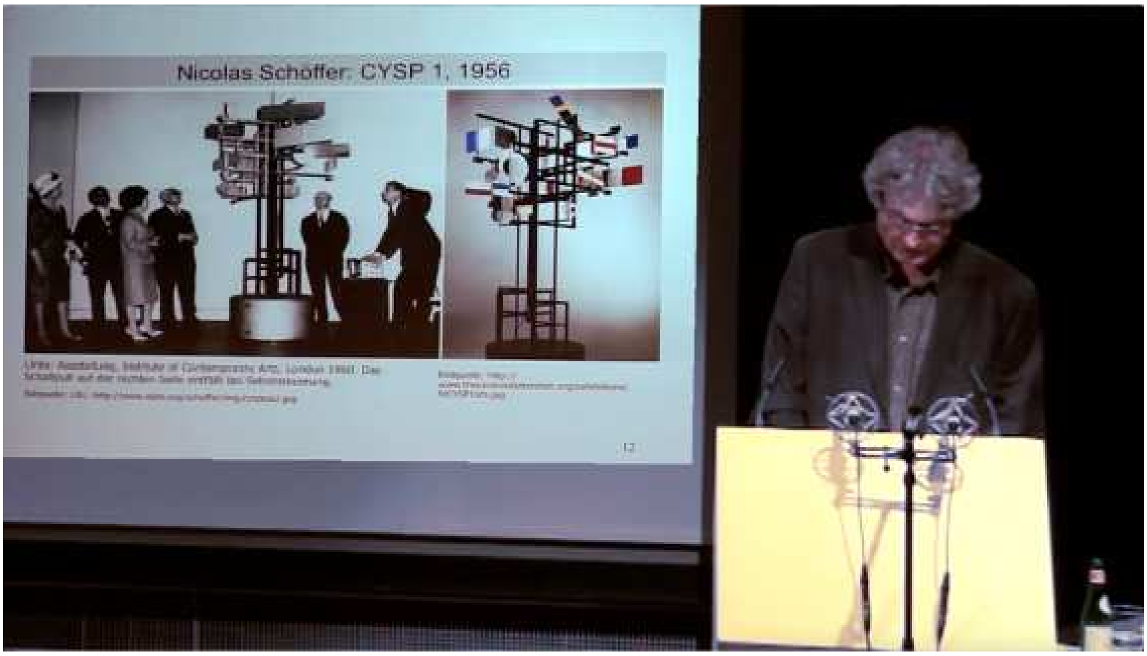
Thomas Dreher

Cybernetics and the Pioneers of Computer Art

Slide show



Lecture (in German), Sprengel Museum Hannover, 10/16/2016 (Vimeo). Part of the "Base Two/Basis Zwei" event series commemorating the 300th anniversary of Gottfried Wilhelm Leibniz (curated by Pit Noack).

Cybernetics, Computer and Art

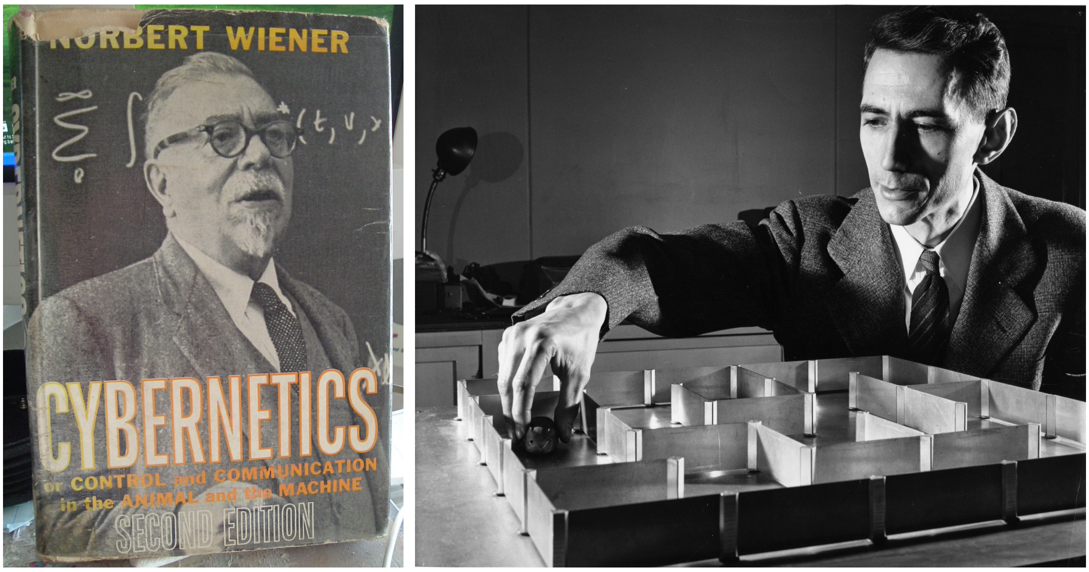
For the first time cybernetics and computer technology have crossed each other during the Second World War. In the early years of cybernetics their researchers proposed solutions to control information processes in using circuit diagrams and applications of mathematical laws. In this way the researchers provided foundations for the development of analogue and digital technologies. Cybernetics began with a search for new ways to apply mathematics in the development of solutions for technical tasks, and evolved to a generalising science.

In the summer of 1947 Norbert Wiener tried to find a title for a book in preparation. He decided to use the term "kybernetes", the "steersman": In controlling the movements of the ship the steersman communicates simultaneously with the ship and with its environment. "Cybernetics Or Control And Communication In The Animal And The

Machine" was the name of the book published in 1948: The title points the readers´ interest to features of machines as well as animals. Wiener's term "cybernetics" for a new research field became established.

For the cyberneticians' interest for computing as a "calculus of reasoning" Wiener regarded Gottfried Wilhelm Leibniz as precursor. In 1703 he developed a mathematical universal language – the binary coding of numbers – and from 1672 to 1720 he planned calculating machines for realisations. Leibniz was interested in facilitations of thought processes by technical means and offered the procedure enabling inventors to achieve this objective: Formalisation enables the mechanisation of calculation. 1 With his reference to Leibniz Wiener offers an opportunity to present cybernetics in a Hanoverian series of events on the occasion of the 300th anniversary of the death of the philosopher and mathematician.

In the fifties and sixties the pioneers of computer art either participated in efforts to develop cybernetic methods (like Gordon Pask) or they were influenced by cybernetics (like Nicolas Schöffer, Georg Nees, Frieder Nake and Herbert Werner Franke).



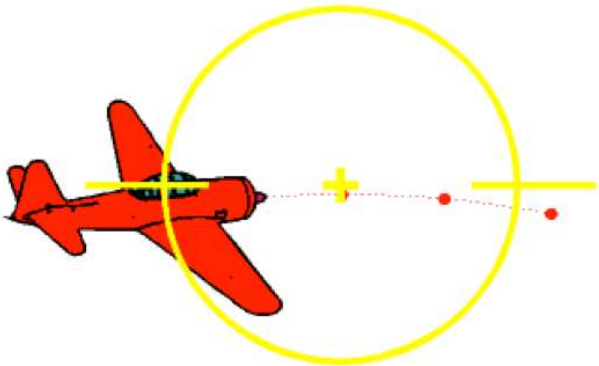
Left: Norbert Wiener (Cover of the 2nd edition of "Cybernetics", 1962).
Right: Claude Elwood Shannon with "Theseus" (1952) and the mouse navigating itself through the labyrinth.
(Credit: MIT Museum, Boston / Nixdorf MuseumsForum, Paderborn)

The Evolution of the Cybernetic Foundations during the Second World War

In 1948 two texts provide the basics of cybernetics. Both inform about the research that made them possible: In "Cybernetics Or Control And Communication In The Animal And The Machine" Norbert Wiener mentions the war research in the United States of America, and Claude Elwood Shannon integrates reports on results of this research in "A Mathematical Theory of Communication". 2 With Wiener's and Shannon's contributions to the prediction of flight paths in fire control systems the American research for an anti-aircraft technology became the initiator of cybernetics.

During the Second World War computing capacities were necessary not only in fire control systems, but also in the cryptography, for whom computers were developed. Via computer-aided cryptography the code of the German Enigma code machine was deciphered.

The probability theory is useful for predictions if the possibilities of a system and the statistic frequency of previous occurrences of these possibilities are known. The probability theory became fundamental in the cryptography as well as in Wiener's and Shannon's research for predictions of the flight paths chosen by pilots to approach a destination. Anti-aircraft systems and cryptography became new fields for the application of mathematics. 3



If the target moves across the course of the fighter, a certain amount of lead has to be taken into account: One has to fire at the point in space where the target will be when the projectiles arrive. The fighter therefore has to fly a curve while firing, i.e. it is turning at some rate. Evidently, there would be no problem if the projectiles arrived instantaneously. Of course they do not, but it is advantageous to reduce the time of flight as much as possible, by using guns with a high muzzle velocity.

Ballistics in the Second World War: Predicted fire against moving targets (Gustin: WWII 1998-99).

An anti-aircraft system receives input data on a moving target and delivers the navigation of a bullet to the target as output. In the time period from input to output the target continues its course. Via computing processes the system must determine possible movements of the target to aggrandize the chances to hit the target. The calculators in anti-aircraft systems of the Second World War were referred to as computers.

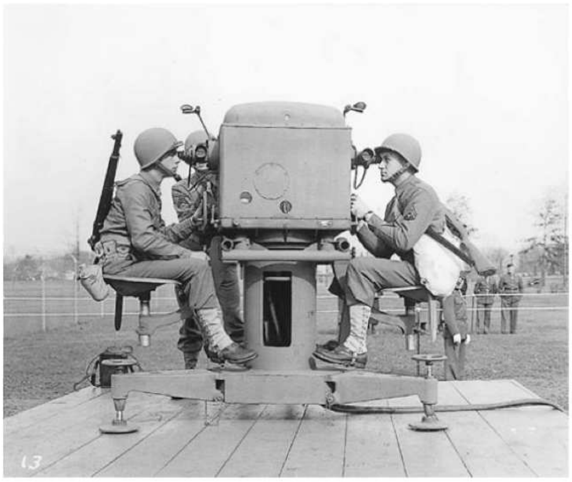


Fig. 9.1. M-9 gun director, tracking head with operators. One follows the target in elevation, the other in azimuth. The unit and the operators rotate while tracking. Courtesy of AT&T Archives.

Source: Mindell: Human 2004, S.128

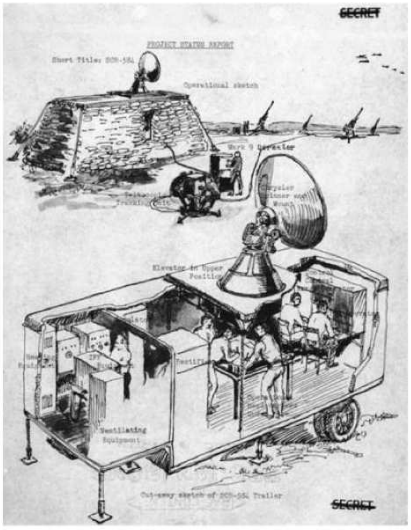


Fig. 9.6. A glimpse of automated war. The SCR-584 radar, driving the M-9 gun director, and 90 mm guns with Sperry servo drives. The 584 itself is in the foreground, as well as buried into a revetment as part of the system in the background. This system proved successful against the V-1 buzz bombs in 1944. Courtesy of MIT Museum.

Source: Mindell: Human 2004, S.352

Left: Pursuit of a goal (one operator) and its localisation (two operators) without radar. Right: Pursuit of a goal with radar and the localisation, the calculation of the goal´s flight line for predictions and their transfers to cannons.

In the circuit of a fire control system the "negative feedback" was important for the control of informations. Great distortions caused by erroneous target tracking were eliminated via filters and a continuous flight path was reconstructed with data smoothing. Thus the data recognized by "negative feedback" were prohibited to initiate the generation of an ouput. 4

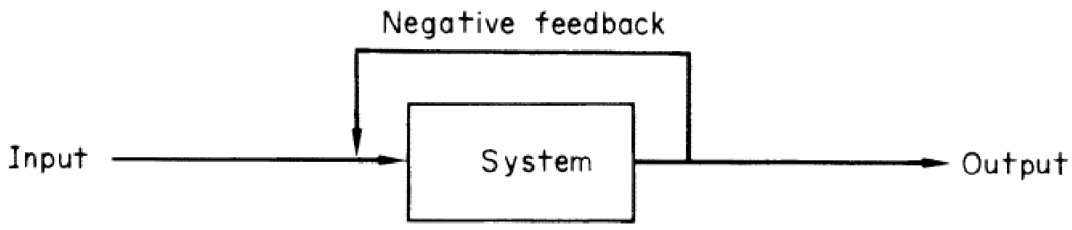
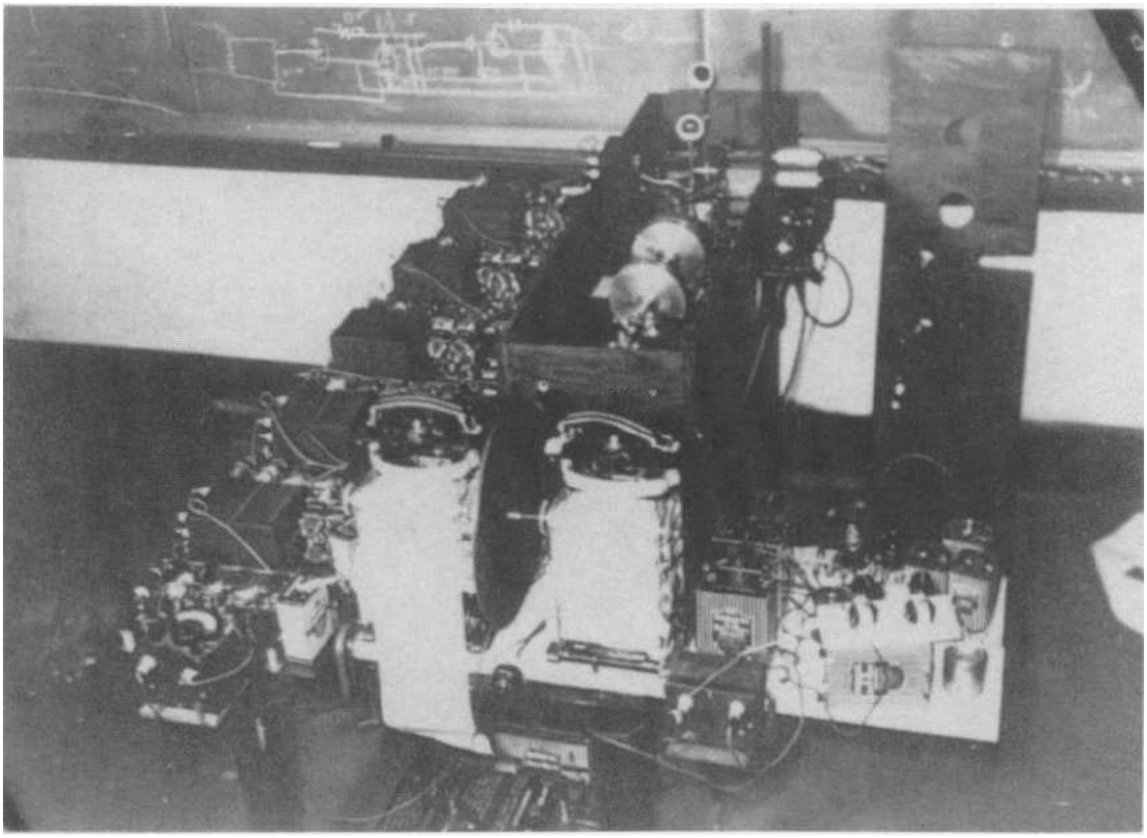


Fig. 2. Negative feedback.

Negative feedback (Apter: Cybernetics 1969, p.259).

