continuous painting is a problematic case for Information Aesthetics insofar as the image must allow for the identification of discrete elementary signs. In this case, we can always superimpose some grid (of one or more dimensions) on the work and then take as primitive signs those cells that are different with respect to the grid. Combining subsets of grid cells into larger units reduces the number of signs that must be counted, but this changes the repertoire of different signs. This process of building supersigns out of lower level signs by collapsing several of them (a process we call superization) allows for a series of information measures. Maser describes such a process in a systematic way [21].

Frank attempted to use Moles' distinction of semantic and aesthetic information for a formal definition and determination of aesthetic information conveyed by a given work. Formally, given the work, we consider it relative to a sequence of repertoires $\Omega_1, \Omega_2, \ldots, \Omega_n$. The repertoires are not totally arbitrary. Ω_i is derived from its predecessor, Ω_{i-1}, by a process of superization. Each of the repertoires establishes the basis for a new calculation of the average statistical information: $H_1, H_2, \ldots, H_n$. The difference $H_{i-1} - H_i$ between two consecutive measurements is an expression for the amount of information in Ω_{i-1} when Ω_i is already known.

If we now assume that our memory is organized according to short-term and long-term attention and perception and that, furthermore, the capacity of the short-term memory is known, we can define a level of repertoire relative to such a capacity. Assume that $C^{(0)}$ (measured in bits) is that mysterious short-term memory capacity. We can then define a critical, or optimal, or interesting level k in the sequence of supersigns such that

$$H_k \leq C^{(0)} \leq H_{k-1}.$$

This level k (of our more or less subjective process of superization) is characterized by the property that on level k the information H_k has dropped below the critical capacity $C^{(0)}$ for the first time, whereas at level k–1 the information H_{k-1} exceeds it for the first time. Whether or not $C^{(0)}$ actually exists is unimportant because we can arbitrarily assign a value for 'capacity' and then study the situation relative to it.

As is the case with any formalization, the proposal does not say much more than that this is a way of, perhaps, getting a bit closer in an explicit way to conceptualizing something we know quite well from experience. If we consider a painting interesting, we spend more time looking at it. During the time we look at it, we let our view wander across the canvas. We also walk away a bit, and get closer again, which amounts to the activities of changing repertoires.

Information Aesthetics begins by considering the work (of art) as a complex sign. The work is structured

in a multitude of ways and can be analysed in terms of subsigns, and subsigns of subsigns, continuing on down to a lowest level (granularity). As a complex sign, the work gives rise to processes of communication and information. The concept of information is taken up as the central notion for an aesthetics that is oriented towards numeric values. Besides the interpretation of Birkhoff's measures of complexity and order as statistical information H and code redundancy R, the information aesthetic approach allows for systematic measurements in a structured way. Apart from Maser [21] and Nake [23] this option has not been further pursued.

However, Frank [13] did suggest two other statistical measures: a measure of *surprise* per sign, and a measure of *penetration* per sign. A sign appearing in the work may surprise the observer. For example, he or she may have been listening to a musical composition, when suddenly a sound appears and disappears that before did not contribute to the flow of sounds. Frank suggests as a measure of that surprise the ratio of the particular sign's information and the average statistical information. Thus if sign σ_k has probability p_k of appearance and if $H = -\sum_i p_i \lg p_i$ is the average information content per sign, then the measure of surprise of sign σ_k is

$$ms_k = -\lg p_k / H.$$

For very small p_k, this results in a large value, and for p_k approaching 1, it becomes 0. (Frank suggested the objective probabilities p_k, as controlling a source of signals, be replaced by subjective probabilities of the signs, i.e., probabilities expressing expectation [13, p. 66].) In contrast, the measure of penetration per sign should go up if the sign appears relatively frequently but, at the same time, does not lose too much in the way of surprise. Formulated in an objective way (i.e., assuming the probabilities are good enough to express an observer's perception – which is questionable), the measure of penetration for σ_k is

$$mp_k = -p_k \lg p_k / H.$$

To summarize, Bense and Moles in the late 1950s had formulated their vision of an aesthetics based on Shannon's measure of information. Whereas Moles was interested more in sequences in time (music, language), Bense favoured arrangements of signs in space (images, text). Both expected that a measure of aesthetic information could be found allowing for judgements of aesthetic objects as such. Moles was one of the first who predicted machines would soon generate aesthetic objects based on automatic decision making.

