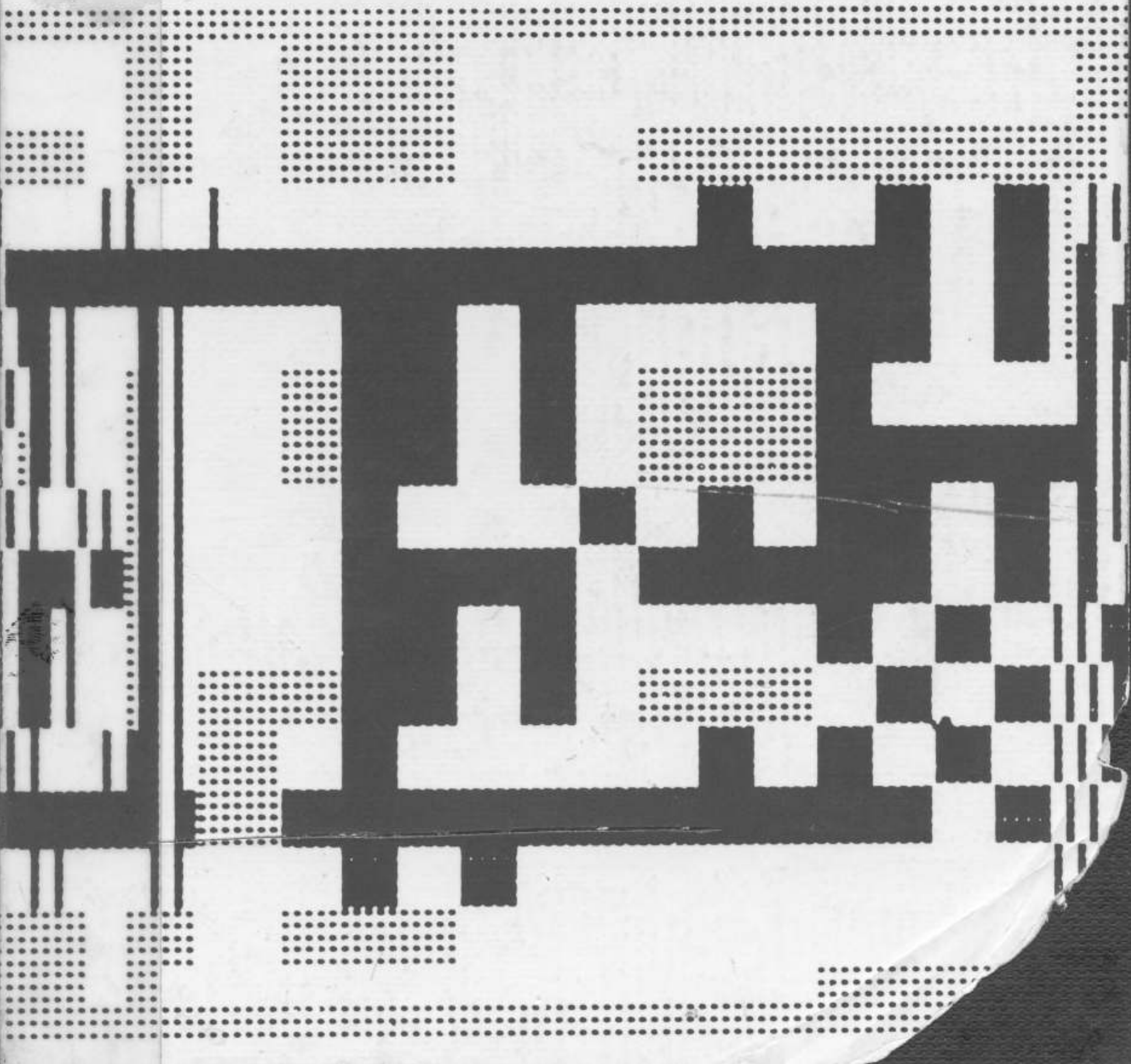
he Computer
n Art

Jasia Reichardt



The computer in art

Computer-aided art is one of the most important links between art and technology. During the last decade functional designs for industry as well as non-functional pictures for pleasure have been produced with the computer. Computer-produced drawings are the work of people from a wide variety of disciplines – a few of them are artists, but most of them are the engineers who have access to computers and their various graphics peripherals, as well as the know-how to use them. The computer has thus enabled people without the ability to draw so much as the simplest design to produce pictures that are both intricate and visually satisfying. Artists generally have to rely on collaboration with engineers to produce computer-aided pictures, though more and more are now learning computer programming, and special computer languages are being devised to meet the requirements of art departments of universities.

This fascinating book shows how computers may be used to produce drawings in black and white and in colour, as well as to make animated films and sculptures, and describes many of the representative achievements in the first decade of this activity. It will stimulate every reader to question the established definitions and boundaries of creative activity.

Jasia Reichardt has been Assistant Director of the Institute of Contemporary Arts, London, since 1963. She is particularly interested in exploring the relationship of the visual arts to society at large. She has organized many major exhibitions, including 'Cybernetic Serendipity' for the ICA in 1968. She has written and edited several books on artists, and has recently edited *Cybernetics, Intuitions and Art* – a unique collection of essays by scientists, philosophers, composers and poets.

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Studio Vista: London
Van Nostrand Reinhold Company:
New York

A Studio Vista/Van Nostrand Reinhold Paperback
Edited by John Lewis

Published in London by Studio Vista Limited
Blue Star House, Highgate Hill, London N19
and in New York by Van Nostrand Reinhold Publishing Company, a Division of Litton Educational Publishing, Inc.
450 West 33 Street, New York, NY 10001
Library of Congress Catalog Card Number: 79–136745
Set in 9/12 pt Univers
Printed and bound in the Netherlands
by Drukkerij Reclame N.V., Gouda
British SBN paperback 289 79550 8
hardback 289 79552 4

The cover illustration is based on a still from a computer-generated film by Stan Vanderbeek, programmed with the BEFLIX mosaic system.

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Acknowledgments
Jasia Reichardt extends her warm thanks to all the contributors for providing their excellent material; to the Institute of Contemporary Arts, London, for several photographs from the Cybernetic Serendipity exhibition; and to Tony Hyman for his very kind advice on the technical aspect of the text.

The whereabouts of computer art

Most art movements are remembered for the relatively few great works which are associated with them and the exceptional individuals who brought them about. Since 1945 we have automatically linked abstract expressionism with the names of Jackson Pollock and Mark Rothko; colour in sculpture with David Smith and Anthony Caro; Pop Art with Claes Oldenburg and Roy Lichtenstein; and Op Art with Vasarely and Bridget Riley. Those trends or movements which demonstrate a current preoccupation but fail to produce works of great quality leave an incomparably lesser trail. This is true, for instance, of Social Realism in Britain in the 1950s, Nouveau Realisme in France, and in the 1960s Psychedelic Art in America.

Since the early 1950s, however, there have been two international movements which in this context constitute an exception. An exception in the sense that there are no masterpieces to be associated with them, nevertheless these two movements have a unique significance both socially and artistically. The first of these is Concrete Poetry, and the second, Computer Art. The salient points are that both these movements are international, that they are motivated by the use of media, technique, and method, rather than an ideology, and that those participating in them come from a variety of professions, disciplines and walks of life. Not all concrete poets are in fact poets, and very few so-called computer artists are in fact what we usually mean by 'artists'.