Since 1940 Norbert Wiener had the task 5 to improve the possibilities to predict the flight path of enemy flying objects. Efforts to refine the precision of the prediction tried to fulfill the goal to increase the hit rate of the anti-aircraft in the Battle of Britain. Wiener divided the motion of a flying object in time phases. This procedure allowed to recognise the repetitions and modifications between the phases. 6

Data produced by soldiers tracking flight objects were used by Wiener as an input of his prediction system. These data were supplied by subjects in a test model – the "antiaircraft predictor" constructed by Julian Bigelow and Paul Mooney. 7 Wiener's application of the theory of probability and statistics was transferred by Shannon to an analysis of relations between time phases in using stochastics' "measurable transition probabilities." 8

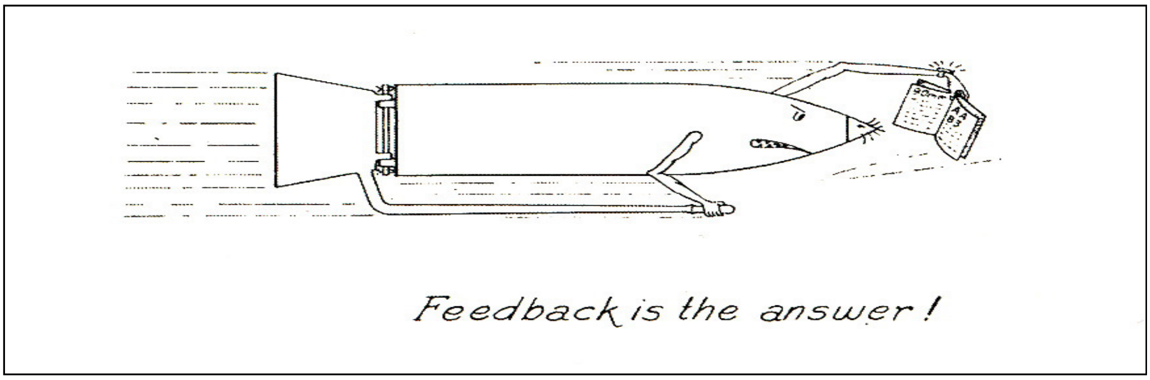


Wiener, Norbert/Bigelow, Julian/Mooney, Paul: Antiaircraft Predictor. Ill. in: Wiener, Norbert: Summary Report for Demonstration (to D. I. C. 5980 A. A. Directors), 10 June 1942, Record Group 227, Office of Science and Research Development, National Defense Research Committee Contractors' Technical Reports, Division 7, MIT, NDCrc-83, National Archives, Library of Congress, Washington, D. C. (Galison: Ontology 1994, p.239).

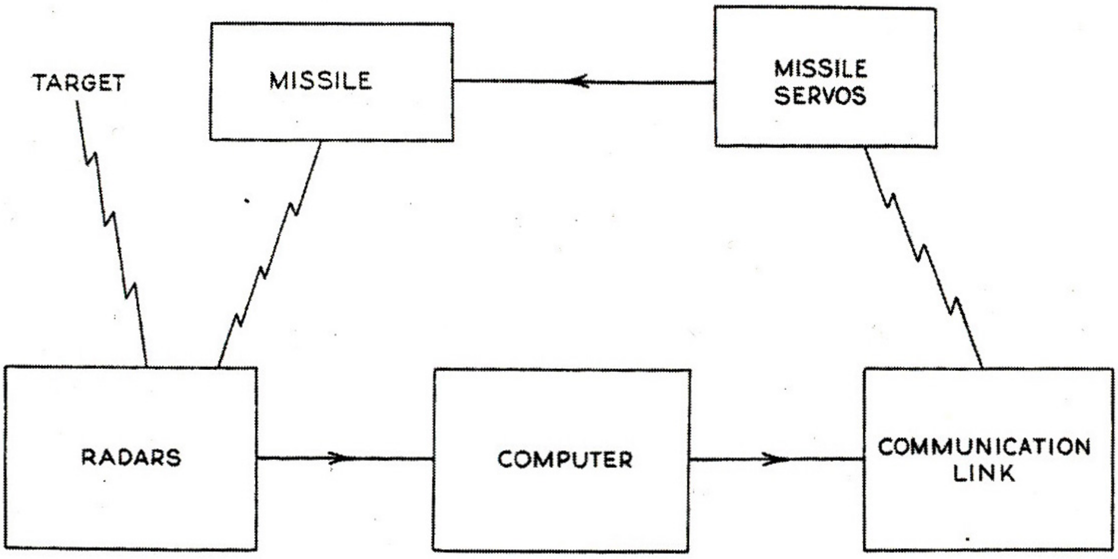
Wiener's "theoretical model" 9 for the command devices of anti-aircraft guns takes attacker and persecutor resp. airplane pilot and gun pointer as elements of one system. Airplane pilots and the gun pointers following their traces are reduced to the characteristics relevant for the antiaircraft system. This constitutes a level without differences between humans and machines. In 1956 Norbert Wiener sums up:

> Therefore, in order to obtain as complete a mathematical treatment as possible of the over-all control problem, it is necessary to assimilate the different parts of the system to a single basis, either human or mechanical. Since our understanding of the mechanical elements of gun pointing appeared to us to be far ahead of our psychological understanding, we chose to try to find a mechanical analogue of the gun pointer and the airplane pilot. 10

During the course of the Second World War the prediction of the airplane pilot´s behavior became increasingly difficult because the airplanes became ever faster and more manoeuvrable. 11 In search for a solution of this problem a research group of the Bell Laboratories – with Shannon as one of the participants – developed the project "Nike-Ajax" as a system for constant corrections of the gun flight path. In 1953 the system was ready to use 12: The answer to an airplane pilot's flight path was the missile's automated recursion of the changing tracking data.



Automated feedback in Nike-Ajax, 1953 (Roch: Shannon 2009, p.158).



Communication diagram Nike, 1945 (Roch: Shannon 2009, p.159).

Since 1937 it was possible to track the target with radar: Thus the amount of incorrect data was reduced. In "Nike-Ajax" the tracking of the target via radar was integrated into the feedback system of a missile reacting in the course of its flight to new input data with changes in direction. 13

Cybernetic Models

The "material models" developed by cyberneticians for a wayfinding by machines (see below) turn the tracking of targets by anti-aircraft systems to civilian tasks.

In some research projects a rule defined as the hypothesis of a "theoretical model" and its proof by the processes in a "material model" supplement each other. 14 Computer-aided cybernetic sculptures (see below) take up characteristics of these cybernetic models.

The "material model" provided the relationships expressed in a "theoretical model" with constructed demonstration material. Hypotheses about processes being crucial for living creatures were exemplified in "material models" constructed with mechanical elements. The "theoretical model" points not only to the relations between the elements used in the "material model" but to these relations as they can be found in other systems with other elements, too.

In 1946/47 William Ross Ashby constructed a model as a functioning example of his theory of "homeostasis". According to Ashby systems are able to react better to their surroundings if they react internally with many parts to changings caused by external forces in one of its parts: Balancing motions between the directly affected part and other parts aggrandise the capacity to react to environments.

FIGURE 8/2/1: The Homeostat. Each unit carries on top a magnet and coil such as that shown in Figure 8/2/2. Of the controls on the front panel, those of the upper row control the potentiometers, those of the middle row the commutators, and those of the lower row the switches *S* of Figure 8/2/3.

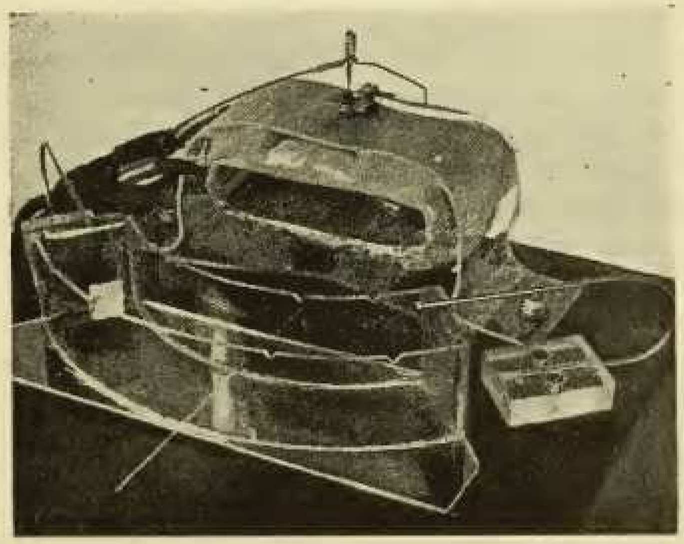


FIGURE 8/2/2: Typical magnet (just visible), coil, pivot, vane, and water potentiometer with electrodes at each end. The coil is quadruple, consisting of *A*, *B*, *C* and *D* of Figure 8/2/3.

Ashby, William Ross: Homeostat, 1946-47 (Ashby: Design 1952/1960, p.101).

The quadripartite technical system "Homeostat" demonstrated Ashby´s system-wide "law of requisite variety". Knobs on each of the four units made it possible to provoke balancing motions of the system reacting internally to voltage fluctuations: A disturbance too strong for a unit was transmitted to the surrounding units. The deflections of each unit were indicated by needles placed in a conductive fluid. 15

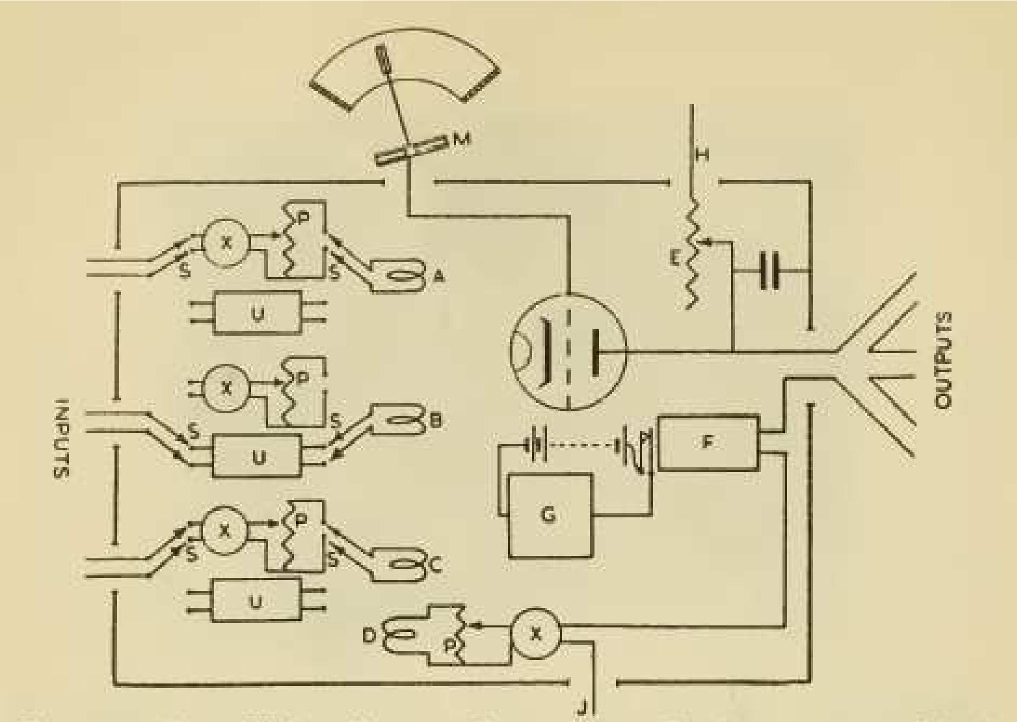
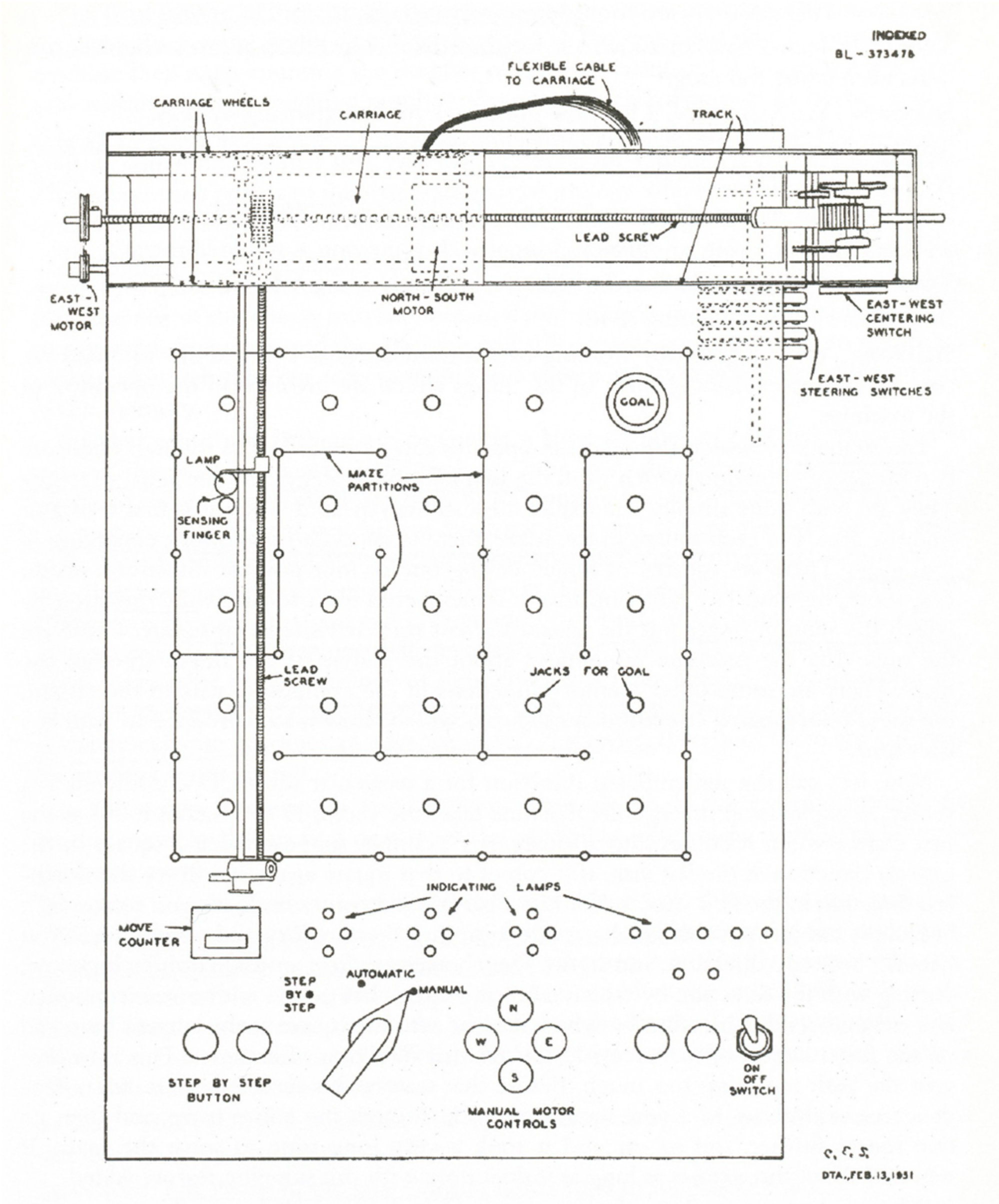


FIGURE 8/2/3: Wiring diagram of one unit. (The letters are explained in the text.)

Ashby, William Ross: Homeostat, circuit diagram (Ashby: Design 1952/1960, p.102).

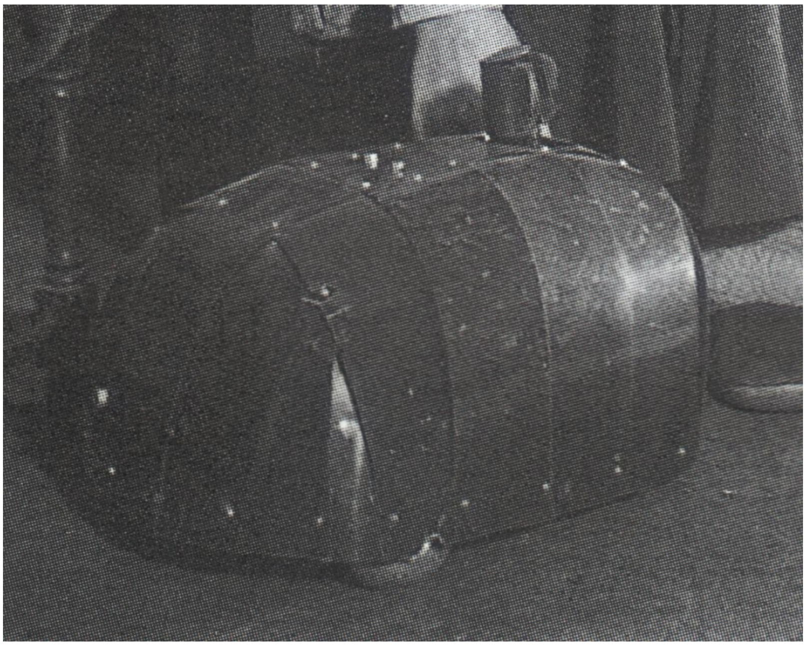
With its multipart internal differentiation the system was enabled to react in a self-regulating way to disturbances caused by the environement and thus to expand its capacity to react. In a stable overall condition all parts were either in an intermediate position or in opposing limit states compensating each other.