In Stuttgart, Gunzenhäuser came up with his new interpretation of Birkhoff's aesthetic measure in terms of information and redundancy, and Frank refined and amended this approach. Frank, however, was not interested in measuring works for comparison with one another because he modelled the individual human observer – even though this was a rather passive and isolated character – as a set of parameters (adjusting personal preferences to probability distributions of a source).

Franke [14] took a slightly different path by assuming that there are certain parameters governing human perception in terms of short and long-term memory. Eventually, however, Franke gave up regarding the isolated aesthetic *object* as the most important subject matter. Instead, he considered the *process* of the human perceiver from a cybernetic perspective, i.e., as a feedback process by which the perceiver adapts his or her perception to the flow of signs (from a dynamic or static source). In this view, the aesthetics of a work became a process of optimizing the granularity level of the repertoire to the capacities of human perception.

Bense had several students who conducted specialized studies resulting in Ph.D. theses. To mention some of the ones more relevant to our discussion: Garnich analysed in great detail hundreds of industrial design objects [15]; Kiemle studied architectural façades [19]; Brög decided on ad hoc repertoires to measure woodcuts by Dürer [8]; Kiefer was the first to concentrate more on semiotics than on numbers [18]. Maser expanded the methods to structures of measures and introduced the term 'numerical aesthetics' [21]. This allowed Max Bense to gradually shift emphasis from a quantitative to a semiotic analysis. Thus semiotic aesthetics became more prominent, although it had always been the starting point.

3. Generative aesthetics and computer art

The Stuttgart School was never a purely analytical undertaking. Bense himself wrote essays and poetry, in particular, concrete poetry. During the decade of the 1960s and beyond, Stuttgart was a European centre of concrete art and poetry. Some of the very first computer-generated texts originated here [20]. Bense was an advisor to the 1968 Cybernetic Serendipity exhibition in London, and the author belonged to the international committee of the Tendencies 4 manifestation in Zagreb at the same time.

Computer art has a date of inception. On 5 February 1965, the first show devoted to computer art, where Georg Nees showed a dozen or so drawings, opened in the rooms of the Aesthetic Colloquium in Bense's Institute. This event marked a step of great importance in the history of Information Aesthetics precisely because it was about generating, and not