Concrete poetry is concerned with the visual and phonetic, as well as the semantic, exploitation of words. It explores the visual and sound equivalents of any literary material. It is the poetry of colour, puns, repetitions and patterns. It is the sort of poetry where a few sentences, words, syllables, or even letters, are pulled, stretched and transformed to yield something that may finally be closer to an abstract picture than a text, or even result in an incomprehensible sound. Following the examples of Mallarmé's 'Un coup de dés' and Lewis Carroll's mouse's tail, those involved in concrete poetry, ever since the term was coined in 1954, are poets, painters, philosophers, composers, sculptors and musicians. When someone announces that he is a concrete poet, we cannot possibly know just on the basis of this scant information, from which of these many directions he has arrived at this particular activity.

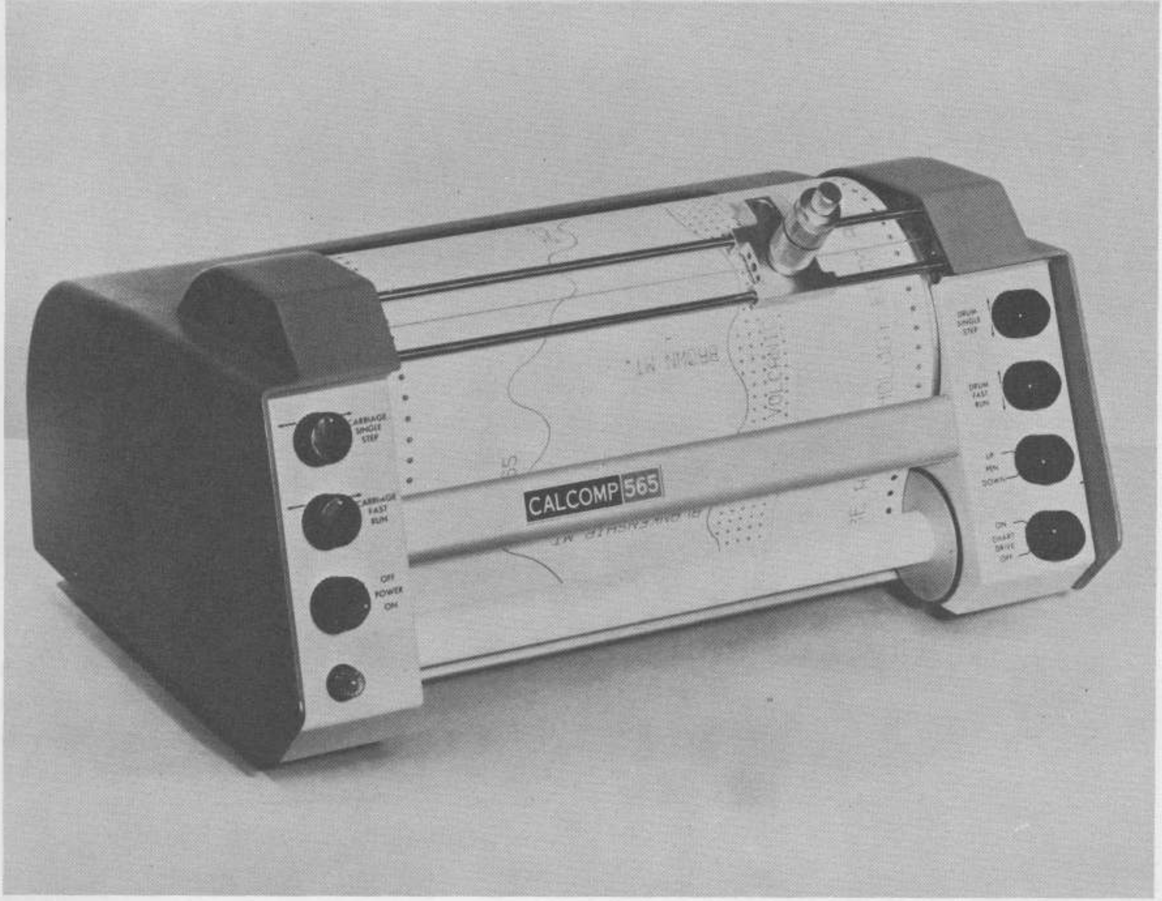
Computer art, of which the first tentative steps date back to 1956, has much in common with concrete poetry. Its exponents are composers, artists, engineers, doctors, mathematicians, philosophers and poets – all those in fact, who have access, know-how, and the desire to exploit the computer and its various printers and graphics peripherals, for making pictures. In the same way that a concrete poet confidently sporting this title, may be a bad, or dull, or just an unoriginal concrete poet, so the computer artist may do little more than produce countless indifferent doodles on reams of paper at great speed. Just because the terms 'poetry' and 'art' are used in these two cases, does not necessarily mean that they are used in the context, or with the associations, to which we customarily aspire. Concrete poetry may have very little to do with poetry, and computer art may not be art in any way whatever. Neither this, nor the fact that these two movements have produced nothing so far that can be called a great work of art, detracts from their importance as the means of reformulating the boundaries and definitions of creative activity as a whole.

These two movements demonstrate that creative activity need not necessarily belong to the conventionally prescribed areas of painting, sculpture, poetry and music. They also demonstrate that creative activity is not the prerogative of those with a diploma from an art college, creative writing course, or an academy of music, or of those professionally engaged in these fields. This is particularly true of computer art where anyone able either to write a computer program, or to use a computer program, can convey visual information to paper without being able to draw, even the simplest design, by hand.

Computer art has been, and is being, practised in Britain, Germany, Italy, Austria, USA, Japan, Canada, and South America. For obvious practical reasons the centres of this activity are industries with research departments, universities with computer centres, and the computer firms themselves. No art department or art college by the end of the 1960s had its own computer, although several art departments of large universities, such as that in Columbus, Ohio, have access not only to the university's computer but also the help of the technical staff, as well as special computer peripherals acquired specifically for its use. However, this is an exceptional situation and in view of this, as well as on the basis of the number of computer graphics that have been published or exhibited, one can assume that there are probably no more than about 1000 people in the world working with computer graphics for purposes other than the practical ones of designing machine tools, car bodies, or the distribution of structural supports for buildings.

It must be noted that the non-utilitarian use of computers extends not only to computer graphics, but also to computer-composed and -played music, computer choreography, as well as computer poems and texts. Of all these creative uses of the medium, one could say that music is by far the most advanced, with Xenakis as its most original and successful exponent; and poetry is probably at the bottom of the list. The simple technical tricks which can make computer graphics appear very complex, as well as attractive and compelling to look at, are not sufficiently developed as yet to cope with the grammatical and semantic aspects of language with an equal degree of success.