In 1950 Claude Elwood Shannon constructed a "Maze Solving Machine" 16 with a "sensing finger" capable to memorise the paths already passed through and to return to them after having reached a blind alley: The model demonstrates a path search with a machine´s memory. 17



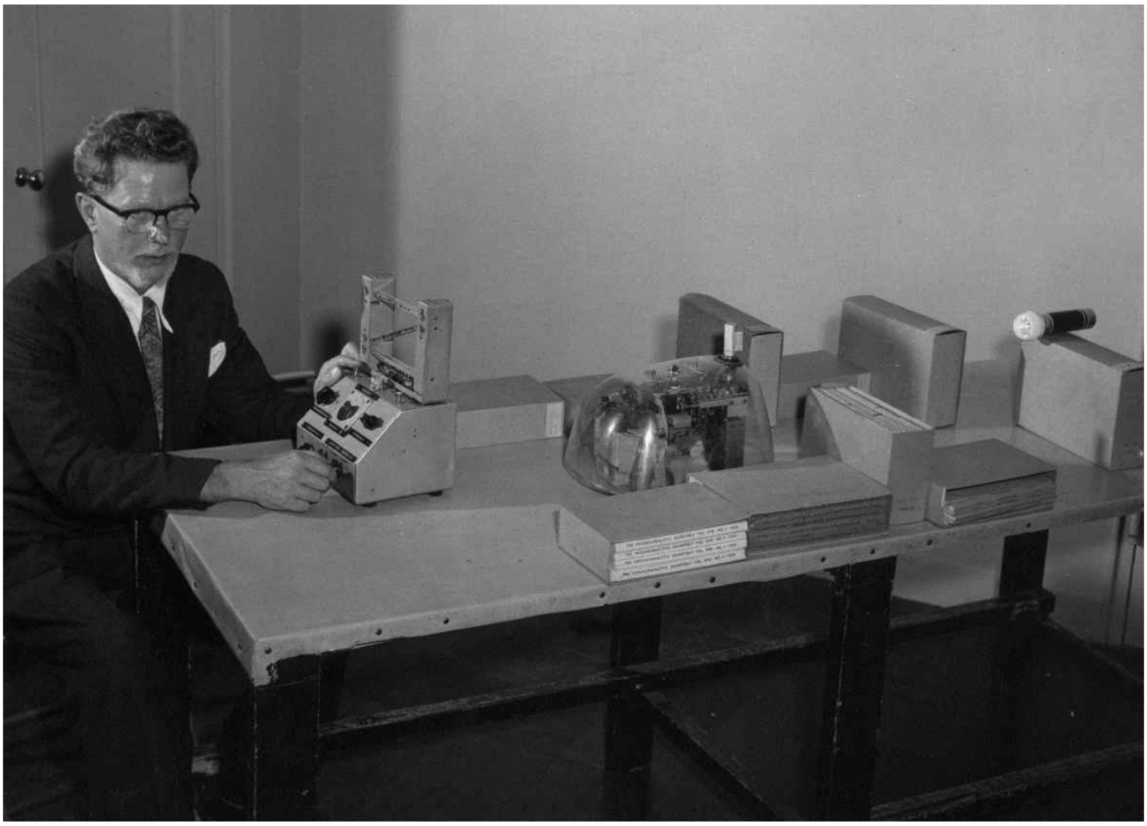
Shannon, Claude Elwood: Maze-Solving Machine, Plan (Shannon: Presentation 1951/2003, p.174, figure 8).

Between 1948 and 1951 William Grey Walter developed moving "material models" equipped with sensors for sound, light and touch. Between obstacles the robots found paths to a garage with power supply. "CORA", built in 1951, was able to memorise the obstacles. 18



Walter, William Grey: Elmer, 1948.

In 1953 Walter wrote about "CORA" in his book "The Living Brain" and compared the robot's "electrical oscillation at low frequency" with electroencephalogram (EEG) measurements of brain waves. With these measurements it was possible to recognise if an event was forgotten or memorised and digested. Walter understood his self-navigating robots as material models equivalent to brain activities. 19



Walter, William Grey: Cora, model for demonstrations on a table, 1951 (constructed by Bunny Warren for the Festival of Britain in London, Exhibition of Science, Science Museum, South Kensington, 1951).

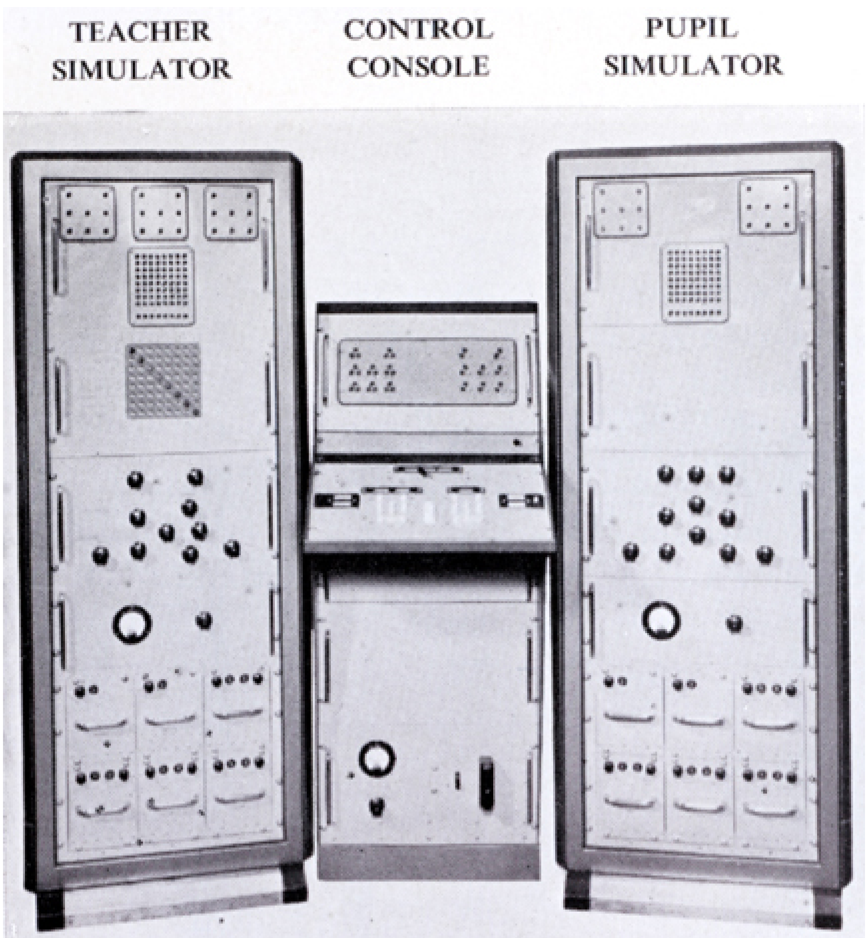
The "material models" presented above exemplify the cybernetic subjects self regulation (Ashby) as well as path detection and memory (Shannon, Wiener). These subjects were discussed before the horizon constituted by contemporary mechanical and electronic technologies, and the validity of hypotheses in biologic systems was tested.

For the cybernetics originating in the prediction for anti-aircraft control units Wiener presented civilian tasks since the end of the war: He reacted to the atomic bombing of Hiroshima and Nagasaki (1945). 20 Among these tasks were relations between homeostasis and anthropology as well as medicine. 21 Also Ashby and Walter worked on this new orientation while Shannon prepared new weapon systems at the Bell Laboratories: The self orientation of his "Maze Solving Machine" and the self navigation of missiles in the project "Nike Ajax" are civilian and military variants of the same problem area.

Cybernetic Sculptures

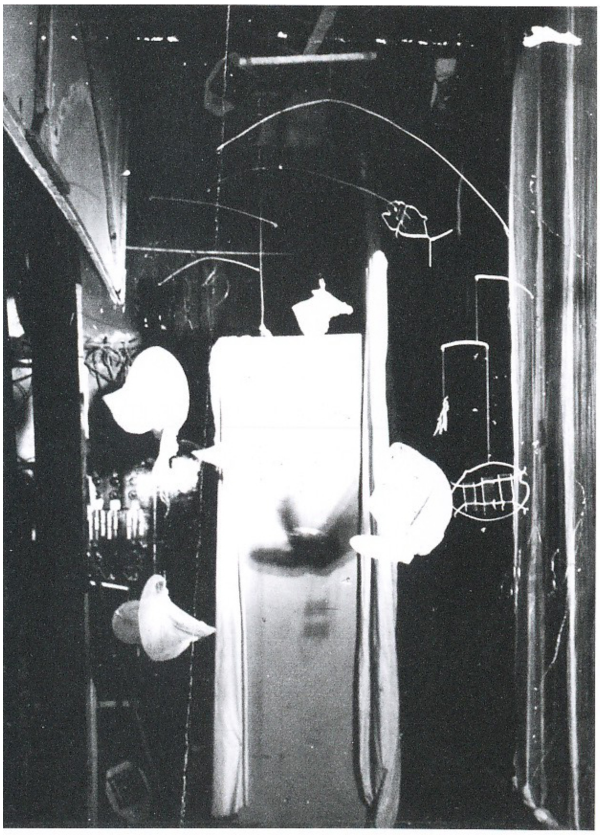
Cybernetic models (see above) contained suggestions for Nicolas Schöffer on how to build cybernetic sculptures (see below). Nevertheless, before Schöffer Gordon Pask, an inventor and author of many texts on cybernetics 22, created the first work of computer art.

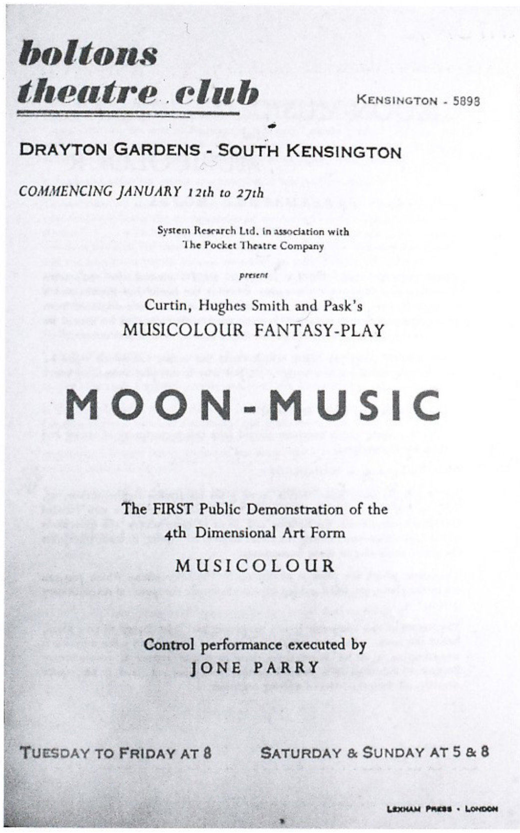
In "An Approach to Cybernetics" (1961) Pask presents "'learning' machines", among them "Eucrates". In 1955 Pask reconstructs the reduced human receptiveness of new input with an electronic learning barrier: After the threshold against the absorption of further informations has grown then the barrier will sink slowly. If new input arrives too late then the system indicates missing input by activities. 23



Pask, Gordon: Solartron EUCRATES II, c. 1956 (Pask: Approach 1961, pl.I 8(i)).

From 1953 to 1957 Gordon Pask and Robin McKinnon-Wood developed the reactive system "Musicolour" for stages. In "Musicolour" the principle of "learning machines" like "Eucrates" is varied: If the input into a microphone decreases then a musician will be initiated by a visual output to create new sounds. Thus the musician is able to control the audio-visual relations of performances via his audio input.

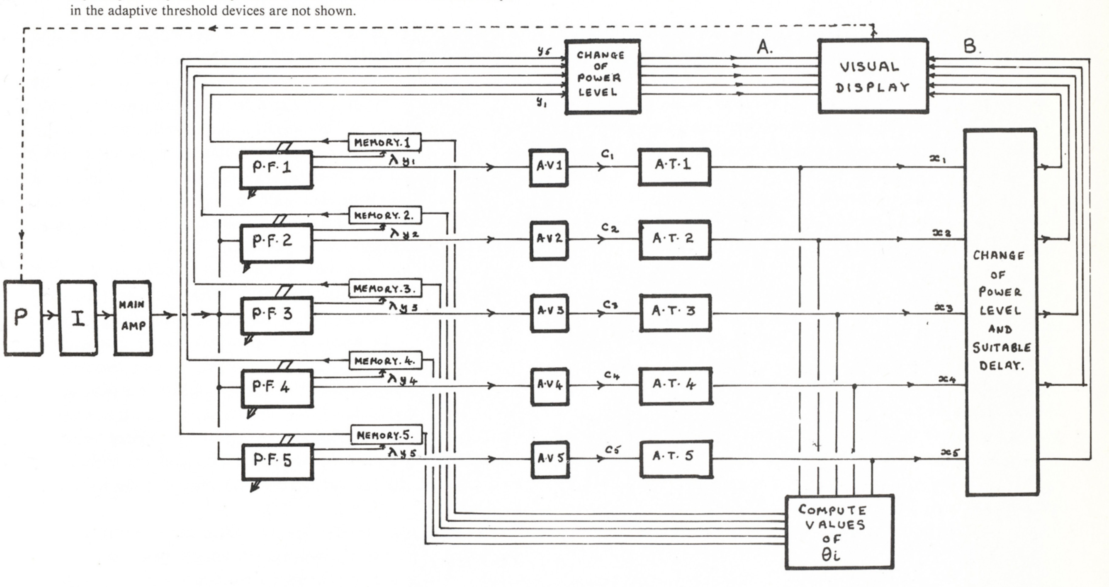




Pask, Gordon: Musicolour, Boltons Theatre Club, South Kensington 1954.
Left: Stage with a projection screen for Musicolour.
Right: Moon-Music, playbill (Rosen: Control 2008, p.139).

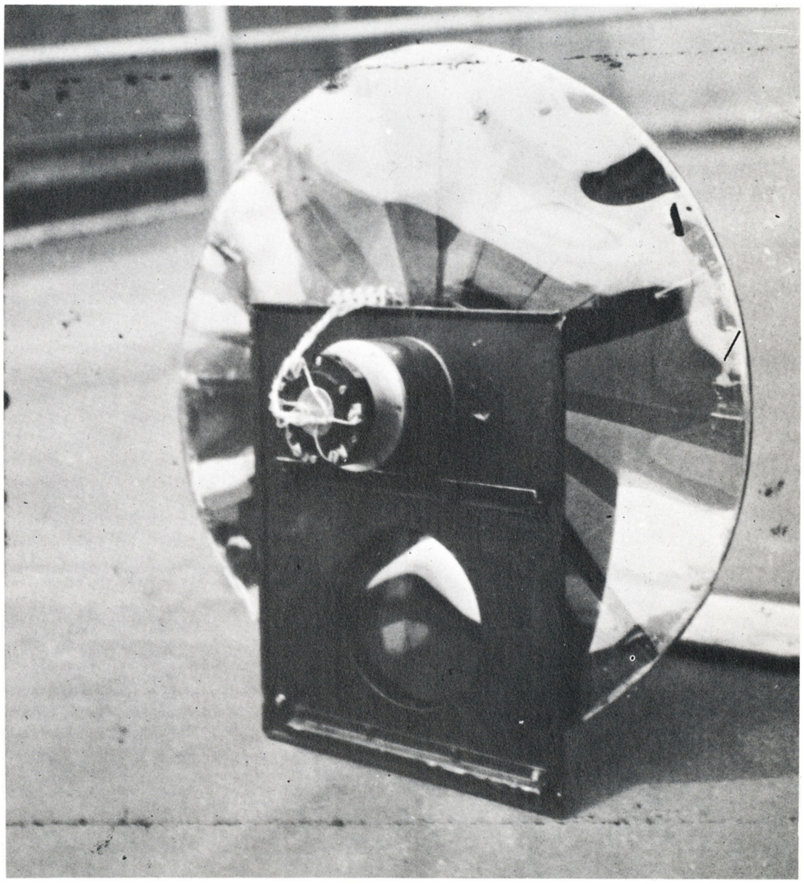
For "Musicolor" Pask and McKinnon-Wood constructed an analog computer. 24 The computer contained sound filters, memory units and elements for the processing of the audio input. The data transformed by the computer caused an output for light projections on a projection screen. This light was modificated by filters producing colour and pattern effects. 25 In a later development phase of the project an electrochemical system was added expanding the possibilities to modificate the light projections. 26

Fig. 26 Outline of a typical Musicolour system. P = Performer, I = Instrument and microphone, A = inputs, y_i, to visual display that specify the symbol to be selected, B = inputs, x_i, to the visual display that determine the moment of selection. PF = property filter, AV = averager, AT = adaptive threshold device. Memories hold values of (y_i) and (y_i). Control instructions for adjusting the sequence of operation are not shown. Internal feedback loops in the adaptive threshold devices are not shown.