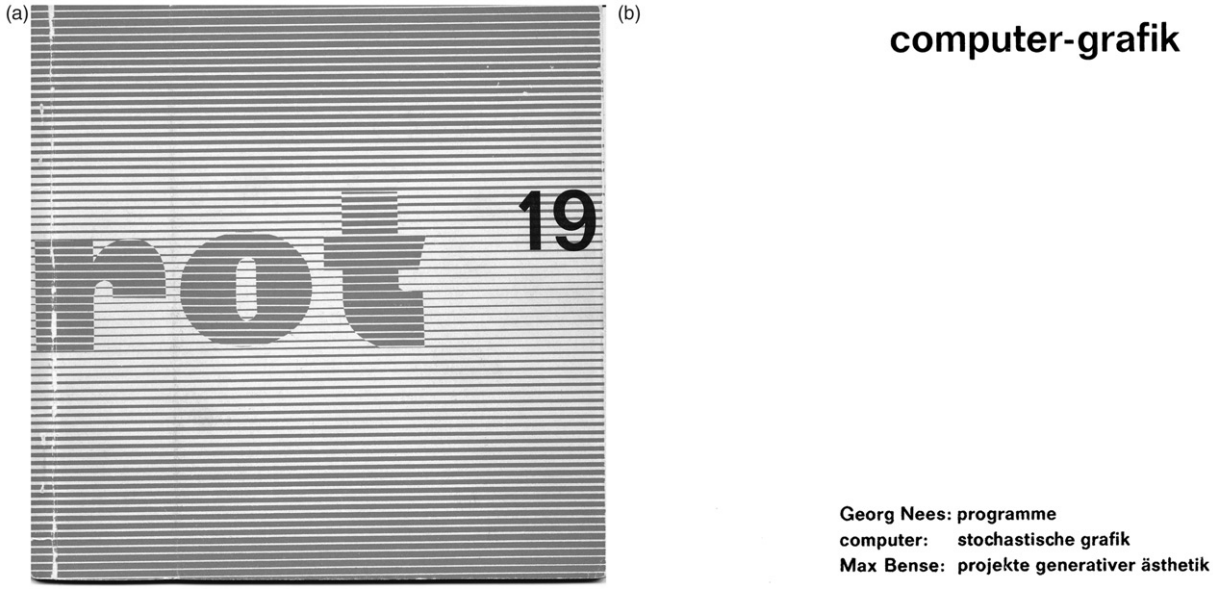

Figure 1. Cover (left) and title page (right) of *rot 19*, the first publication on computer art. With permission from Elisabeth Walther and Georg Nees.

analysing, works that were meant someday to become art.

Nothing was particularly exciting about the show announced to open that day in February 1965, except its title. No one whom I have asked about it, including the artist himself, seems to remember it. But it was clear that the computer played a role. Guessing only a bit, the announcement notice may have read 'Computer-Grafik' or 'Computer-Bilder' or similar. Or it may also have been 'Generative Computergrafik'. This is, indeed, quite likely because a little brochure (Figure 1) was published for the occasion and this brochure uses the phrase, 'generative aesthetics'. We have here the first use ever of this term.

In the twentieth century, new art movements often began with a manifesto, a scandalous exhibition, and certainly a lot of fuss. This one was different, and the audience at the opening may not even have been aware of the sensation. To have drawings by computer shown in a gallery was certainly new. None of the participants had ever seen such. But people did not feel alienated. They were curious.

The brochure [5] contained a small selection of the drawings (Figure 2), short texts in a style of natural language pseudo-code (by Nees) plus a very brief essay by Bense (in German). Its title was: *Projects of generative aesthetics*. (The essay was later published in an extended English translation in [2].) The opening passage that started the original German version, here translated into English, reads:

> Generative aesthetics therefore implies a combination of all operations, rules and theorems which can be used deliberately to produce aesthetic states (both distributions and configurations) when applied to a set of material elements.

The remarkable step taken here is the step from aesthetics as a rigorously rational analytic aesthetics to a generative method. About the same time, a similar step had also been taken by Noam Chomsky in his attempt to identify the syntactics of natural languages. Bense continued by saying:

> Hence generative aesthetics is analogous to generative grammar . . .

The interpretation that we traditionally expect from an aesthetics gets changed into construction. The effort to rigorously define measures in order to evaluate certain characteristics of the work (of art), in the case of the model of Information Aesthetics is shifted to the opposite effort of algorithmically generating such works. Scientific and engineering methods break into the realm of the humanities – a provocation!

The story of what took place on a quiet and friendly afternoon in Stuttgart, Germany in 1965 has a footnote that may be worth telling. A group of well-known artists and designers from the Stuttgart Academy of Fine Arts was present as often, when Bense invited people to an opening. It seemed that this afternoon their number was a bit larger. After Bense talked about generative aesthetics, Nees gave some indications of what one had to do in order to make a computer calculate a drawing and actually control another machine to carry out the drawing. After he had ended, a professor of painting raised his hand to ask: 'All very fine. But tell me: can you make your