The role of the computer in the arts extends beyond its actual use, for there are many works based on the ethos of computer technology but which have not been made with the aid of the computer or its peripherals. Many interactive devices, sound and visual systems and ingenious cybernetic environments which operate on a feedback system owe their existence directly to those principles on which computer hardware and software are based. These works, which are a direct development of kinetic and light art, involve different skills than those required for the production of computer-aided drawings or other works which involve the writing of a computer program. Notably many cybernetic

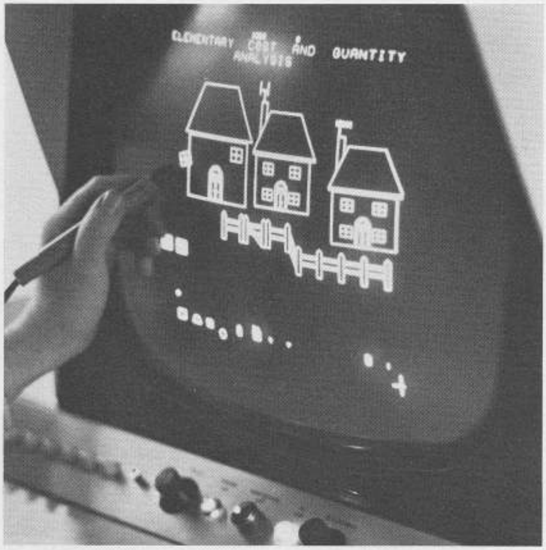


1. CalComp model 565, 12-inch drum plotter.

sculptures are closer in spirit to the latest inventions in electronic engineering, rather than to what we have come to describe as three-dimensional art objects. Whereas this particular field appears to have a far greater potential than computer-generated art, which in the early 1970s is largely limited to computer graphics, it is the computer graphics that forms the core and basis of computer art to date.

Computer graphics

There are three main ways in which computer graphics are made. First they can be made with a computer-driven graphic plotter which may be a pen moving along a horizontal rod which draws on to paper rolled on a drum, moving vertically. Each line is composed of very small steps which are visible when the drawing is closely examined and each step corresponds to a specific instruction conveyed to the plotter from the magnetic tape. The

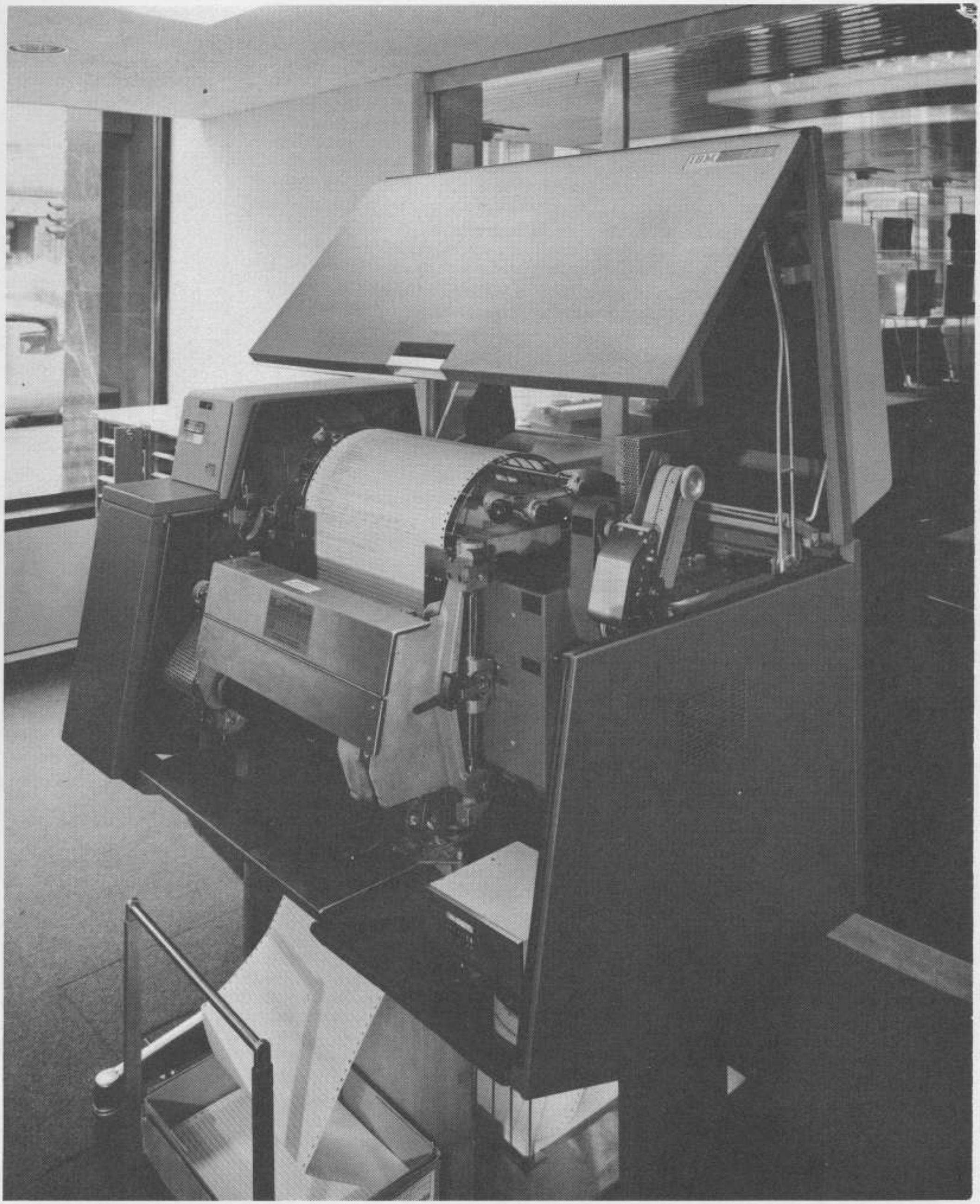


2. Cathode ray tube display with light pen – ICL 4100 graphical display system.

second and more flexible method is a cathode ray tube display or television tube, on which one can draw; and finally there are many types of printers which can produce patterns composed of letters and whatever other symbols are to be found in their repertoire. Of these three methods the cathode ray tube display has a particular advantage in that it can be used interactively, that is, it allows direct access to the person drawing so that he can alter the image or the data with no significant lapse of time. He is able to control many parameters in combinations of his own choice, and is able to evaluate the relationships of the forms he is manipulating, making use of both intuition and the knowledge of the problem in hand. This sort of man/machine interaction makes for a very effective method of working in computer-aided design. Thus the computer takes over the burden of routine operations: accurate drafting, checking for consistency with any prescribed rules, or physical requirements such as that the leg of a chair shall not break.

Non-interactive graphics (those which involve a time-lapse between feeding the program into the computer and obtaining the results) are usually done with the aid of a graphic plotter. The drawings which are thus produced have a wide range of uses. Interactive graphics allows the evolution of conceptual designs in a flexible and dynamic way, and the computer can be seen as a means for visualizing a model of a structure in animation which allows one to come to grips with the spatial implications of forms. It is possible to produce isometric views, rotate the image about any designated axis, alter

3. A cathode ray tube display as a computer-generated picture by Leon Harmon and Kenneth Knowlton. A conventional photograph was scanned and broken up into fourteen different shades of white, grey and black. Each shade was represented by a tiny hieroglyphic symbol: telephone, face, animal, aeroplane, and so on. When looked at from a close range the individual elements which make up the pattern are clearly visible, although the overall picture clicks into position only at a certain distance.



4. Computer line printer with covers open, IBM 1403.

the scale, delete elements, translate dots into lines and vice versa, alter parts of a complete drawing while other parts are held fixed, and have multiple figures displayed simultaneously. One can also alter geometric shapes according to specifications which are themselves stored, and also translate the displayed figures and data to an x-y graph plotter for permanent record. The cathode ray tube display may also be given a three-dimensional capability by the use of variable intensity, by the plotting of normals to surfaces, by perspective drawings, or by the use of fully stereoscopic systems. Colour display may also be used and there is no reason in principle why shading should not be employed.