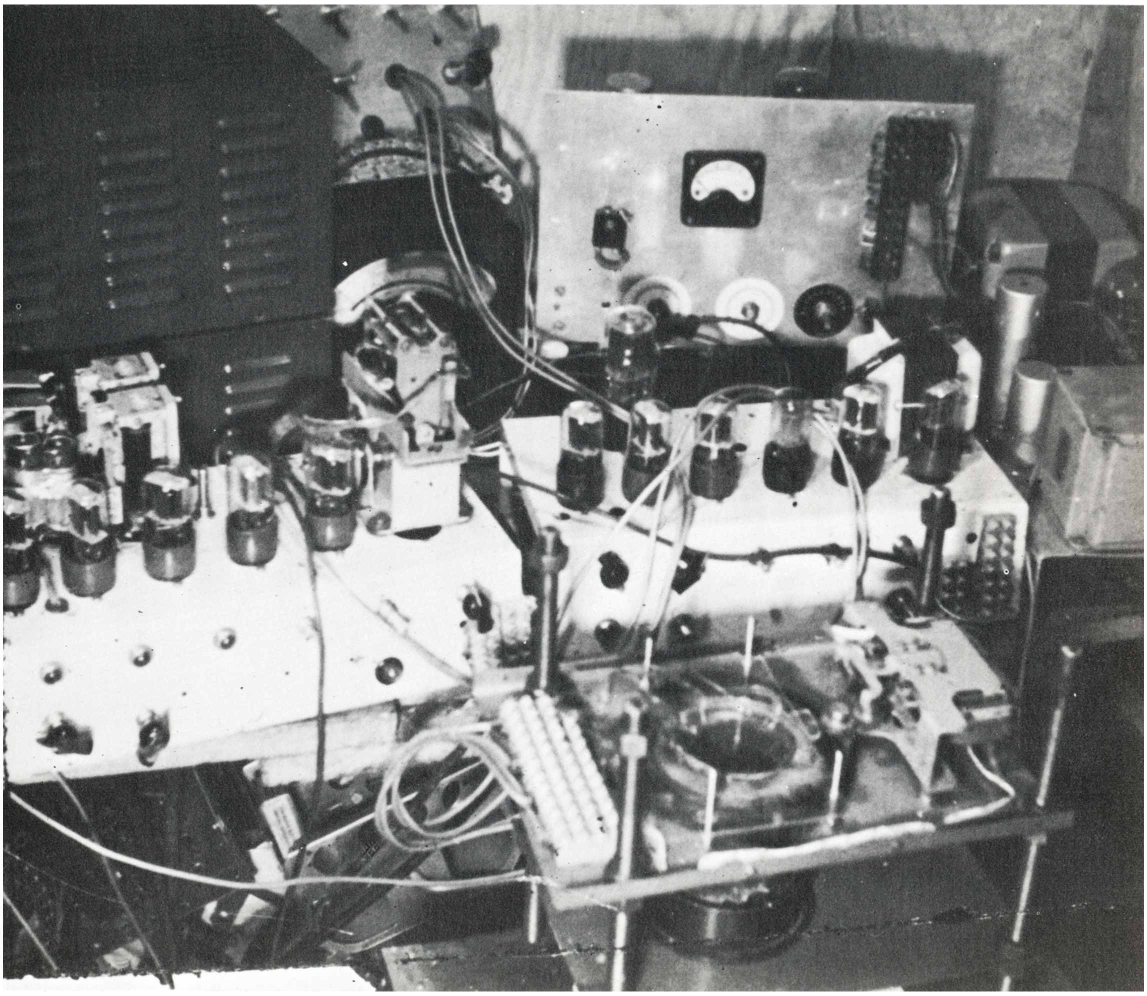
Pask, Gordon: Musicolour, 1953-57, circuit diagram (Pask: Comment 1971, p.79, fig. 26).

Pask described the musician and the machine as parts of a "learning mechanism" with mutual adjustments presupposing learning capabilities of the machine, too. 27 "Musicolour" was a "responsive environment" 28 being integratable in wider performance systems. The environment was a challenge to develop extraordinary performance concepts for the system.



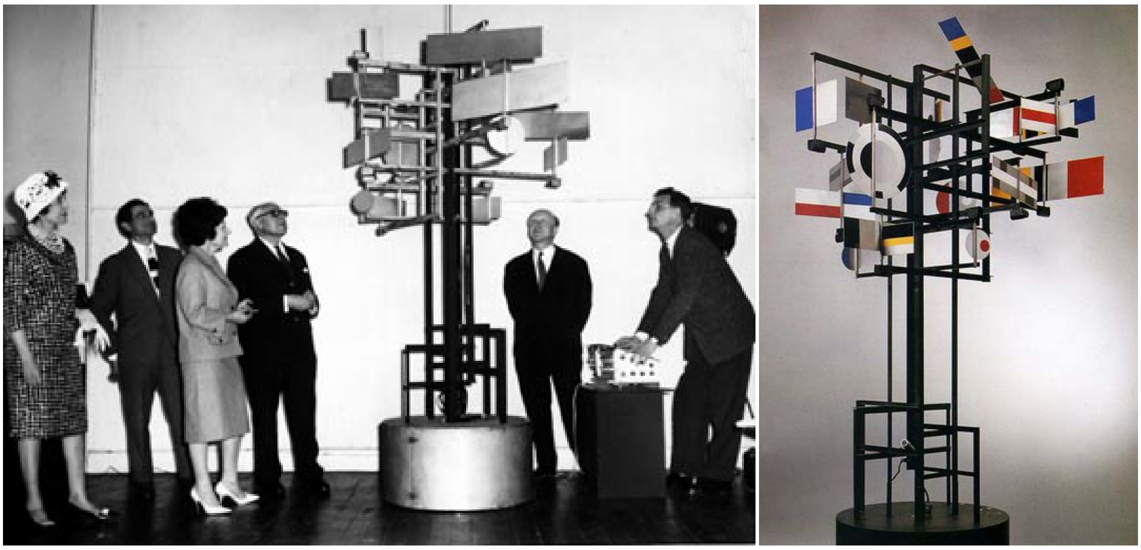
Pask, Gordon: Musicolour, 1953-57, projection wheel controlled by a servomechanism (Pask: Comment 1971, p.81, fig.27).

Pask transformed the possibilities to react, as they were developed in systems integrating humans and machines in the Second World War (see above), and the "material models" of cybernetics to "learning machines" to present examples how machine assistance enhances cognition.



Pask, Gordon: Musicolour, 1953-57, electrochemical system (Pask: Comment 1971, p.85, fig.31).

In 1956 Nicolas Schöffer constructs "CYSP 1" as a mobile kinetic sculpture. Meanwhile the socle moves on rubber wheels and searches its path via self-navigation, the aluminium discs rotate on a steel frame. The motions of the socle and the aluminium discs are coordinated by an "electronic brain" («cerveau électronique») with tube technology. Photoelectric cells and a microphone were installed as sensors to enable "CYSP 1" to register the environment´s modifications of colours, light and sound intensity.

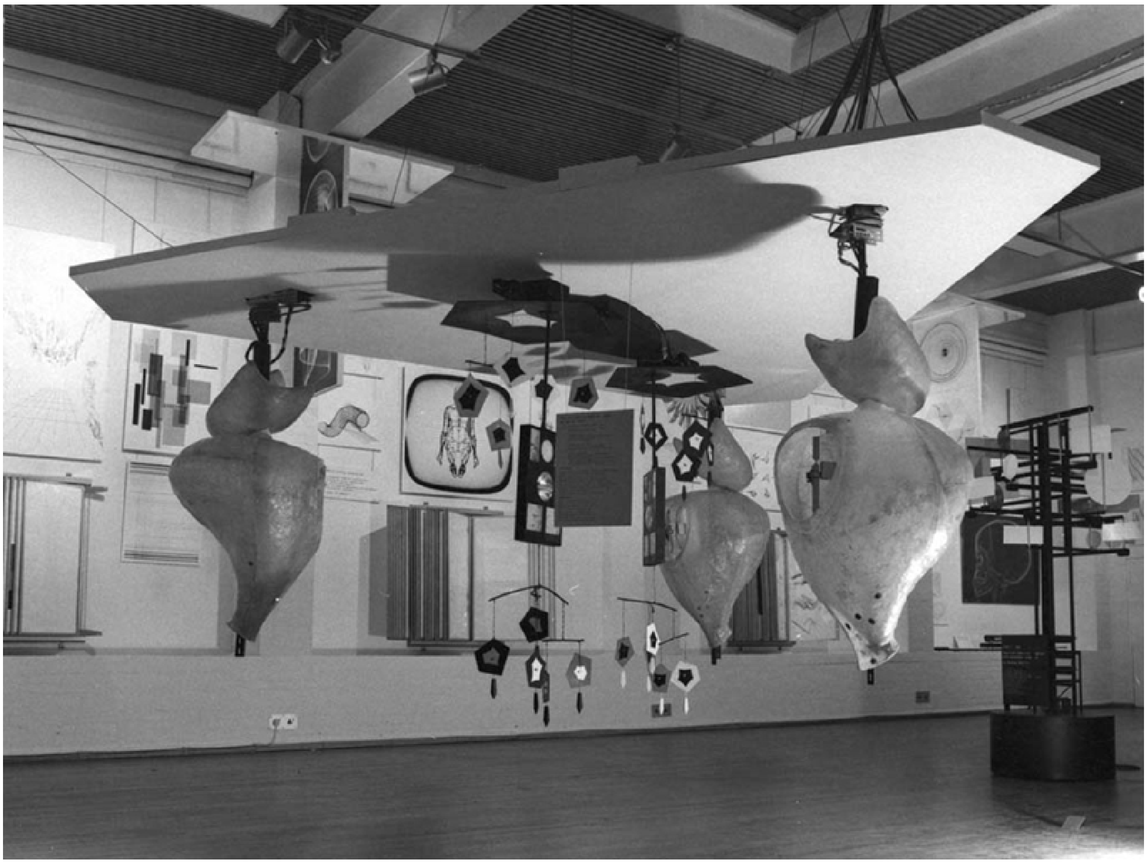


Schöffer, Nicolas: CYSP 1, 1956. Left: exhibition, Institute of Contemporary Arts, London 1960. The navigation desk at the right side was normally substituted by autonavigation.

With Ashby's "Homeostat" (see above) "CYSP 1" has in common the system's proper motion with a random generator and a limited capability to adapt to environmental conditions. Nicolas Schöffer and Jacques Bureau, the constructor of the "electronic brain" integrated into "CYSP 1", describe the functions of cybernetic sculptures like "CYSP 1" in using Ashby's terms "homeostasis" and "homeostat". 29 In "CYSP 1" the controls of the "Homeostat" are substituted by sensors, and the internal balancing between parts as a reaction to disturbances is substituted by a computer installed to process the environmental data for the navigation. The self navigation of William Grey Walter's robots (see above) is superseded in "CYSP 1" by a navigation via electronics. With his sculpture as mobile and self navigating Op Art Schöffer transfers cybernetic models to cybernetic sculptures.

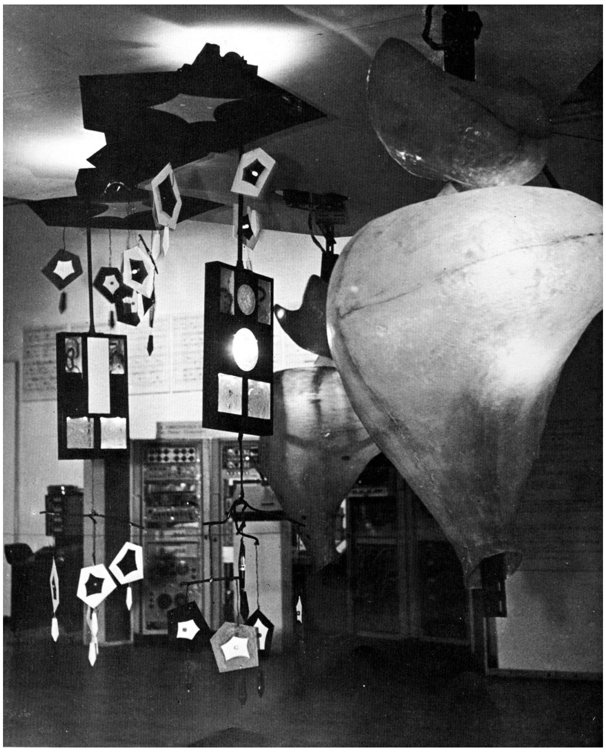
The motions of aluminium discs characterised "CYSP 1" as an early example of Op Art's kinetic variant. For Abraham André Moles Op Art was a research subject for information aesthetics. Moles submitted the investigation of aesthetic aspects to natural scientific methods (see below).

Gordon Pasks reactive installation "Colloquy of Mobiles" (1968) consisted of a triangular panel with obtuse-angled corners hanging from the ceiling and three rotating fibreglass bodies with organic forms hanging from the triangular panel. These bodies were illuminated from the inside. Two mobiles with inorganic formed parts were attached to an oblong element rotating under the triangular panel. These mobiles were named by Pask as "Males" and the fibreglass bodies as "Females".



Pask, Gordon: Colloquy of Mobiles, 1968, exhibition "Cybernetic Serendipity", ICA London 1968 (right, rearwards: Schöffer, Nicolas: CYSP 1, 1956).

Electric motors turned the "Males" and "Females" around vertical axes. These motors were controlled by a computer placed closed to a wall and connected with the installation by a cable being mounted on the ceiling. The computer was constructed by Mark Dowson, Gordon Pask and Tony Watts.



Pask, Gordon: Colloquy of Mobiles, 1968, exhibition "Cybernetic Serendipity", ICA London 1968 (Pask: Comment 1971, p.97, fig.40).

In the "Males" photo cells were installed together with elements to send light to mirrors being mounted in openings of the "Females". The photo cells of the "Males" were able to register the light reflected by the mirrors of the "Females". In their reactions to each other the rotating elements were capable to memorise and to learn. The visitors could change states of the complex stimulus-response-system by interventions with pocket torches: Then the visitors substituted the "Males" in their activity to send light to the "Females'" mirrors.

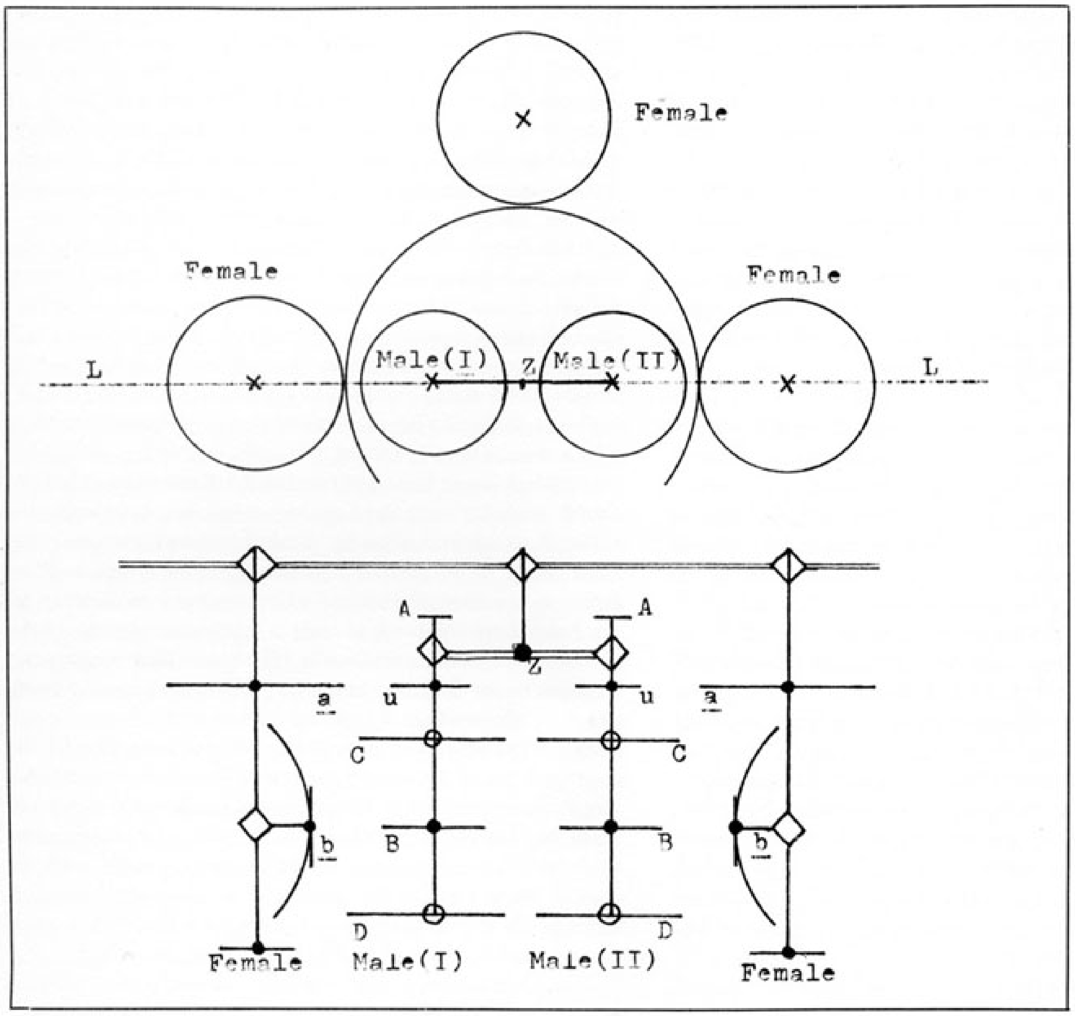


Fig. 34 A rough sketch of powered mobiles.
a Horizontal plan
b Vertical section taken through line *L* in horizontal plan.
A = drive state display for male
B = main body of male, bearing 'energetic' light projectors *O* and *P*
C = upper 'energetic' receptors
D = lower 'energetic' receptors
U = non-'energetic', intermittent signal lamp
a = female receptor for intermittent positional signal
b = vertically movable reflector of female
Z = bar linkage bearing male I and male II

◇ = Drive motor
= Free coupling
= Fixed coupling
= Bar linkage

Pask, Gordon: Colloquy of Mobiles, 1968, ground plan and elevation of the mobile elements (Pask: Comment 1971, p.90, fig.34).