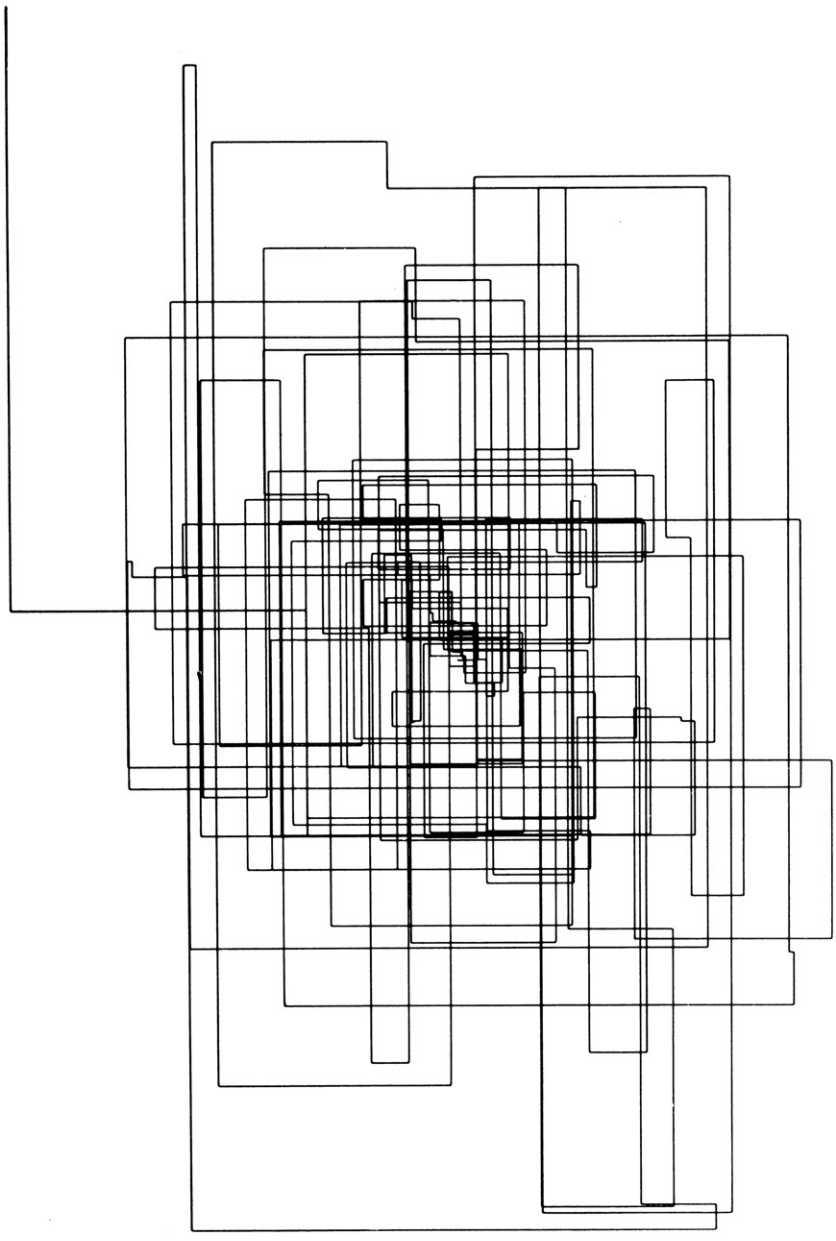

Figure 2. One of the drawings on display at Georg Nees' show *Generative Computer-Grafik*, February 1965. With permission from the artist.

machine paint in the style I do?'. (He used the typical German expression: ***in meinem Duktus***, meaning the way he holds and draws and presses the brush against the canvas.) Nee's answer was a classic, soon to become a general motto appropriate for many discussions about the relation of humans to their algorithmic machines. After a little pondering, he said, in a typical reduced engineering voice: 'Oh yes, I can – if you tell me how you do it'.

To make things explicit, to make them utterly clear and unambiguous, that is the task one faces in programming (in his dissertation [24], Nees says much more on this). In the case of art, we may tend to dislike this, but mathematical models to evaluate works (of art) are exactly about such a reduction to an algorithmic determination, which usurps the place of the traditional open interpretation. Interpretation is open to contradiction and debate; determination allows for one correct case only.

Let me add to this episode about the first day ever devoted to generative aesthetics and computer art. Three years later I spent a year at the University of