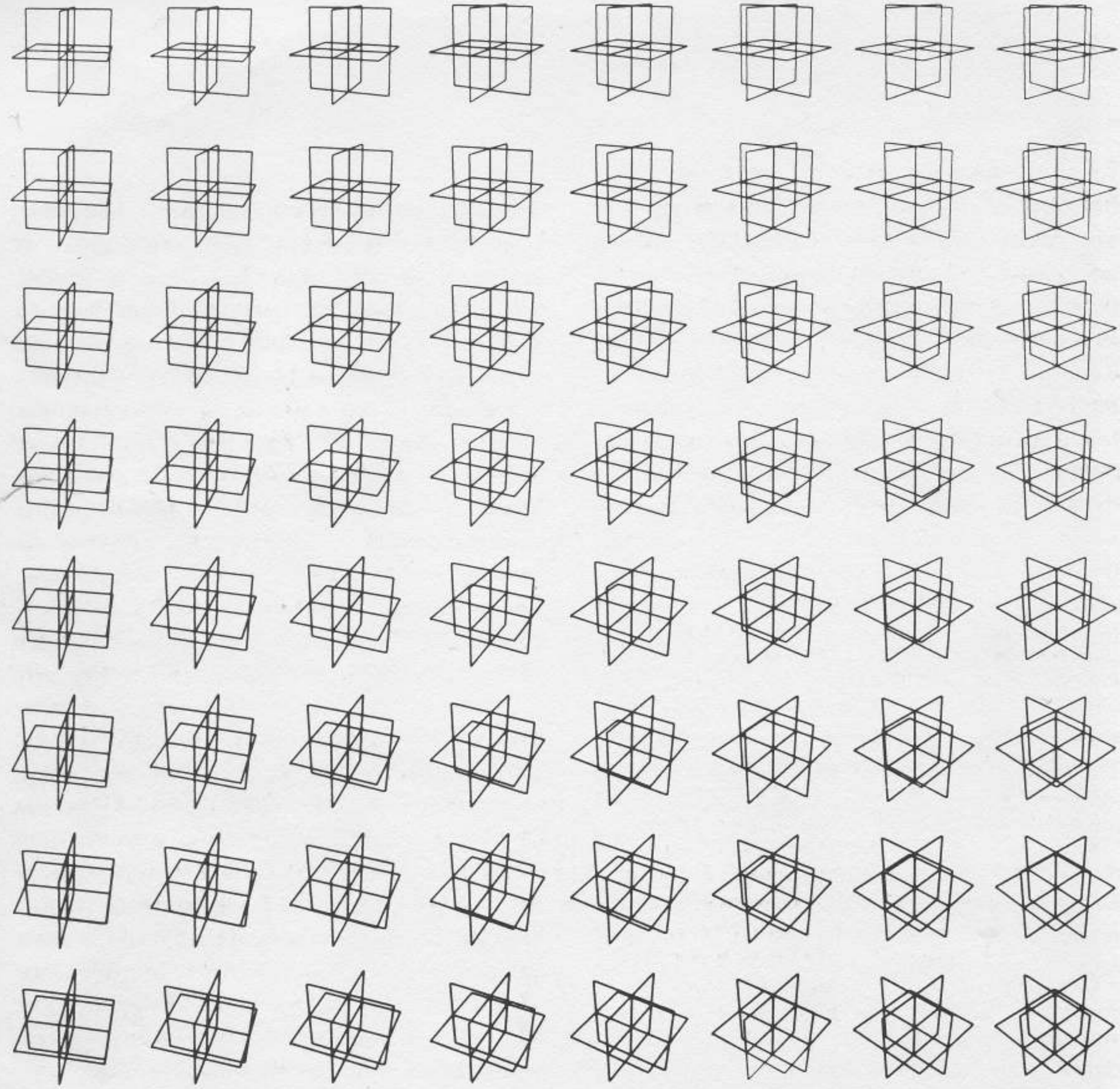
Every single element that is drawn is automatically coded and can be recalled and used in a conglomerate form which in turn will have its own code. Thus everything that can be drawn on a cathode ray tube display can carry with it a description which includes the possibilities of all on-line manipulations.

Computers can be used to make tapes from cathode ray tube display data for the automatic milling of objects in manufacture, or indeed sculptures. After a drawing is produced, a series of instructions is written indicating the path the cutting tool must follow in the operation. The result is a magnetic tape which is first used to produce a precision drawing on a graphic plotter, and at this stage errors that have been made on any part of the tape can be corrected. Later a tape can be made for directing a particular milling machine. When the first part is cut and is proved to be correct, the tape can be used on a production basis.

It is also possible to start off with a computer-guided system which synthesizes and develops all specified elements. Here the process of scaling, fitting and drawing has been pre-programmed – a procedure that is particularly useful in industrial applications where the question of aesthetic choice is irrelevant. In this way a large number of simple, clear, visually real drawings are produced with very accurate dimensions at low cost and in a minimum of time. It was found already in the early 1960s that industrial components designed with computer aid reduced cost and time, and considerably fewer, less experienced men were needed for the job.

It is difficult to make a strict demarcation line between computer graphics which fulfil a purely utilitarian function, like those of the Boeing Company, and others such as those of Charles Csuri and the Computer Technique Group from Tokyo, which are experiments towards an aesthetic end. The term 'computer graphics' is applied to both. In both categories problems are solved and results achieved with the same media and processes. It is also true to say that many of the graphics made with the sole intention of a practical end in view are extremely satisfying visually and had one not been aware of their purpose, one might easily have thought them to be images produced as works of art.

In order to get a clear picture of the sort of work that has been done so far, it is necessary to consider how, why, and for what purpose the various exponents of computer graphics have turned to this medium.



5. Computer-generated perspective transformations.

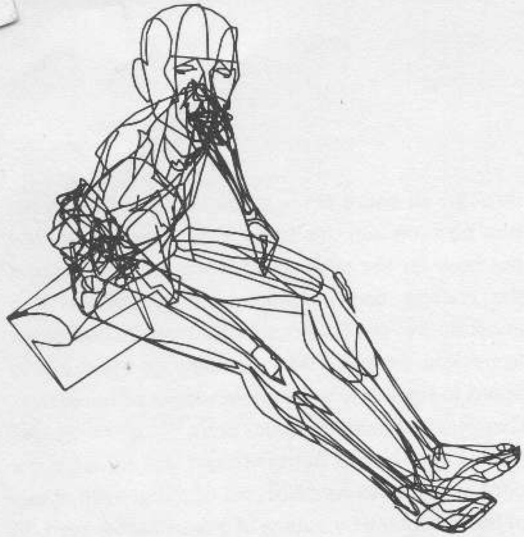
The exponents of computer graphics

One of the first exponents of computer graphics was William Fetter of the Boeing Company, for whom the medium represented from the very beginning, a new stage in the art of visual communication. It struck him, quite by chance, that Babylonian characters have an unprecedented similarity to those punched on IBM cards. His comments when he described the process of making computer graphics to an uninitiated audience in the early 1960s, are of considerable interest:

> The techniques of typesetting and the photomechanical processes fulfil the role of translating thought into visual form. Computer graphics represent a further stage in this process involving the skills of a designer, programmer and an animation specialist. In this latest stage, however, there is less scope for ambiguity because the information must be communicated descriptively and accurately. There are three important stages which have to be considered in making computer graphics: first comes the communicator who has an idea or message to communicate; second, the communication specialist who decides on the best way to solve the problems – for instance, whether it should be done graphically, verbally or as a combination of both; third, the computer specialist who selects the computer equipment and interprets the problem so that it can be dealt with by the computer. It frequently happens, of course, that the communicator, the communication specialist and the computer specialist are one and the same person.