After Ashby's "Homeostat" Pask offers with "Colloquy of Mobiles" a further model for the "law of requisite variety" (see above). The "Homeostat" is constituted by subsystems observing themselves mutually as environment. This coordination of subsystems was taken up by Pask in "Colloquy of Mobiles'" kinetic elements reacting to each other. The possibilities of visitors to intervene are caused by Pask's enhancement of the "Homeostat" by capacities to memorise and to learn as well as by the way how the kinetic elements communicate with each other: The system's possibilities to react to external (light) effects are the results of the system's internal differentiation in relations between its parts. This relation between the system and its environment confirms Ashby's "law of requisite variety". 30

Computer Literature

A combination of elements being documented as having a high occurrence has a higher probability to reappear in the future than a seldom occurring combination. First the computer literature and then the computer graphics were using possibilities limited by criteria of frequencies of occurrences. Then, within these predeterminations, one of the possible occurrences was chosen by chance operations.

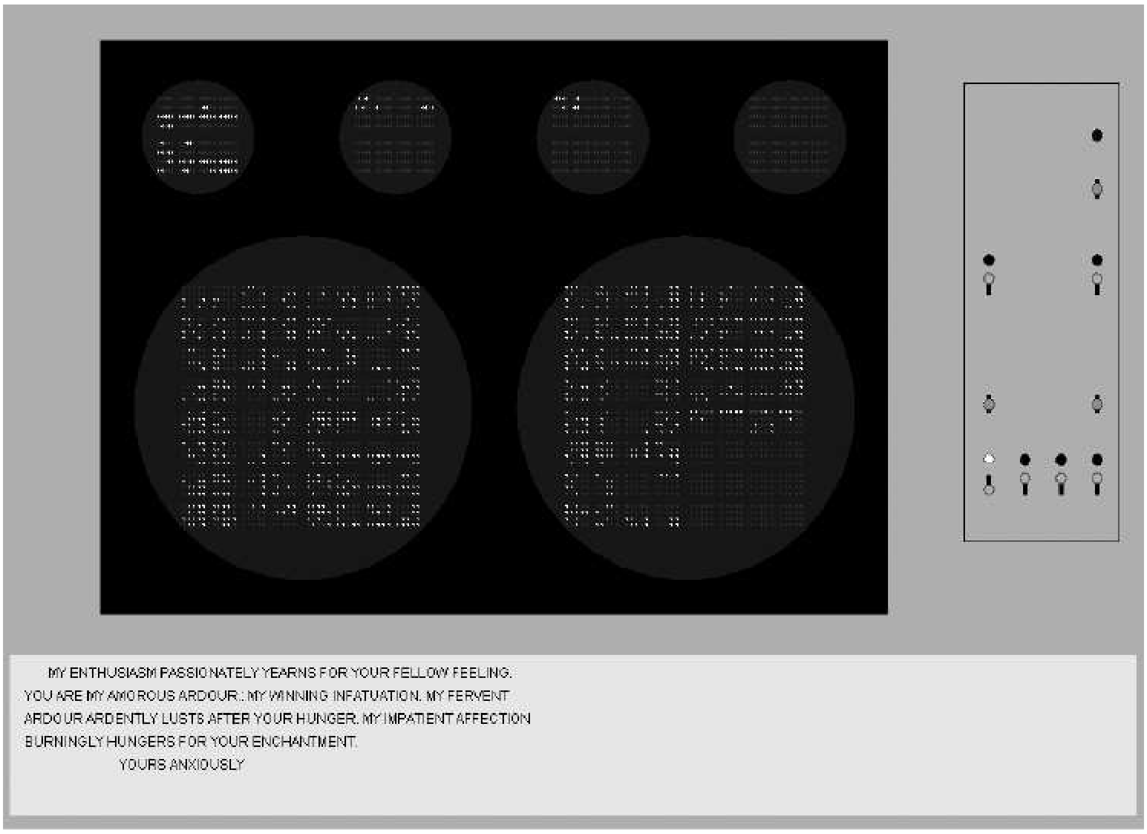
In 1948, in "A Mathematical Theory of Communication", Claude Elwood Shannon proposes to proposes to generate words in using stochastics' combination of probability theory and statistics. The fundament of this generation by combinations of letters consists of statistic data indicating how often certain combinations of two or three letters occur in English words. From the possibilities being limited by statistics of letters sequences – which letters follow one after another – generates a computer via pseudo-random selections letter sequences comparable to words. Shannon proposed to combine words – selected from a database containing English words – to sentences in the same manner as the generation of words: a combination of words guided by statistical probabilities. With the method of repeated uses of statistical criteria for the selection of combination possibilities Shannon tried to demonstrate that "the resemblance to ordinary English text increases quite noticeably". 31

Shannon's method to generate artificial languages is a variant of a cryptographical method for decoding: An encrypted message is compared with the frequencies of sign combinations in the language used to write the message. 32

The similarity of an artificial language generated with Shannon's method to the everyday language – simultaneously with the remarkable differences – provided suggestions to authors for the generation of computer literature. Their ways of programming reoccur in computer graphics (see below).

In June 1952 Christopher Strachey has been employed as "Technical Officer" by the British National Research and Development Corporation. A year earlier he programmed the game Checkers 33 and computer music 34 for British mainframe computers like Manchester Mark I (1948-50) and Ferranti Mark 1 (1951).

In 1952 Strachey wrote a program to generate "Love Letters" with a Ferranti Mark 1. Words selected from Roget's Thesaurus constituted a database for the program to choose some of the words via random generator. As the words were stored they were combined with syntactical indices (for adverbs, adjectives and substantives). These words were inserted into two sentence structures: "My—[Adjective]—Substantive—[Adverb (adv)]—Verb (verb)—Your—[Adjective]—Substantive" or "You are my—Adjective (adj)—Substantive (noun)". 35 The headline used words for a salutation being stored under the category "Letter Start". Then were five sentences generated with the structures described above. The scheme"Yours—Adverb—MUC" (MUC = Manchester University Computer) was used for the last line of the letter. The results of these computing processes were printed without commas by a teleprinter.

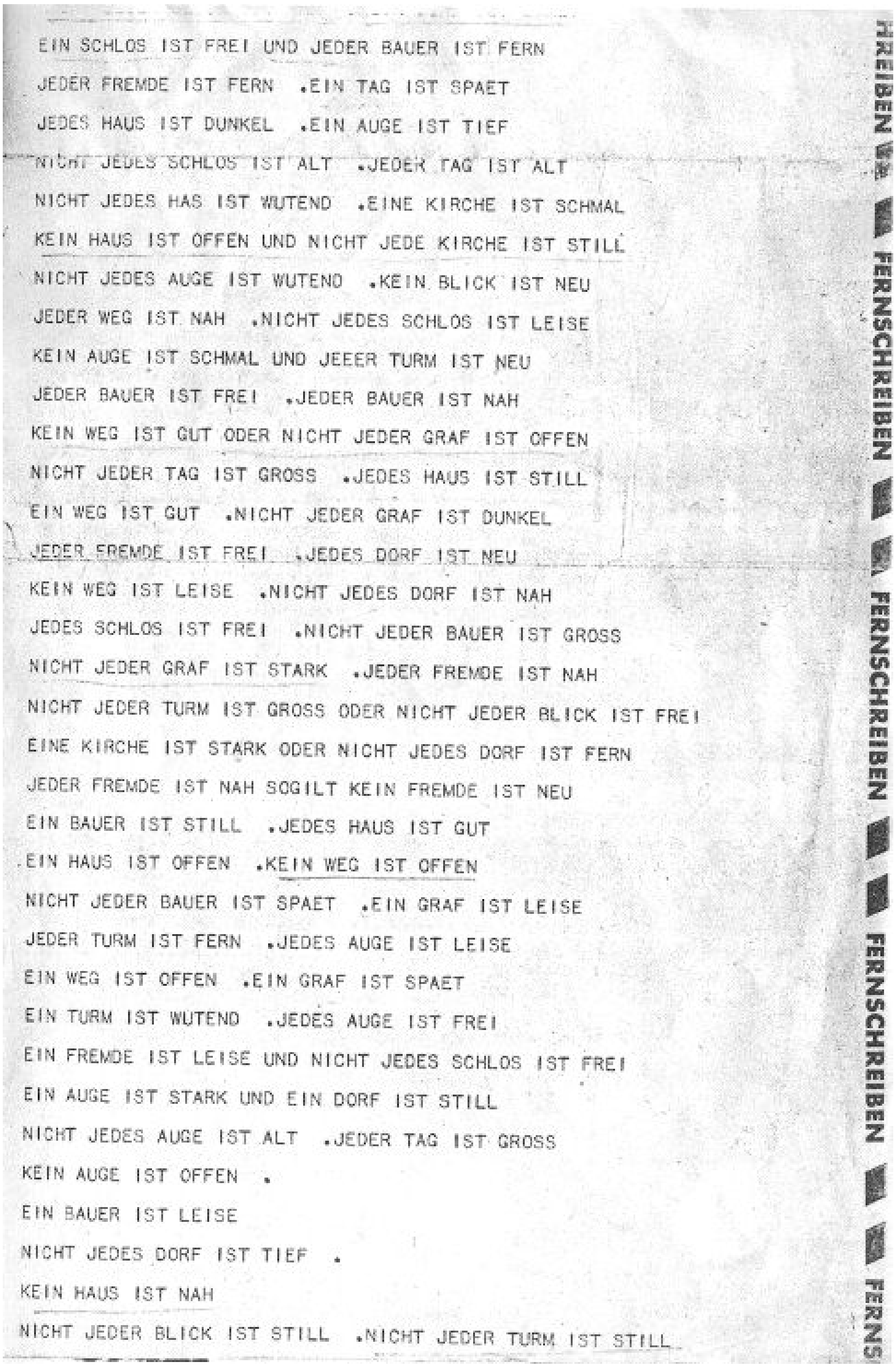


Link, David: Ferranti Mark I Emulator with Christopher Strachey's "Love-letters" (1952; Link: Angel 2006, p.16, fig.1).

Strachey divided his program in a random generator, a selection of stored elements and a syntax for combinations. With this structure and with the printer output as the form of presentation Strachey anticipated the foundations of computer literature and computer graphics of the sixties.

Because Strachey's program for the generation of sentences did not care about semantic fields changing from sentence to sentence the generated "Love Letters" could include semantic deviations to usual love letters. These deviations could be understood as comments to the contemporary 'language of love' and its gender norms: Were Strachey's "Love Letters" not rather a programmed non-conformity than an unsuccessful trial to generate love messages with the goal to fake human authors? 36

In 1959 Theo Lutz produced "stochastic texts" at the Rechen-Institut of the Technische Hochschule in Stuttgart. At this time Lutz was a degree candidate of Max Bense. He proposed to Lutz to install "a database with 100 words from Franz Kafka's novel 'The Castle' and simple sentence structures" 37 in his text generating program. Lutz picked up this proposal in his selection of words for the database of his program written in ALGOL. The program was installed on a valve computer Zuse Z 22 (1958) to select words from the database and to generate syntactically correct sentences.


EIN SCHLOS IST FREI UND JEDER BAUER IST FERN
JEDER FREMDE IST FERN .EIN TAG IST SPAET
JEDES HAUS IST DUNKEL .EIN AUGE IST TIEF
NICHT JEDES SCHLOS IST ALT .JEDER TAG IST ALT
NICHT JEDES HAS IST WUTEND .EINE KIRCHE IST SCHMAL
KEIN HAUS IST OFFEN UND NICHT JEDE KIRCHE IST STILL
NICHT JEDES AUGE IST WUTEND .KEIN BLICK IST NEU
JEDER WEG IST NAH .NICHT JEDES SCHLOS IST LEISE
KEIN AUGE IST SCHMAL UND JEEER TURM IST NEU
JEDER BAUER IST FREI .JEDER BAUER IST NAH
KEIN WEG IST GUT ODER NICHT JEDER GRAF IST OFFEN
NICHT JEDER TAG IST GROSS .JEDES HAUS IST STILL
EIN WEG IST GUT .NICHT JEDER GRAF IST DUNKEL
JEDER FREMDE IST FREI .JEDES DORF IST NEU
KEIN WEG IST LEISE .NICHT JEDES DORF IST NAH
JEDES SCHLOS IST FREI .NICHT JEDER BAUER IST GROSS
NICHT JEDER GRAF IST STARK .JEDER FREMDE IST NAH
NICHT JEDER TURM IST GROSS ODER NICHT JEDER BLICK IST FREI
EINE KIRCHE IST STARK ODER NICHT JEDES DORF IST FERN
JEDER FREMDE IST NAH SOGILT KEIN FREMDE IST NEU
EIN BAUER IST STILL .JEDES HAUS IST GUT
EIN HAUS IST OFFEN .KEIN WEG IST OFFEN
NICHT JEDER BAUER IST SPAET .EIN GRAF IST LEISE
JEDER TURM IST FERN .JEDES AUGE IST LEISE
EIN WEG IST OFFEN .EIN GRAF IST SPAET
EIN TURM IST WUTEND .JEDES AUGE IST FREI
EIN FREMDE IST LEISE UND NICHT JEDES SCHLOS IST FREI
EIN AUGE IST STARK UND EIN DORF IST STILL
NICHT JEDES AUGE IST ALT .JEDER TAG IST GROSS
KEIN AUGE IST OFFEN .
EIN BAUER IST LEISE
NICHT JEDES DORF IST TIEF .
KEIN HAUS IST NAH
NICHT JEDER BLICK IST STILL .NICHT JEDER TURM IST STILL

Lutz, Theo: Stochastic Text, 1959. Zuse Z22, teleprinter's output.

The database divides the stored words in 16 subjects and 16 predicates. The program combined selections of one subject and one predicate with selections of one of four "logical constants" ("und", "oder", "so gilt", "." ["and, "or", "if...then", "."]) and one of four "logical operators" for a subject's existence ("ein", "jeder", "kein", "nicht jeder" ["one", "each", "no one" and "not each"] in feminine, masculine and factual German forms). The frequencies of the subjects and the predicates as well as of the logical constants and logical operators were determined to be the same. Only the "relative frequency" of the point (the sign for the negation of a combination between words) was fixed at a higher rate then the other logical constants.

While Max Bense integrates the semantic terms "true" and "false" in his cybernetically based information theory 38, Lutz does not take into account questions of truth because his program generates sentences like "Jeder Fremde ist nah, so gilt kein Fremder ist alt" 39 ("[Because] each stranger is near [so] it is valid [that] no stranger is old"), although this conclusion is false in the light of our knowledge of the world. Lutz's "stochastic texts" effect an "aesthetic information" as it was defined in 1960 by Max Bense in "Aesthetica".

In the computer literature's combinations of words the "aesthetic information" provokes tensions with "semantic information". 40 While readers of generated texts are confronted with the truth criteria of "semantic information" even if the programming does not care about them, computer graphics (see below) substitute the problem by the task how to direct visual perception by the programming of graphical signs and their distribution on a plane.