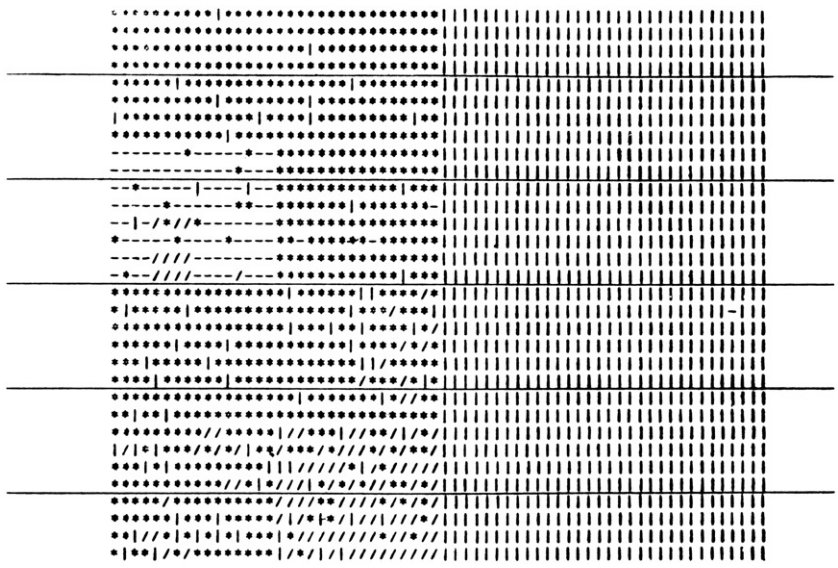

Figure 3. Print-out of one of *Generative Aesthetics I*'s patterns. Frieder Nake, Experiment 4a.5, 1969.

Toronto, equipped with a gracious stipend to do whatever I wanted to do. I decided to take generative aesthetics more seriously and developed a program that was fed with a vector consisting of all the aesthetic measures known to me. The program was supposed to come up with a work of art that would satisfy exactly those conditions.

A bit more precisely, the information content, the measures of surprise and penetration, and the relative frequencies were restricted, for each selected colour, to arbitrarily chosen intervals. The aesthetic measure according to Gunzenhäuser was to be optimized. The problem was a non-linear optimization problem with non-linear constraints. The program determined whether a solution was possible at all, and if there was one, it tried to approximate an optimum. The solution to this task was, of course, only a probability distribution. People had not really been aware up to then that the information aesthetic method collapsed all works into equivalence classes where each class was represented by a probability distribution. Only the number of different primitive signs mattered. In fact, only their ideal frequencies mattered.

So, if the grand idea of prescribing certain aesthetic measures and having a machine generate an image accordingly should work at all, this image should be nothing but a probability distribution: an infinity of images. Therefore, another program had to take over and actually derive, from the calculated probability distribution, a geometric distribution (of colours in a grid). This turned out to be an interesting and exciting job. The end result was that I had learned a lot about mathematics, quadtree structures and algorithms. I also learned a lot about the high flying hopes of numerical aesthetics. And I gave up believing in them. In a material sense of the word, I realized only two of the many dozens of line print output patterns (see Figure 3) that were generated by the program. One of them was thrown into the dustbin by my mother. The other one is kept at Museum Abteiberg in Mönchengladbach, Germany (Figure 4).

4. Flaws in Information Aesthetics

Algorithmic aesthetics is an aesthetics performed algorithmically, i.e., by computer. If we adopt the position that aesthetics is concerned with sensual cognition, algorithmic aesthetics must by necessity reduce sensual cognition to those aspects, or approaches, that are standard, common, or average within a population and do not depend on individual living persons. A model agent must be assumed as the target. To what extent such an average agent would be capable of cognition may be left open, as well as the question of how it could perceive sensually.

Aesthetics may justifiably be split into a generative and an evaluative perspective, an investigation against the horizons of production as well as of interpretation. Automating evaluation would exclude a living agent. It would make sense only in the context of automatic (machinic, algorithmic) production. Such purpose requires that we strive towards an advanced dynamic process of aesthetic generation. Today, this would encompass interactive art, animation, net art, and software art – all forms of current aesthetic production that don't need automated evaluation, nor would they gain much from such.