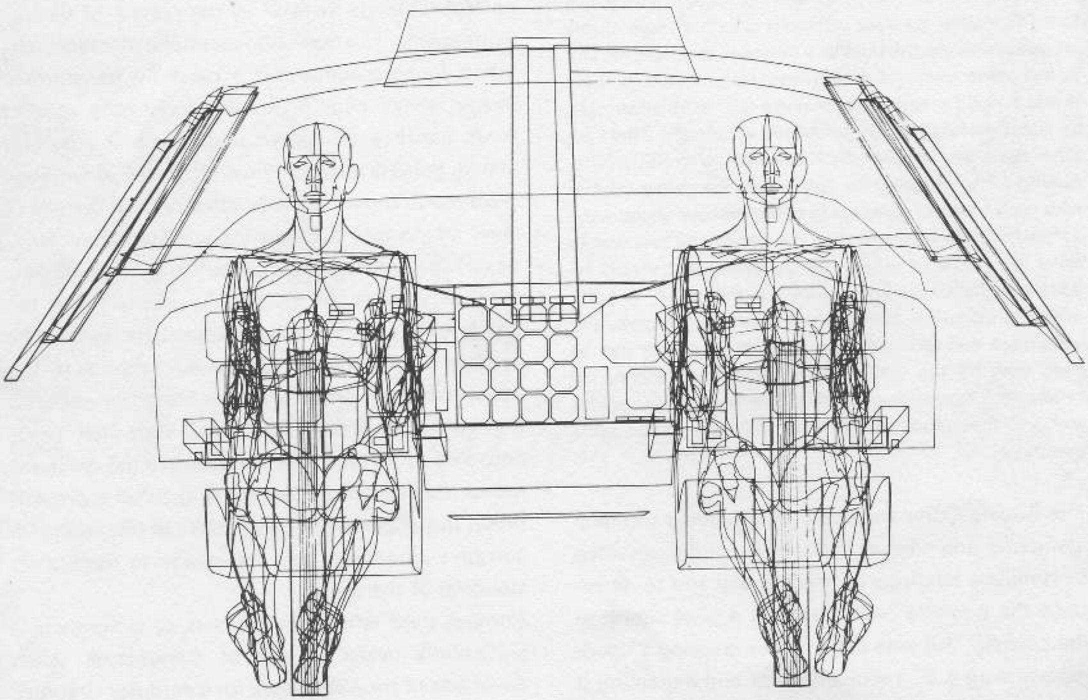
The Boeing Company, which first coined the term 'computer graphics' in 1960, have used them since to stimulate landings on the runway and to determine the possible movements of a pilot sitting in the cockpit. This was achieved by creating a figure representing a 50-percentile pilot and animating it through an entire range of movements from a sitting position. On this basis it was possible to find out how far the pilot could reach and then model the cockpit and instrument panels around him accordingly. The findings could then be compared to cockpit designs made manually on the drawing board to see if any adjustment would be necessary. Computer-animated films were also made for testing instruments in the cockpit and showing the pilot appropriate views of part of the ground ahead of the aeroplane by means of a television screen. In this way it was possible to simulate faulty and correct landings as well as the results of various manoeuvres. The television was not a true representation in perspective but a carefully transformed image which made it possible to identify specific areas easily and inspect objects on the ground ahead, in slow motion. Films of simulated landings were made showing the procedure from the pilot's view taking into account the specific characteristics of the carrier and the speed and angle of descent, as well as the pilot's eye position after the compression of the shock absorbers when the aeroplane sets down. The last ten seconds of the carrier landing simulation, for instance, required 240 computer-drawn plots. These were later hand-coloured by an artist to add realism to the diagrammatic representation. Seeing a graphic representation in perspective of any physical phenomenon can give an entirely new dimension to the understanding of the event.

Another field where the process of simulation is particularly useful is that of architecture. Allen Bernholtz of the Laboratory for Computer Graphics

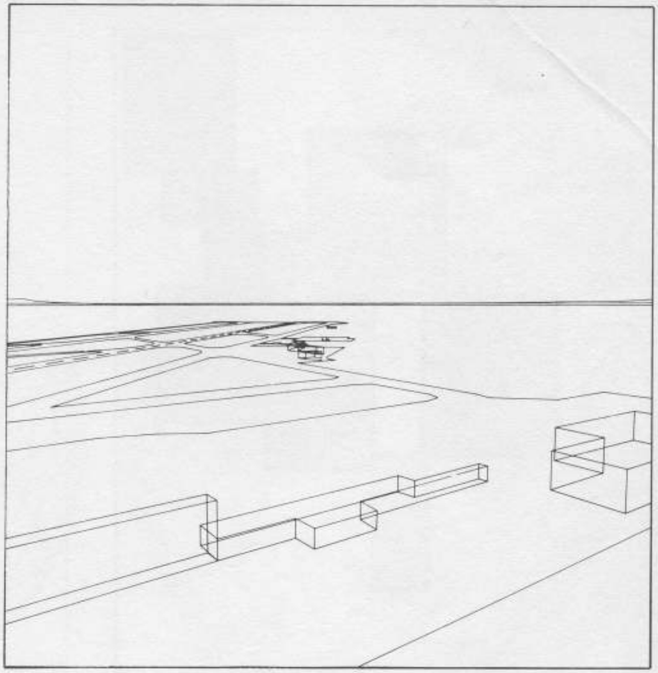


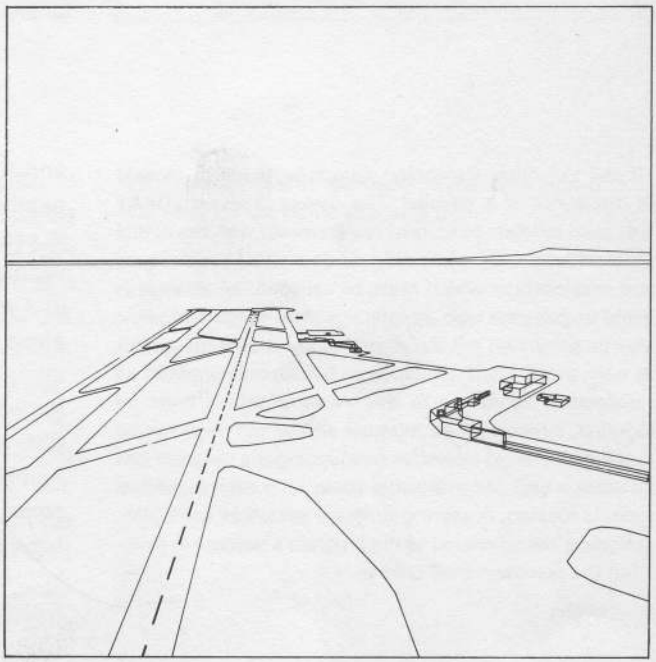
6. Boeing computer graphic: one of the Boeing projects was the animation of the human figure by the computer, including film sequences which showed the movement of the various limbs. Each of the figures is a creation of Air Force data and the Boeing designer, and represents the 50-percentile pilot of the US Air Force. The manipulation of the figure was used to determine man's possible movements in the cockpit and the arrangement of instruments for easier reach.