Computer Graphics

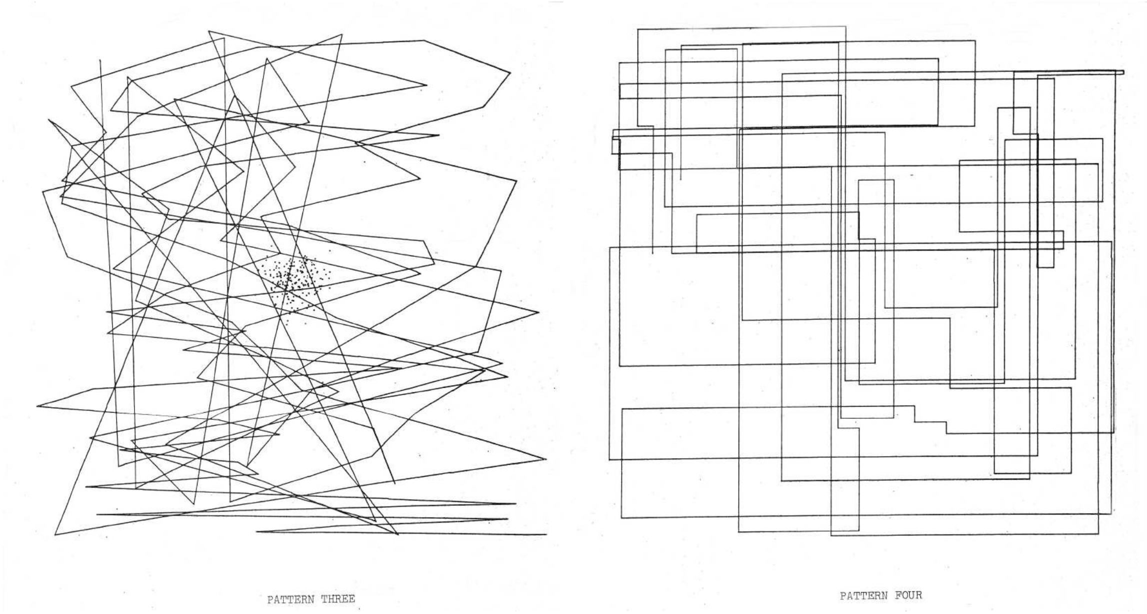
In the sixties A. Michael Noll (since 1962), Frieder Nake (since 1963/64) and Georg Nees (since 1964) created computer graphics in programming mainframe computers 41 with FORTRAN and ALGOL. Because of these higher programming languages for the then relatively recent compilers it was no longer necessary to write programs in machine language. Christopher Strachey, Theo Lutz and other authors used the following procedures in computer literature before they reoccur in the computer graphics by Noll, Nees and Nake:

- the selection of elements,
- a random generator,
- determinations of the frequencies how often a program can choose elements, and
- a syntax for combinations of these elements.

Often points and lines were used as elements. The lines were constructed as connections between points. The relations between a programmed distribution of elements on a plane and the optical effects in a total view substituted the readability of text characters combined in lines.

Planes were structured in zones. In each zone the program is able to restart the same procedure for the selection and combination of elements. The visual overall impression is influenced by the zoning of a plane, the determination of the frequency how often a (pseudo-) random generator can choose the elements for each zone, and the combination possibilities.

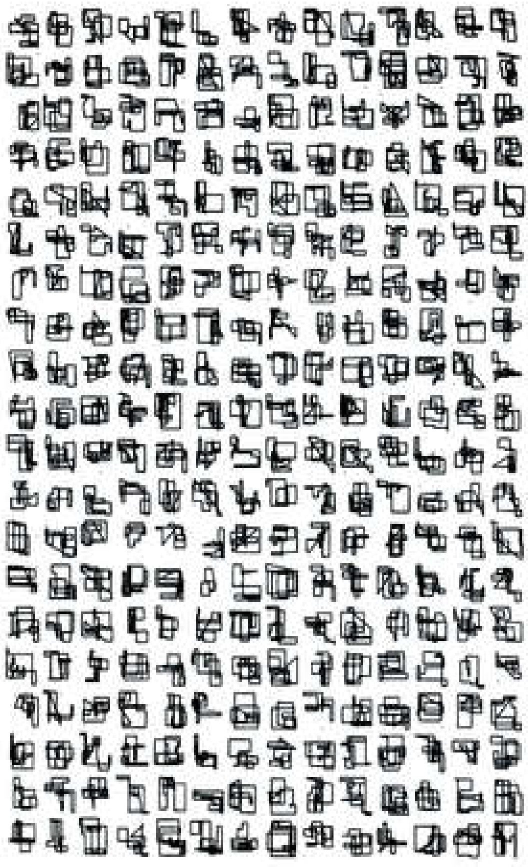
In summer 1962, when A. Michael Noll worked in a department for telephone transmission at the Bell Laboratories (Murray Hill/New Jersey) 42, he programmed "Patterns" in FORTRAN for an IBM 7090 (since 1959). 43 A Stromberg Carlson 4020 Microfilm Plotter presented the "Patterns" on a cathode ray tube. The image on the screen was photographed and the 35 mm negative was "multiplied by photoprinting in different seizes." 44



Noll, A. Michael: Links: Pattern Three, 1962, photo print.
Rechts: Pattern Four, 1962, photo print (Noll: Patterns 1962, unpaginated).

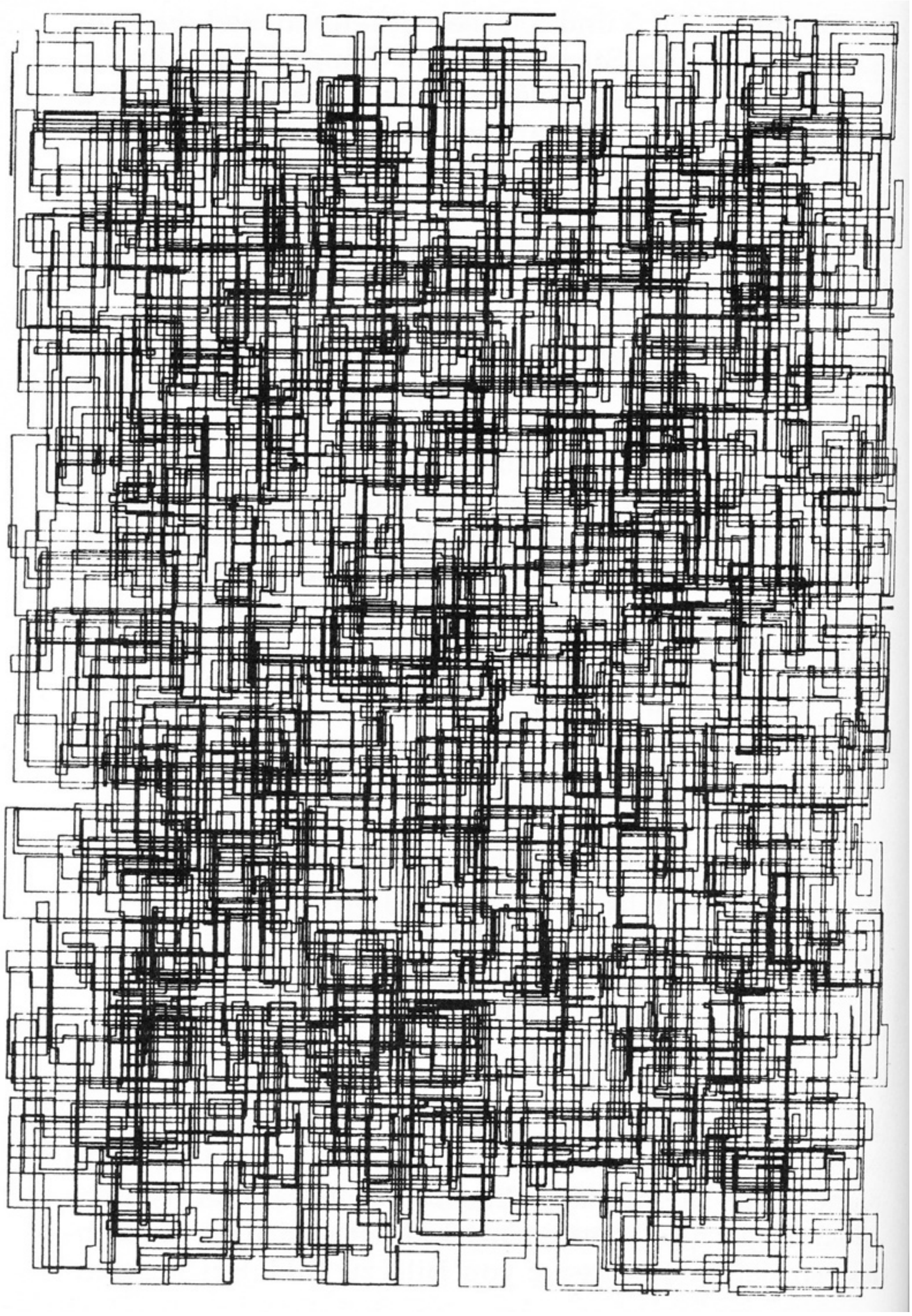
Points were located via random procedures, and lines were constructed as programmed connections between the points. In this way jagged lines were produced – or the combinations were reduced to lines meeting each other at right angles.

Noll's "polygon moves" ("Polygonzüge") – as they were designated by Frieder Nake 45 – were picked up by Georg Nees in computer graphics illustrated in issue 3/4 of the "Grundlagenstudien aus Kybernetik und Geisteswissenschaften" ("Basic Studies in Cybernetics and Humanities"), published in December 1964. 46 The instructions were written in ALGOL. They controlled a mainframe computer (Siemens 2002, 1959-66) in processing the polygon moves several times next to each other and one below the other: The algorithm starts the polygon moves anew in predetermined zones. 47 The number of lines in each zone is fixed by the program, and a random generator selects the length and the distribution of the consecutive lines before they were printed by a Zuse Z 64 Graphomat.



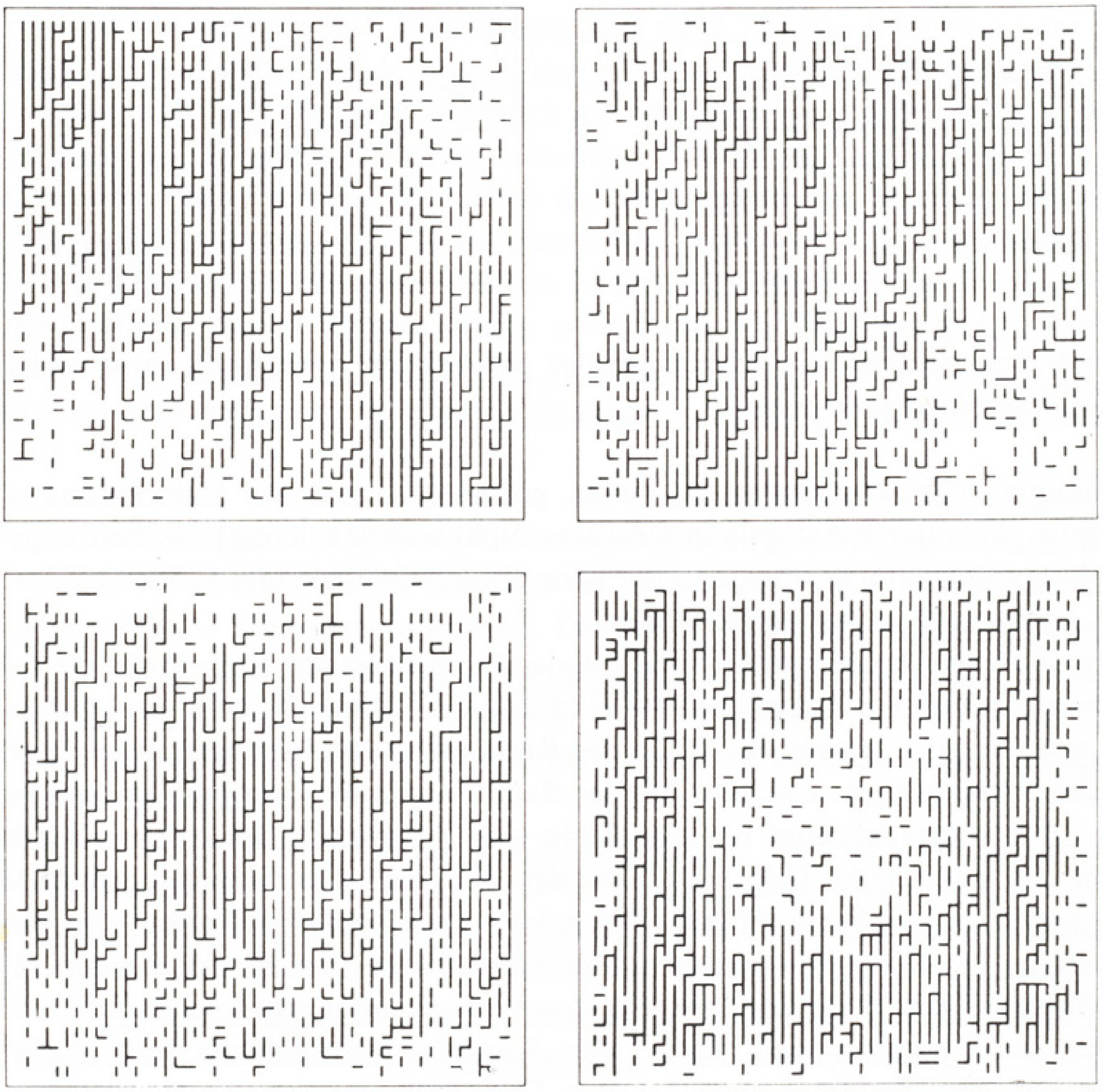
Nees, Georg: 23-Ecke, 1964, plotter drawing (Nees: Variationen 1964, p.124, ill.2).

In a series of computer graphics realised between 1965 and 1968 the program determines how far the "polygon moves" can transgress the zones within which the consecutive lines will be restarted. 48 The transgressing polygon moves interpenetrate each other. In an overall view the polygon moves appear as snarls of lines with variing densities or simply as a confusion of lines 49: The "creation of texture by overlapping" ("Texterzeugung durch Überlappung") 50 – in Nees' words – provokes a "gradation of the type heap – variation – gestalt" ("vom Typus Haufen – Variation – Gestalt"). 51 Nees programmed the computer graphics with regard to the optical resolutions variing in close-up and distant views: "Gestalts are different information units with a local and distal nexus." ("Gestalten sind unterschiedliche Informationseinheiten mit Lokal- und Distalnexus.") 52



Nees, Georg: Untitled (Micro Innovation), 1967, plotter drawing (Nees: Computergraphik 2006, p.222, ill. 31).

In 1966 Frieder Nake developed the program "walk-through-raster" in "ALGOL60" ("with some assembler-sub-programs"/"mit einigen Assembler-Unterprogrammen", realised with Telefunken TR4 (since 1962) and Zuse Z64 Graphomat) and chose "six modes" in which computing processes proceed step by step across the plane. 53 Furthermore in Nake's procedure to select elements from a repertoire each subsequent range of possibilities depended "from the last chosen sign". As explained by Nake, the program simulated a "short memory". 54 At specified positions for the exchange of elements the program was determinated by "transition probabilities" ("Übergangswahrscheinlichkeiten") in its selection between alternatives. 55 For the "six modes" as ways of a computing process to step across the plane Nake programmed six variants with a "defined repertoire and defined probabilities" (mit "festem Repertoire und festen Wahrscheinlichkeiten"). 56 The sign repertoire of the series "2.1" was constituted by blank fields as well as by vertical and horizontal lines in various lengths. 57 The distribution of these signs of the repertoire on the flat support provokes a shimmering overall view.



Nake, Frieder: Walk-Through-Raster, series 2.1, 1966, four realisations, plotter drawings (Nake: Ästhetik 1974, p.236, ill. 5.5-5).