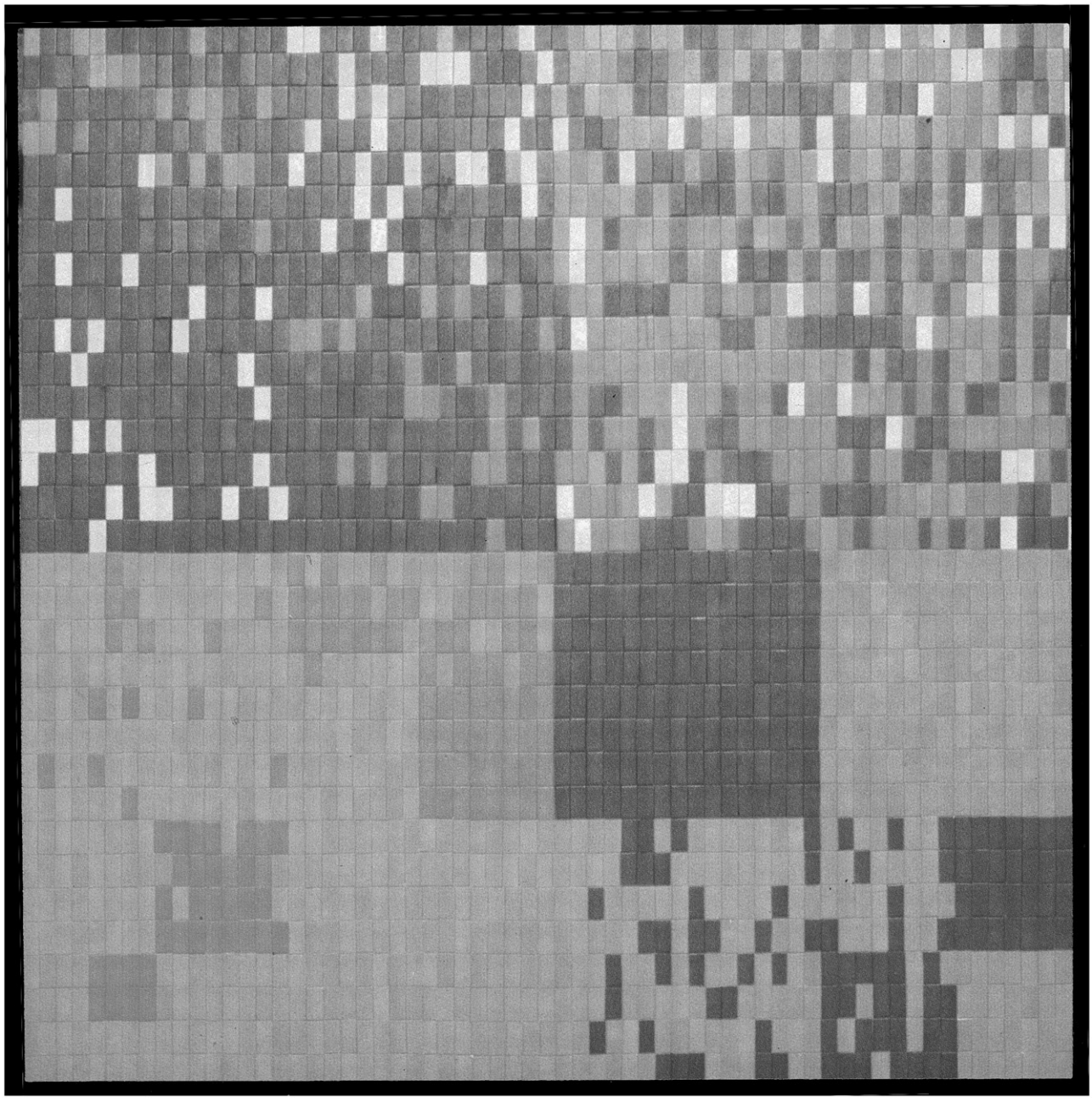

Figure 4. Realization by hand of one of *Generative Aesthetics I*'s patterns. Frieder Nake, Experiment 6.22, 1968/9 cm, 128 × 128 cm, four colours. With permission from Sammlung Etzold, Museum Abteiberg Mönchengladbach.

In this article, I have chosen Information Aesthetics as the mathematical model of the aesthetic process because it made strong claims and pertained to production and evaluation alike. Information Aesthetics separates aesthetic production from critique of its products. This allowed Bense to draw a clear line between the artificial and the natural, between the made and the given. During the first decade of Information Aesthetics, his efforts were mainly oriented towards the critical aspects.

However, we must not ignore that text production by computer had become a theme as early as 1958/1959 [20], and that Bense was a poet himself, though without taking his poetry to the realm of computers. With his Studien-Galerie, he provided a medium between artists and audience. Thus evaluative theory came in touch with productive practice. The event of visual computer art dramatically opened the domain in 1964/1965. In retrospect, Bense's 'Projects of generative aesthetics' appears as the manifesto of this new art.

Any mathematical model must start from a suitable abstraction. In Information Aesthetics, this is the work (of art) as a complex sign realized from a given repertoire of discrete material elements by processes of selection, combination and distribution. Such complex signs realize aesthetic states both as process and as finished product. Such states carry aesthetic information, which can be (and must be) measured. The measuring procedure must be defined rigorously and can, therefore, be turned into algorithms. To allow for even richer kinds of evaluation, sets of measures were defined on different levels of repertoires.