7. Boeing computer graphic: two 50-percentile pilots in a cockpit.

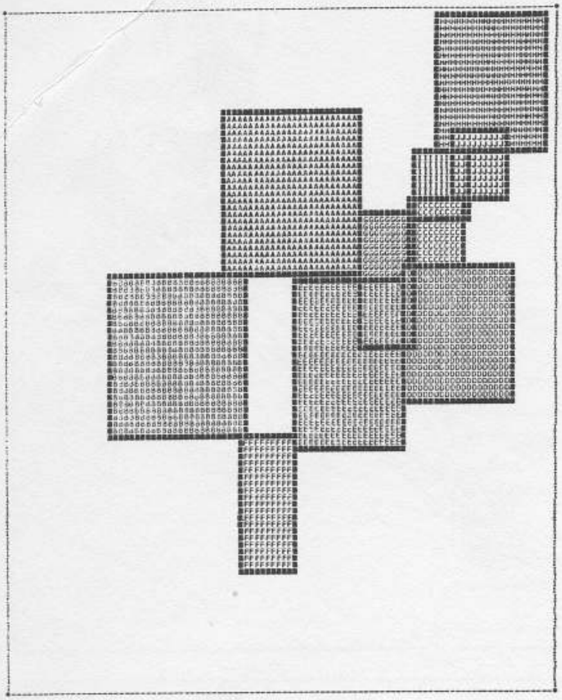


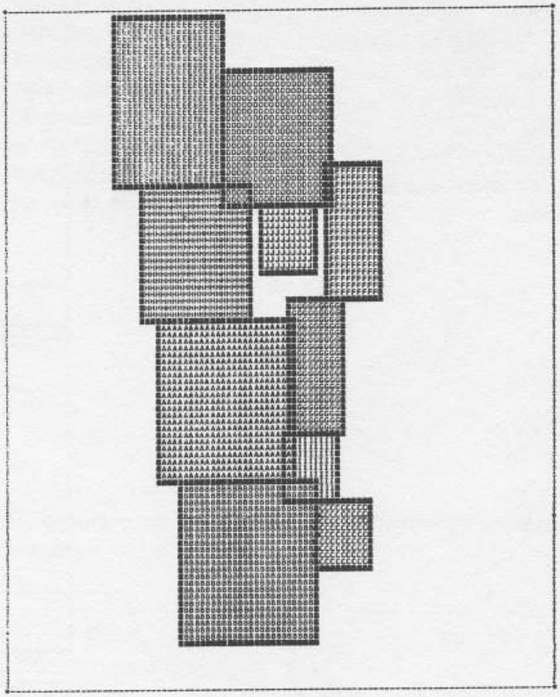
8. Boeing computer graphic: Seattle-Tacoma Airport. This was the first airport configuration to be used in animation for simulating landings. The plot relates to a particular aircraft manoeuvre, with angle of descent, distance and speed taken into account. Sequences simulating the view of the airport from an aircraft which is about to land are used in training pilots.





9. Boeing computer graphic: another view of the Seattle-Tacoma Airport.

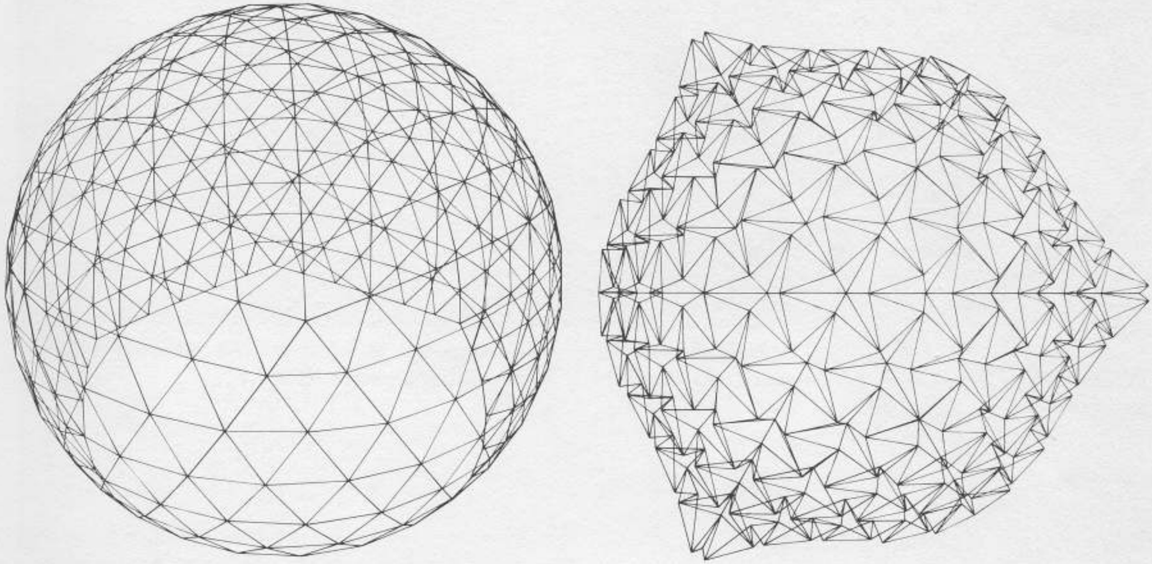




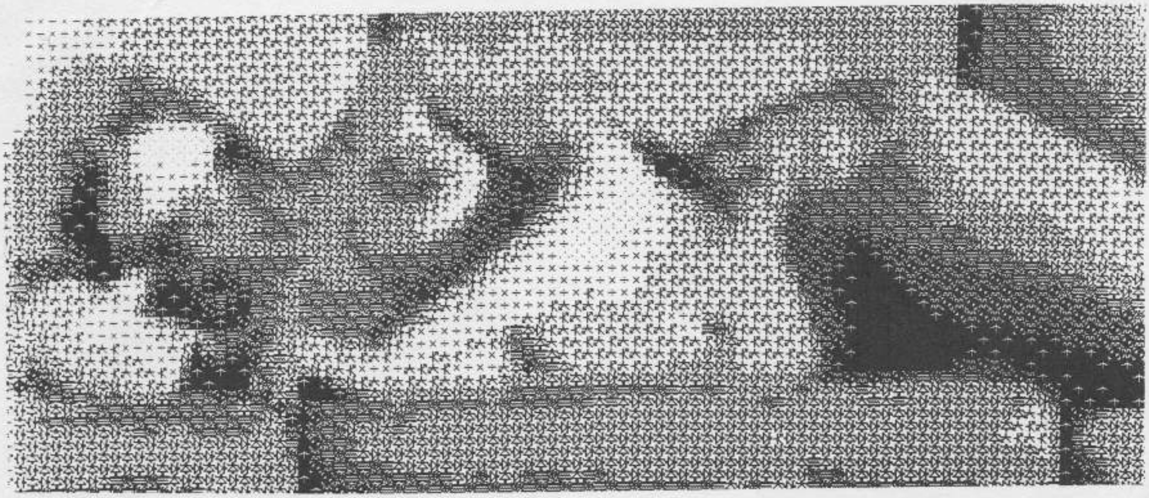
10 and 11. Allen Bernholtz: computer graphics studies of the layout of a hospital. The design program LOKAT was used to relate functional requirements with the actual physical layout. By combining random choice techniques and relationships which must be satisfied, an attempt is made to generate plan alternatives. Any number of plans may be generated but the algorithm constrains the output to only those plans which have been predetermined as satisfactory, according to the elements which must be together, which may be together and which must not be together. To avoid excessive overlapping the program sets up areas which become buffer zones after each individual room is located. A scoring function evaluates each plan, assigning values related to the program's success in satisfying the predetermined criteria.

and Spatial Analysis at Harvard has worked on a number of architectural projects where a computer is used to determine the possible relationships of various areas such as patients' rooms and services in a hospital, or the plotting of sound levels of a given area and then superimposing this information on the existing building plan. These graphics which are absolutely functional are difficult to distinguish in terms of aesthetic appeal from many graphics done purely for pleasure. These two are some of the results of projects done at Harvard between 1967 and 1969 under the direction of William Warntz.