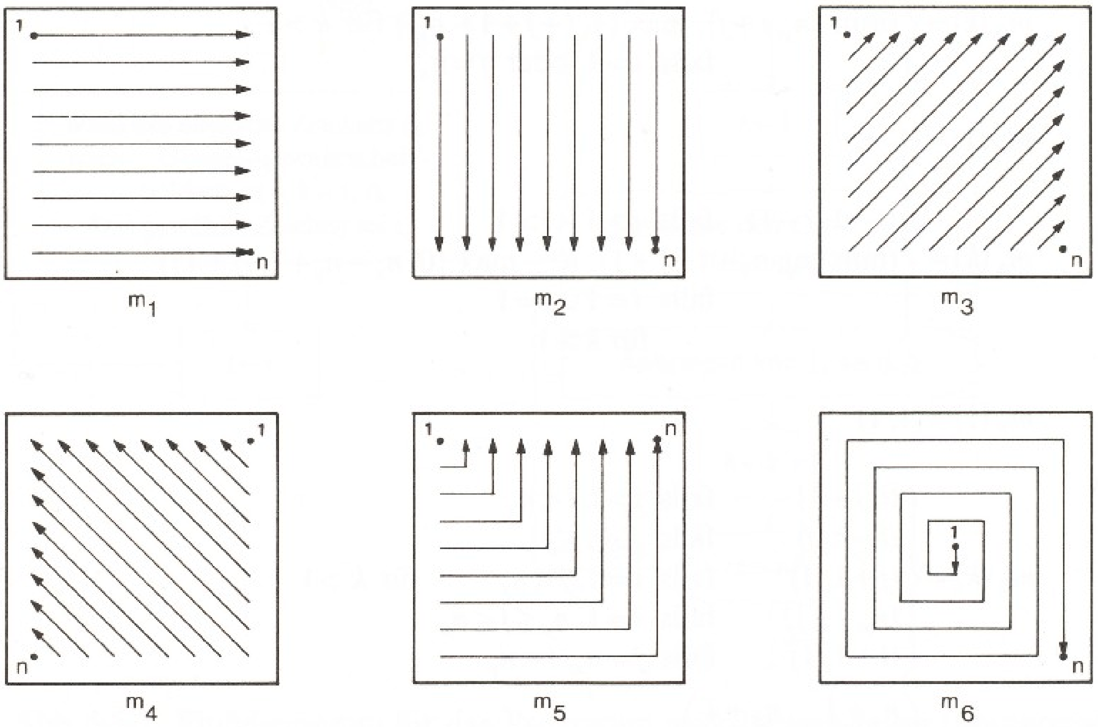


Abb. 5.5-1. Sechs Modi für das Auftragen einer linearen Kette in der Ebene

Nake, Frieder: Walk-Through-Raster, 1966, six modes of a computing process to step across the plane (Nake: Ästhetik 1974, p.229, ill. 5.5-1).

Comparisons with serial works by Richard Paul Lohse, Karl Gerstner, Francois Morellet, Marcello Morandini or Sol LeWitt demonstrate characteristics uncommon to computer graphics: Instead of Serial Art's sequences caused by repeated executions of a mutation rule, the computer graphics of the 'three N's' offer variations joining together to an overall view, in spite of irritating zones – as elements fitting together in a visual structure, but with some disturbances. Serial works provoke sequencing ways to perceive them. In this kind of perception visual impressions and reconstructions of the rules guiding the production of a work can be related to each other step by step, *in phases*. Unlike this mode of perception computer graphics complying with criteria of information aesthetics provoke beholders to eye movements *sliding* between the overall view and outstanding details. Nevertheless computer graphics can be distinguished from an abstract art created intuitively like artworks realised among others by members of De Stijl, for example by Piet Mondrian (since 1914) and Theo van Doesburg (since 1917). These artists arranged lines and colour fields in their efforts to achieve an overall view via a visual balance between contrasting elements. Overlappings, accumulations and disturbances were avoided.

Meanwhile in computer graphics the distribution of signs on a flat support seems to be the result of intuitive decisions it is in fact the result of an interplay between program and chance. This becomes apparent if the relations between repeated combination modes and irregularities are reconstructable as consequences of the program. The program includes a random generator being constituted by algorithms, too. The computed arrangement of signs influences the oscillation of the perception processes between overall view and details.

The static medium of graphics printed by plotters is a result of a computing process and it provokes perception processes refering back to the computing process as it was controlled by the artist via programming. The programming makes different plotter prints possible: Each print presents one of the program's possibilities meanwhile abstract works guided by the artistic intuition of the members of De Stijl mentioned above don't have such a *state of possibilities*. In abstract paintings of De Stijl the placement of a sign can't have the same state as in plotter prints: Here the relations between the elements can be as they were printed – or they can be other ones within the range of possible prints being realisable by the program.

Informations Aesthetics

Max Bense and Abraham André Moles defined the "aesthetic measure" by exploring the best possible relation between the "complexity" of the visual "information" and the "orderliness" ("redundancy") that can be recognised in the process of perceiving the work. Bense determines the aesthetic measure in using George David Birkhoff's definition as 'order divided by complexity' ("Birkhoff's quotient"). 58. In contrary Moles refers to empirical investigations of visual perception in his plea for the 'multiplication of order by complexity'. 59 Shannon's "statistic information" provides the basics for this numerical definition of the aesthetic measure. 60. It presupposes precise knowledge of the number of used elements ("sign repertoire") and the possibilities to combine them. 61

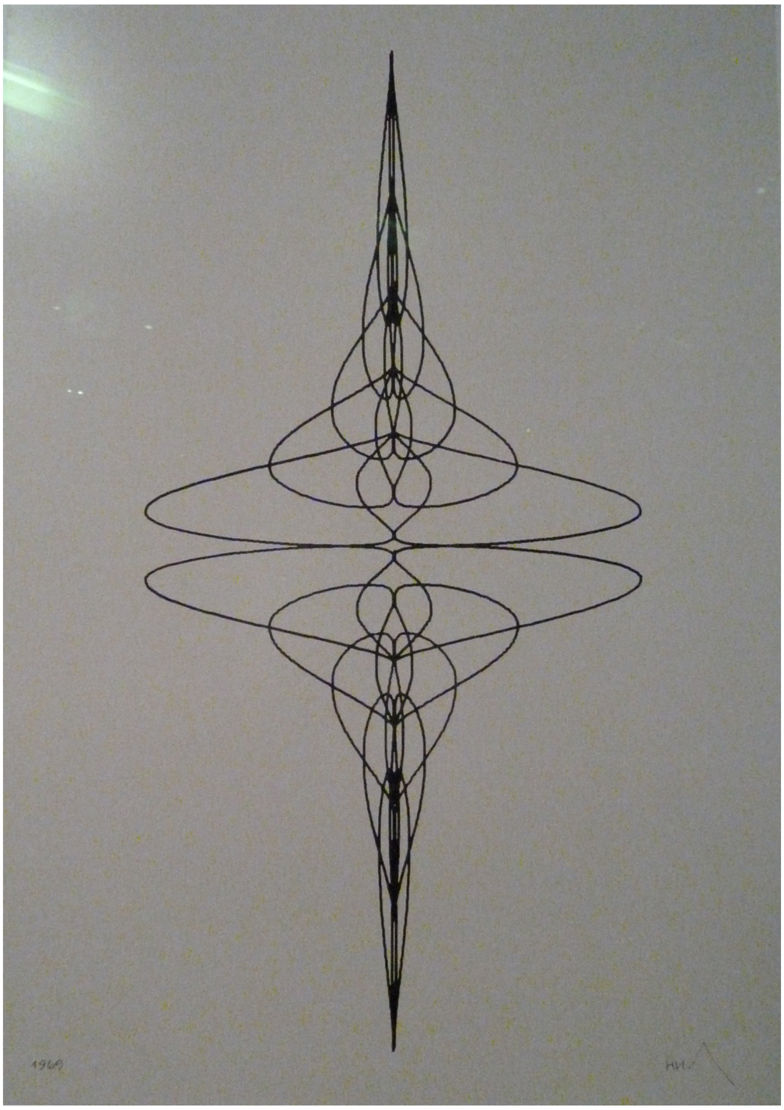
In addition to the cybernetic term "statistic information" the information theory established a further use of the term information as one side of the conceptual pair information/redundancy: If the probability of one of the possible elements is low then in case of its occurrence the "surprise effect" is larger and the "information content" higher. For the perceptibility of order some elements should occur more often and with higher probability: This reduces the "information content" and hightens the redundancy. Information aesthetics try to find paths between information and redundancy. In this way information aesthetics are a facilitation for artists in their efforts to develop solutions for the coordination of order with complexity from the point of view of an artwork's forms and the coordination of information with redundancy from the point of view of the visual perception.

As proposed by Bense, in art improbable orders should be realised by the "elemination of the avoidable" ("Ausscheidung des Vermeidbaren)" and the "reduction of redundancy" ("Verringerung der Redundanz"). 62 Meanwhile Bense discusses the criteria to care for the "unavoidable" (das "Unvermeidbare") as a required porperty of works of art, Moles thematises their perception. In Moles' reflections the receiver's "limit of apperception" and its dependency on the observer's previous knowledge are dominant subjects. If the visual complexity is above the "limit of apperception" then there is no order recognisable. For Moles it is a reasonable conclusion to avoid transgressions of this limit. 63

Thus a certain amout of redundancy is inevitable. In the computer graphics presented above and realised by Nees and Nake in 1965 and 1967 the need for redundancy is fulfilled by the constantly repeated horizontal and vertical lines as well as by a visual perception guided by 'distribution patterns'.

Max Bense' s differentiation between "micro-" and "macroaesthetics" inspired Georg Nees to program graphics with visual features keeping the beholders' eyes in motion because the distribution patterns are shifting between image areas as well as between close and distant views. 64 Frieder Nake went a step further and integrated "an amount of information aesthetic measurements" ("eine Anzahl informationsästhetischer Messungen") into his "walk-through-raster" program: For the programming and the generation of graphics the visual perception becomes relevant via its information theoretical capture. 65

Meanwhile Nees and Nake realised programs for their works before they wrote about them in books to give them an information aesthetic context, Herbert Werner Franke wrote in 1967 a book titled "Phänomen Kunst" ("Phenomen Art") about information aesthetics before he realised in 1969 his first digital computer graphics with algebraic curves: the body of works named "KAES". They pose difficulties for the translation from forms of computer graphics to criteria for measurements of order and complexity. Franke's "experimental aesthetics" was at the same time oriented to problems of production as well as of reception, with a domination of the last one. 66



Franke, Herbert Werner: KAES, 1969, plotter drawing.
Nixdorf MuseumsForum, Paderborn.

The first-order cybernetics were geared towards machine processes and for the engineering sciences their researchers developed scientific augmented 'applied mathematics'. From these first-order cybernetics emerged the information aesthetics: They shifted the focus to designs for the human perception. The authors of second-order cybernetics Margaret Mead, Gregory Bateson, Heinz von Foerster, Ernst von Glasersfeld, Gotthard Günther and Humberto Maturana combined their subjects 'cognition' and 'observing systems' to theses on self-observation (or observation of observation, second-order observation). Gordon Pask anticipated with his "learning machines" not only this reorientation but developed his learning models further to a conversation theory thematising the relations between learning processes and symbolic interaction. 67

Within these changes of the cybernetic research the pioneers of computer art localised themselves with their works and texts. Either they emphasised the possibilities to integrate observers of cybernetic sculptures into circuits, or they oriented their production of computer graphics to cognitive aspects of the visual perception. In contemporary art this division is dropped in favor of a plurality of alternative presentation modes integrating cognitive aspects in different manners.

Forerunners of the art of the sixties and its exploration of new media were not only Buckminster Fuller and Marshall McLuhan 68, but cybernetics, too. 69 Cybernetics were ignored from an art criticism based on classic humanities (hermeneutics and style analysis). 70 Computer art influenced by cybernetics was exotic 71 – today we recognise in its initiatiors the pioneers creating the fundaments of the development of computer art in the following decades.

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Annotations:

All abbreviations for texts used in the annotations present first the last name of the author or editor, then – after a colon – the first noun of the title. If titles present a name as the first noun then the abbreviation contains the family name. The third part of the abbreviation is constituted by the year of the publication.
Another abbreviation: t.o.f.p. = title of the first print in the author´s language.

1 The term "Cybernetics" (and its use by precursors): Wiener: Cybernetics 1948/2007, p.19s. (quote p.20). Cf. Galison: Ontology 1994, p.232; Masani: Wiener 1990, p.251s.; Pask: Approach 1961, p.15s.; Pierce: Introduction 1961/1980, p.208ss.; Wiener: I 1956, p.321s.
Leibniz´ calculating machine: Lehmann: Schickard 1995, p.276-286.
Norbert Wiener's interest in Leibniz: Galison: Ontology 1994, p.255s.; Masani: Wiener 1990, p.219,254; Wiener: Cybernetics 1948/2007, p.19sf.

2 Shannon/Weaver: Theory 1949/1998; Wiener: Cybernetics 1948.
On Shannon' s report of the results of his scientific research for military goals in "A Mathematical Theory of Communication" (Shannon/Weaver: Theory 1949/1998): Roch: Shannon 2009, p.145: "Shannon worked out first the answer for the discrete case of a secure communication in `A Mathematical Theory of Cryptography ´ ([Shannon: Theory 1945]), then he prepared the continuous case of a disturbed transmission for `Transmission of Information´ ([manuscript]1947, [publication: Shannon: Communication 1949]). In 1948 Shannon brought the methods and results of all preparatory works together in `A Mathematical Theory of Communication´ [Shannon/Weaver: Theory 1949/1998]. Shannon problematised not only the question of an effective communication, but concretely the theoretical basics of a secure and effective navigation of electronic air defence systems." (Translation by the author)
Roch: Shannon 2009, p.104, citing Shannon: "`When I came out with my paper in 1948, part of that was taken *verbatim* from the cryptography report, which had not been published at that time.´ [Shannon in Price: Conversation 1985, p.170] For the scientific public Shannon simply devided his 114 pages long `cryptography report´ in two parts: one part more about communication theory and another one on codes." (Translation the author).
Cf. Roch: Shannon 2009, p.82,120ss.,128ss.,144s.,159.
Norbert Wiener on feedback and the theory of prediction in its use in antiaircraft fire in the Second World War: Wiener: Cybernetics 1948, p.11-14,23s.,55; Wiener: I 1956, p.249-255,260-265.
On Wiener´s anti-aircraft research and its pioneering role in cybernetics: Bluma: Wiener 2005, p.108ss.,116; Mindell: Human 2004, p.381-389; see ann.7.

3 Bluma: Wiener 2004, p.78ss.; Kittler: Intelligenz 1990/2013, p.234,241,245ss.; Roch: Shannon 2009, p.55-66.
On Enigma's decipherment: Hodges: Turing 1983/1992, p.222-255.

4 Rosenblueth/Wiener/Bigelow: Behavior 1943, p.19 (cf. Wiener: I 1956, S.252). Data smoothing was developed by Claude Shannon, Hendrik Bode, Richard B. Blackman and Ralph Stackman in the Bell Laboratories' research (Bluma: Wiener 2004, p.105s.; Mindell: Human 2004, p.435s.; Roch: Shannon 2009, p.80ss.).

5 On behalf of the NDRC (National Defence Research Committee) Norbert Wiener worked under the direction of Vanevar Bush (Bluma: Wiener 2004, p.53-69,99-117; Galison: Ontology 1994, p.241s.; Roch: Shannon 2009, p.55-70,74ss.,79ss.).

6 Roch: Shannon 2009, p.63,69; Galison: Ontology 1994, p.242. Cf. Wiener: Extrapolation 1949, p.1: "Time series are sequences, discrete or continuous, of quantitative data assigned to specific moments in time and studied with respect to the statistics of their distribution in time."

7 On the "the antiaircraft predictor": Bluma: Wiener 2004, p.104-109; Galison: Ontology 1994, p.229,236-240,244; Masani: Wiener 1990, p.184-191; Mindell: Human 2004, p.382-387,391s.; Roch: Shannon 2009, S.60ss.; Wiener: I 1956, p.249-252. The efforts failed, to use data from one test person for predictions of the behavior of other test persons (Galison: Ontology 1994, p.237).

8 Roch: Shannon 2009, p.78,81; Roch/Siegert: Maschinen 1999, p.222s.

9 "Theoretical models": Rosenblueth/Wiener: Role 1945, p.320.

10 Wiener: I 1956, p.251s. Cf. Galison: Ontology 1994, p.233,240.

11 Bluma: Wiener 2004, p.103.

12 Roch: Shannon 2009, p.156.

13 Mindell: Human 2004, p.335-356; Roch: Shannon 2009, p.158-161; Shannon/Weaver: Theory 1949/1998, p.68.

14 Rosenblueth/Wiener: Role 1945, p.317s.,320. Cf. Bluma: Wiener 2005, p.142s.

15 Ashby: Design 1952/1960, p.100-107; Ashby: Homeostasis 1952/2003; Ashby: Introduction 1957, p.202-219; Ashby: Variety 1958; Burnham: Sculpture 1968, p.336s.; Cariani: Homeostat 2009, p.141-144; Pickering: Brain 2010, p.101-105; Pierce: Information 1961/1980, p.218s.; Porr: Systemtheorie 2002, S.11ss.

16 Bluma: Wiener 2005, p.157; Shannon: Presentation 1951.

17 Cf. the further development resulting in "Theseus", 1952, in: Roch: Shannon 2009, p.22.

18 Walter: Brain 1961, p.241: "turn-and-push manoevre".
On "Elmer": Hoggett: M. speculatrix 2009.
On "CORA": Hoggett: CORA 2009; Pickering: Brain 2010, p.64-67; Walter: Brain 1961, p.118,155ss.,245-250.