Such a radically anti-subjective program for aesthetics must be understood as a reaction against the horrors of Nazi Germany. For many intellectuals, it seemed to be impossible to allow for any irrational or emotional aspects in aesthetics. Too successfully had the Nazi regime used aesthetics (sensual cognition) in their manifestations of supremacy and power. One could predict that such a clear approach would come to its end because the historic and social conditions would change. The aesthetics of the object would come to its close.

But the anti-metaphysical basic assumptions, intriguing as they were at the time, were flawed. Shannon's measure of information content applies to a source that is permanently spewing out messages. The average amount of a quantitative characteristic of such a source is what the formula measures. It yields a statement about the source, not about the individual message. The elementary signs appearing in a message may well be counted to get at relative frequencies. Frequencies only approximate probabilities. By equating the two, as a matter of practice, a fundamentally wrong assumption slipped into all further considerations: the neglect of the difference between infinite class and individual instance.

The aesthetic process involves at the very least the artist, the work and the audience. We can certainly justify an analytic concentration on nothing but the work's objective and syntactic aspects. Interesting results will, however, become possible only for certain kinds of aesthetic processes. Any kind of participation, for example, is eliminated immediately.

The model of communication assumed by Information Aesthetics was the most trivial one: the purely technical model of a message being issued by a source and transmitted via a channel to a receiver under constant conditions. Along the channel, noise could mutilate the message. This simplistic model was good enough for the study of traffic over telephone lines, but it had no relevance for the study of human communication. The essence of art is of a totally different kind. It appears weird that the glamour of the concept of information (as it had emerged during World War II) was strong enough not only to be applied in art but in other domains of the humanities as well.

To try and measure a degree of aesthetic appeal as the quotient of order relative to complexity, as Birkhoff suggested, can only work in macro-aesthetics – a differentiation in aesthetic evaluation that was not known then, although for the practicing artist it had always existed if only subconsciously. Shannon's measure of information is based on statistics. As such it is a micro-measure. Gestalt, form, symmetry, neighbourhood and the like are not known to it. Thus, only micro-aesthetics could possibly gain anything. But on the elementary level, O/C simply does not make sense: order does not exist here.

Researchers of Information Aesthetics did not realize that they were effectively reducing the work to an *instance* or representative of a *class* of objects. Each class was characterized by the probability distribution according to which elementary signs were to be selected from the finite repertoire. The works, that the researchers studied, were really probability distributions. This flaw, although the most abstract, may be the final reason why none of the limited number of empirical studies came up with convincing results.

On the other hand, in the transgression from analytic to generative aesthetics this basic error amounted to an important insight for digital art. The individual work is here, indeed, reduced to one instance of an entire class, and since the sensual appearance of the work is much more a process than a final product, this necessary distinction is not all that important. The audience is immersed in an interactive process for a while and then leaves. The work is much closer to the senses, and thus to the body than a piece of ink-on-paper could ever be. So, in a tricky way, the algorithm in digital art again stands more immediately for the work than it did in early computer art.

Algorithmic art programs can be extremely rich in terms of the complexity of the events, the signs and the structures of the output that they are capable of creating. Therefore, the spectrum of works generated by a single program may be enormous. To accept the position that such a rich program stands for a vast collection of individual pieces, and that those individual pieces are not interesting by themselves, may stretch the argument to its limit. My program of 1966, *Walk through Raster*, required as its first parameter the abstract repertoire of signs that it was supposed to work on. I still believe this is a way to go – a way of double selection: the material elements first, the structures and neighbourhoods of

chosen elements, their probabilistic distributions, second.

Algorithmic art was only the first phase of digital art as we now know it. The end of the story of Information Aesthetics seems to be that never before had such a rigorous effort been ventured at founding aesthetics on a solid, purely rational and mathematical fundament. This was heroic. It was an act at a time and place of historic uniqueness. It may also be the case that seldom was the result of an exciting scientific endeavour so flawed in its basic assumptions. Those who ventured out into the open ocean had a great vision. Their heroism may have blinded them against critique.

What remains in the end is the semiotic approach to aesthetics, not the numeric. But that's a completely different story.

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