Ronald Resch has referred to conventional architectural planning on the drawing board as a dialogue between man and the physical world, in which a question is raised, and perhaps months later some kind of information is extracted. For him, the particular usefulness of the computer is that it cuts out the time lapse and thus simplifies the job. His own work at the University of Illinois has involved variable geometric structures including a geodesic dome. This particular project was based on two variables: a. the number and type of divisions (e.g. triangular, hexagonal) of the surface, and b. the portion of the spherical section of which the dome was to be composed. Another variable with which he has worked is the alteration of the shape of the dome with or without changing the lengths of the component members.



12. Ronald Resch: geodesic dome structure (left); a variation on the dome structure (right).



13. Leon D. Harmon and Kenneth C. Knowlton: mural based on the photograph of a nude which was scanned and translated into eight brightness levels realized in the finished picture as symbols. This computer-produced nude was completed in 1966.

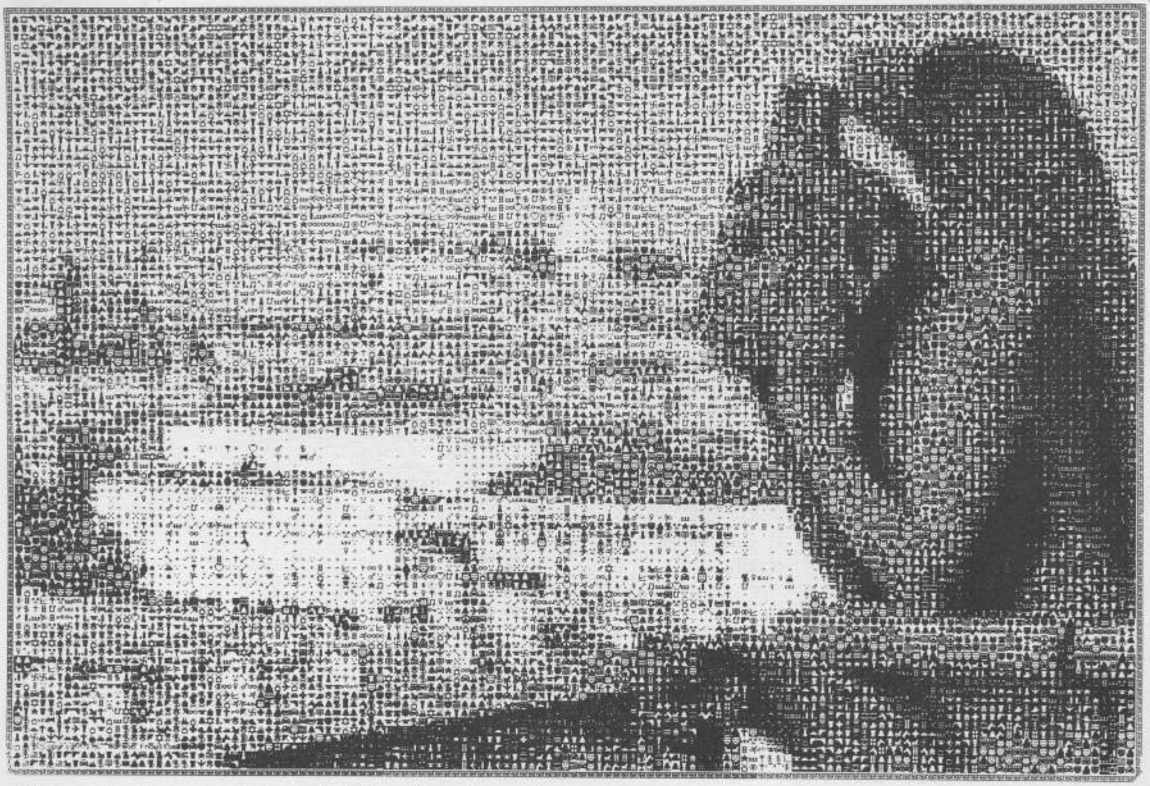
If one were to look for any one centre which has produced more, and a greater variety of computer-generated images than any other, one would probably have to turn one's steps to New Jersey and the Bell Telephone Laboratories. It is there that a number of individuals working in different departments, have contributed original systems and ideas in the field of computer graphics and computer animation. Leon D. Harmon and Kenneth C. Knowlton produced their first computer graphics at Bell Labs in 1967, after Harmon was asked to make a 'modern art' mural to decorate an office. The complete idea, according to Harmon, emerged within minutes, and two months later the office was emblazoned with a 12-foot long, and by now famous, nude made up of alphanumeric characters and produced with the aid of a computer. The nude, and various other images generated in the same way, Knowlton and Harmon referred to as computer processed pictures'. They described their method as follows:

A 35mm transparency is made from a photo of some real-world object and is scanned by a machine similar to a television camera. The resultant electrical signals are converted into numerical representations on magnetic tape. This provides a digitized version of the picture for computer processing.

The first step taken by the computer is to fragment the picture into 88 rows of 132 fragments per row. The average brightness level of each fragment is computed; thus 11,616 (88 × 132) numbers are generated. That is for gull, gargoyle and telephone pictures. The nude has only 50 rows with 100 fragments per row; thus only 5000 numbers are generated for that picture.

The brightness levels are encoded into numbers 0 through 15 which stand for white, black, and 14 intermediate shades of grey. The original picture is now represented by 11,616 numbers each one of which represents a small area having one of 16 possible density (brightness) values. The nude is represented by only 8 brightness levels.