19 Walter: Brain 1961, p.163 (quotation). Cf. Burnham: Sculpture 1978, p.331,334s.; Pickering: Brain 2010, p.64ss.

20 Galison: Ontology 1994, p.253; Mindell: Human 2004, p.393s.; Wiener: I 1956, p.293-309.

21 On Norbert Wiener's path out of the military research: Wiener: Cybernetics 1948, p.134s.,185-188; Wiener: Concept 1953; Wiener: Homeostasis 1951; Wiener: I 1956, p.293ss. Cf. Ashby: Comments 1985.
On Shannon's military research after the Second World War: Roch: Shannon 2009, p.133-140,144,148-152,155,157,159.

22 Among others, in Pask: Approach 1961 the author offers a well comprehensible introduction into his own understanding of cybernetics (see Glanville: Approach 2007).
Bibliography of selected publications written by Pask: Glanville/Müller: Pask 2007, p.223-227.

23 "`Learning´ machines": Pask: Approach 1961, p.89.
Eucrates: Burnham: Sculpture 1968, p.337; Pask: Approach 1961, p.32, pl. I(i), p.67-70. In 1955 "Eucrates" was created by C.E.G. Bailey, T. Robin McKinnon Wood and Gordon Pask (Pask: Approach 1961, p.67).

24 Pask on the musician's activity as improvisation: Pask: Conception 1963, p.163.
On the analog computer: Rosen: Control 2008, p.154.

25 Pask: Comment 1971, p.78ss.; Pickering: Brain 2010, p.314, fig. 7.2, p.316; Rosen: Control 2008, p.136.

26 Pask: Comment 1971, p.86.
Gordon Pask´s "electro-chemical display" is a part of a research investigating the relations between "stability and variety" in "self-organizing systems". In the course of the research Pask began to develop "chemical computers": "Chemical computers arise from the possibility of `growing´ an active evolutionary network by an electro-chemical process." (Pask: Approach 1961, p.105) On the insights in emergence that Pask was able to win within the research project: Cariani: Emergence 1991, p.789; Cariani: Ear 1993; Pickering: Brain 2010, p.334-343; Whitehead: Metacreation 2004, p.223.

27 Pask: Comment 1971, p.86: "From the performer´s point of view, training becomes a matter of persuading the machine to adopt a visual style which fits the mood of his performance. At this stage in the development of the rapport, the performer conceives the machine as an extension of himself, rather than as a detached or disassociated entity."

28 "responsive environment": Burnham: Aesthetics 1970, p.108; Burnham: Systems Esthetics 1968, p.35; Krueger: Computer 1976; Krueger: Environments 1977/1996, p.481s.; Krueger: Videoplace 1985, p.145,147.
On Pask's understanding of "responsive environments" as "observing systems" and thus as precursors of "second order cybernetics": Glanville: Magic 2007, p.128.

29 Buderer: Kinetische Kunst 1992, p.124s.,190,193s.; Schöffer: Spatiodynamisme 1955 (I thank Jean-Noël Montagné for the tip about that text). Bureau presents the "electronic brain" in "Annotations of the Philips Company..." (Bureau: Anmerkungen 1963) as "homeostat" (Cassou/Habasque/Ménétrier: Schöffer 1963, p.45s.).

30 Pask: Comment 1971, p.88-98; Pickering: Brain 2010, p.355-360; Rosen: Control 2008, p.166-174. Realisation of the fibreglass bodies: Pip and Adele Youngerman. Electronics: Mark Dowson.

31 Shannon/Weaver: Theory 1949/1998, p.39-44 (quote p.44); Shannon: Communication Theory 1949, p.656s.; Shannon: Redundancy 1950, p.249. For the generation of words letters can be chosen with regards to criteria how often a specific third letter follows certain preceding letters. According to Shannon it is possible to create artificial languages in generating combinations of generated words. (Shannon/Weaver: Theory 1949/1998, p.42s. Cf. Bense: Aesthetica 1982, p.335s.; Guizzo: Message 2003, p.32s.; Kawano: Aesthetics 1968/2011, p.309s.; Pierce: Information 1961/1980, p.47-54; Roch: Shannon 2009, p.26s.; Wardrip-Fruin: Media 2005/2007, p.236-239).

32 Pierce: Introduction 1961/1980, p.50s.; Roch: Shannon 2009, p.96-106, esp. p.100.

33 Copeland: History 2000, chap. "The Manchester Machine"; Link: Angel 2006, p.17; Strachey: Machine 1954, p.27; Wardrip-Fruin: Media 2011, p.304s.,312ss.

34 Fildes: Computer Music 2008; Link: Angel 2006, p.17s.

35 In the case of repetitions the second structure was reduced to "My—adjective—substantive" (Link: Angel 2006, p.19).

36 On "Love Letters": Bülow: Sinn 2007, p.148-151; Cox: Introduction 2012; Hodges: Turing 1983/1992, p.477s.; Link: Angel 2006; Wardrip-Fruin: Media 2011, p.302-316. Examples: Bülow: Sinn 2007, p.150; Strachey: Machine 1954, p.26.
Re-engineering: Link, David: LoveLetters_1.0. MUC=Resurrection. A Memorial. Exhibited in: YOU_ser 2.0. Celebration of the Consumer. ZKM/Center for Art and Media. Karlsruhe 2009. In: URL: http://www06.zkm.de/ zkmarchive/ www02_youser_you/ you/ index_com_content_ article_98_ loveletters10_82_en.html (8/8/2016).

37 Walther: Bense 1999. From 1950 to 1963 Max Bense was an Associate Professor at the Technische Hochschule of Stuttgart (since 1967: Universität Stuttgart) and in 1963 he was appointed Full Professor.

38 On the semantic terms "true" and "false": Carnap/Bar-Hillel: Outline 1953.
On the semantic terms "true" and "false" in the information theory: Bense: Begriff 1963/2000, p.151: "It makes no difference for the statistic information theory if a sequence of signs is true or false. Only its statistic innovation, novelty, information is relevant. But the semantic information theory takes into consideration if a statement is true or false." (Translation by the author)
On semantic information in the context of logic (semiotics), the information in cybernetics (information theory) and its relations to the "general communications research" ("allgemeine Kommunikationsforschung"): Bense: Aesthetica 1982, p.303s.; Bense: Begriff 1963/2000, p.152.

39 Lutz: Texte 1959. Cf. Bense: Einführung 1969, p.111; Bülow: Sinn 2007, p.152-156; Cramer: Statements 2011, p.186s.; Funkhouser: Poetry 2007, p.37s.; Gunzenhäuser: Synthese 1963/2004, p.175-178; Hartling: Autor 2009, p.300s. (referring to Lutz´s manual postprocessing on the prints); Herrmann: Programmierung 2004, p.155,161s.; Moles: Art 1971, p.167; Stürner: Poesie 2003, p.18-21.
Re-engineering: Auer, Johannes: free lutz. Municipal Gallery Wroclaw/Polen 2005. In: Auer: Lutz 2005.

40 Bense: Asthetica 1982, p.291-299. From 1954 to 1960 "Aesthetica" was published in five parts.
On "semantic information" and "aesthetic information": cf. Alsleben: Redundanz 1962, p.24.

41 Further examples of early computer graphics: Dreher: History 2013-2014, chap.III.2.2 with ann.41. Examples of elder analog computer graphics: Dreher: History 2013-2014, chap. III.2.1, amongst others examples of Kurd Alsleben (and Cord Passow) were listed as they were published in his book "Aesthetische Redundanz" ("Aesthetic Redundancy". In: Alsleben: Redundanz 1962, p.51s.).

42 Noll: Beginnings 1994, p.39.

43 Noll: Patterns 1962.

44 Noll: Patterns 1962, p.4 (quote); Patterson: Vision 2015, Ebook mobi position 735.

45 Nake: Ästhetik 1974, p.199.
Noll was not inspired by information aesthetics (Klütsch: Computergrafik 2007, p.165s.), but with his "polygon moves" he offered to Georg Nees and Frieder Nake a programming strategy with capacities to be developed further with criteria of information aesthetics.
The comparison between computer literature and computer graphics demonstrates that the last one takes up programming procedures of the first one. An early and important step to computer literature was offered by Shannon (see above). Thus Noll does not abandon the intersection of cybernetics and the programming of computers.

46 Nees: Variationen 1964. Cf. Nees: Computergraphik 1969/2006, p.XIs., ill.4; Nees: Künstliche Kunst 2005, unpaginated, ill.1s.

47 Zones resp. "Matrizenanordnung" ("arrangement of matrices"): Nees: Computergraphik 1969/2006, p.208.

48 Nees: Computergraphik 1969/2006, p.208.

49 Herzogenrath/Nierhoff-Wielk: Machina 2007, p.434s., nr. 309s.; p.314, 317ss.; Nees: Computergraphik 1969/2006, p.216ss. and 222ss. with ill.28-33, p.231 with ill.36, p.244 and 247s. with ill.9-41.

50 Nees: Computergraphik 1969/2006, p.220.

51 Nees: Computergraphik 1969/2006, p.209.

52 Nees: Computergraphik 1969/2006, p.213.

53 Nake: Ästhetik 1974, p.229, ill.5.5-1.

54 Nake: Ästhetik 1974, p.229.

55 Nake: Ästhetik 1974, p.237s.
On "transition probabilities" ("Übergangswahrscheinlichkeiten"): Kawano: Aesthetics 1968/2011, p.310s.; Nake: Ästhetik 1974, p.232.

56 Herzogenrath/Nierhoff-Wielk: Machina 2007, p.426, Nr.267; Klütsch: Computergrafik 2007, p.152ss.; Nake: Ästhetik 1974, p.236s. with ill.5.5-5; Rödiger: Algorithmik 2003, p.98,134,141,164.

57 Nake: Ästhetik 1974, p.236, ill.5.5-5.

58 Bense: Aesthetica 1982, p.33s.,322s.,328s.,354s.; Bense: Einführung 1965/1968, p.30-35; Bense: Einführung 1969, S.43ss.,55s.; Bense: Informationstheorie 1963/2000, p.136; Birkhoff: Measure 1933.

59 Moles: Information 1965/1968, p.23; Moles: Art 1971, p.24ss.

60 Bense: Aesthetica 1982, p.212,325; Bense: Einführung 1965/1968, p.34; Shannon: Communication Presence 1949, p.16.

61 On the "aesthetic measure" in the writings of Birkhoff, Bense, Moles and others: Nake: Ästhetik 1974, p.75ss.,82ss.

62 Bense: Aesthetica 1982, p.225. Cf. Alsleben: Redundanz 1962, p.20: "From a statistic point of view the term rarity corresponds to the terms surprise, newness, information and improbability. A rare event has a greater surprise effect and a greater information value." (Translation by the author)

63 Moles: Théorie 1958, p.170,180.

64 Nees: Computergraphik 1969/2006, p.220. Cf. p.177 with a further quote from Bense's "Aesthetica" (part V, 1956. New in: Bense: Aesthetica 1982, p.342) on the differentiation between "micro-" and "macroaesthetics" ("Mikro-" und "Makroästhetik"). In Nees: Computergraphik 1969/2006, S.24 Bense's

differentiation between "microaesthetics" ("arrangements and complexity"/"Ordnungen und Komplexität") and "macroaesthetics" ("redundancies and information"/"Redundanzen und Information"), as it was published in Part V of "Aesthetica" in 1965, is quoted at length (Bense: Aesthetica 1982, p.334. Cf. Klütsch: Computergrafik 2007, p.67-71).

65 Nake: Ästhetik 1974, p.236,262.

66 Herbert Werner Franke's information aesthetics: Franke: Phänomen 1967 ("experimental aesthetics"/ "experimentelle Ästhetik", p.17s. On the relation work-perception, p.23s.). Algebraic curves of the series "KAES", 1969: Herzogenrath/Nierhoff-Wielk: Machina 2007, p.345, nr.86s. Further works of the series: Franke: Information 1971, p.29-40.

67 On Gordon Pask and second-order cybernetics: Glanville: Pask 2007, S.58: "Pask was aware that his work contributed to the creation of Second-Order Cybernetics..." Cf. Glanville: Magic 2007, p.128.
On cooperations between Gordon Pask and Heinz von Foerster: Scott: Cybernetics 2007, p.33.
Gordon Pask's development from "learning machines" to a theory of learning and conversation: Glanville: Approach 2007; Glanville: Magic 2007; Pickering: Brain 2010; Rosen: Control 2008, p.135,162s.,165s.,178s.; Scott: Cybernetics 2007, p.34-51.
On the statistic prediction as a foundation for theories of learning: Masani: Wiener 1990, p.321.

68 Vesna: Fuller 1998.

69 On cybernetics and their influence on the British culture of the sixties: Pickering: Brain 2010, p.158s.,183-195,204-210,256-261,347-355,361-371,384s.,387.
Some clues on the reception of cybernetics in the English-language art context (England, U.S.A.):
On cybernetics as an inspiration for members of the Independent Group (since 1952), especially for Lawrence Alloway, Richard Hamilton, Toni del Renzio, Geoffrey Holroyd and John McHale: Mason: Computer 2008, p.26; Whiteley: Art 2012, p.53-58.
Lawrence Alloway on the relation between mass media and cybernetics: Alloway: Technology 1956, p.22 (In a caption Alloway designates a Science Fiction cover as "Cybernetics and the image of man").
On cybernetics in the courses and lectures at the Hochschule für Gestaltung (HfG) in Ulm: Hamilton: Ulm 1959/1982, p.160 ("Cybernetics" are mentioned as a part of the education).
Information theory as a method to discuss modes of representation in pictures: Gombrich: Art 1960/2000, p.39,88,205s.,406,411,424.
Roy Ascott on "the cybernetic spirit", "cybernetic vision" and "feedback": Ascott: Art 1966; Ascott: Art 1967. On "cybernation" in Ascott's practice in teaching and education in the sixties: Mason: Computer 2008, p.53-66.
"Cybernetics" as mentioned in the catalogue of the exhibition "Cybernetic Sculptures" (Reichardt: Serendipity 1969), Institute of Contemporary Arts, London 1968: Above the table of contents on page 3 a short definition of "cybernetics" is presented and on page 89 Nobert Wiener's definitions of "cybernetics" are quoted. The quotes are taken from "The Human Use of Human Beings" (Wiener: Use 1950). The exhibits are realised amongst others by Stafford Beer, Gordon Pask, Nicolas Schöffer, Frieder Nake and Georg Nees.
In 1968 Jack Burnham writes in "Beyond Modern Sculpture" on William Ross Ashby ("Homeostat"), Max Bense, Gotthard Günther, Gordon Pask, Claude Elwood Shannon, William Grey Walter, (Cybernetic Sculptures and) Nicolas Schöffer: Burnham: Sculpture 1968, p.204,334-338,344s. Cf. Burnham: Notes 1970, p.11.
In 1970 Gene Youngblood writes in "Expanded Cinema": "My indebtedness to the thoughts of R. Buckminster Fuller, John McHale, Norbert Wiener, and Marshall McLuhan is quite clear." (Youngblood: Cinema 1970, p.44, cf. p.62,71 and others).

70 This is particularly true in the case of the English-language context of the sixties for the art critics of the "modernism" Michael Fried, Clement Greenberg and Rosalind Krauss dominating the public opinion on art. In Western Germany the authors of texts about information aesthetics formed a group of its own within the sixties' debates about art (Kurd Alsleben, Max Bense, Helmar Frank, Herbert Werner Franke, Karl Otto Götz, Rul Gunzenhäuser, Siegfried Maser, Günter Otto, Günter Pfeiffer, Hans Ronge). Cf. Ronge: Kunst 1968.

71 On the evolution of American art from Abstract Expressionism to Pop Art and Minimal Art as a paradigm for the history of Post-war art that should not be prolonged by Conceptual Art because a "paradigm shift-off" seemed necessary: Atkinson/Baldwin: Work 1972, p.167. In this 'paradigm of a sequence of paradigms' installations, performance art, computer art and experimental films were left out: The sequence of paradigms, as it was established by contemporary art criticism and the exhibition circuit (museums and galleries), had an excluding character: The art world (art museums, art market, art criticism, history of art) marginalised the computer art, and with it pushed cybernetics to the peripheries of the art context, too.

(Lecture, Sprengel Museum Hannover, 10/16/2016. The lecture was a part of the series of events "Basis Zwei" commemorating the 300th anniversary of Gottfried Wilhelm Leibniz's death (curated by Pit Noack) and is based on Dreher: History 2013-2014, chap.II-III (with detailled descriptions of the works).)