In the processed picture a given density is reproduced by the number of black dots occupying an 11 × 11 square (the nude is simpler with 10 × 10 dots for each micro-pattern, and the telephone more complex with 15 × 15). This dot array is produced on microfilm by a microfilm

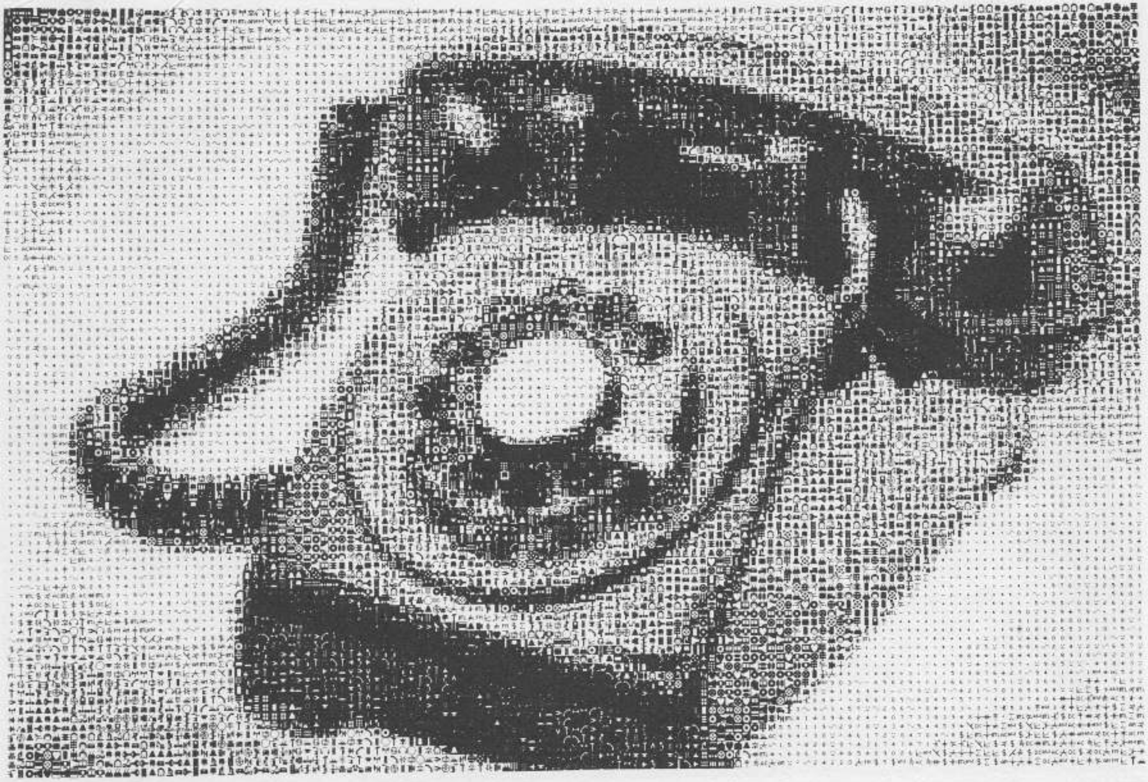


14. Leon D. Harmon and Kenneth C. Knowlton: *Gargoyle,* studies in perception III.

printer. Instead of randomly sprinkling black dots over the 11 × 11 square in the proportion called for by any given brightness level, the dots are organized into micropatterns which can be seen at close range. For example, a light gray (say brightness level no. 5) requires (ideally) 42 black dots. So approximately this number of black dots is structured to form either a house, or a cat, or a stop light, or an umbrella, etc. Similarly a nearly black element (say level 14, requiring 111 black dots) might be a lightning flash, a white division sign on a black background, etc. There are a total of 141 patterns. Again, the nude is simpler, having only 16 possible patterns (2 at each level), and the telephone has greater variety (196 different micropatterns). Some brightness levels have as many as 14 to choose from, while others have as few as 5.

When a particular brightness level is called for, the computer makes a random choice among the set which fits that level; different probabilities may be assigned to different patterns within a given level.

The overall picture is actually produced on 6 frames of microfilm (12 for the more detailed telephone picture) because the resolution of the microfilm printer is only 500 separable dots horizontally, whereas we need 132 × 11 = 1452 dots along that dimension. The 6 microfilm frames are then enlarged photographically, pasted together, and rephotographed to produce a final high-contrast 8 × 10 negative. This negative is then used to produce large prints. At close viewing distances the many tiny patterns are clearly visible, but unless you know exactly what to look for, the large picture (the overall Gestalt) cannot be perceived. With increasingly great viewing distances the small patterns disappear, and the overall picture emerges.

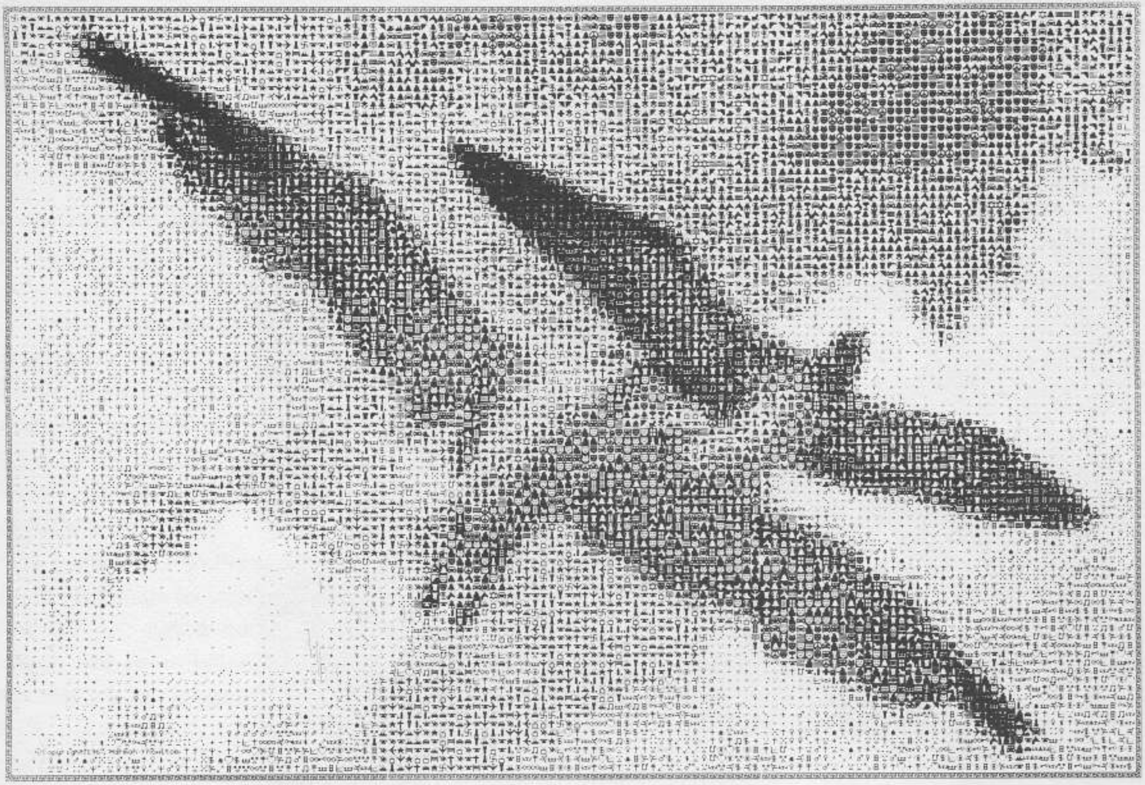


15. Leon D. Harmon and Kenneth C. Knowlton: *Telephone,* studies in perception I.

Harmon and Knowlton give the following reasons for experimenting with these pictures:

To develop new computer languages which can easily and quickly manipulate graphical data;
To explore new forms of computer-produced art;
To examine some aspects of human pattern perception.

What is interesting here is that neither Knowlton nor Harmon sought an image that would be either abstract or synthetic, or indeed invented or in any way transformed. Quite rightly they considered that a common recognizable image would be the best vehicle to demonstrate the technique they had invented. On the other hand, their aim was also to produce something in the idiom of 'modern art'. Had they been attempting this before the advent of Pop Art perhaps the imagery would have been drawn from the vocabulary of abstract expressionism. This is a mere speculation but it may well have some significance in relation to the range of subjects in the first decade of computer graphics.
Apart from his collaboration with Harmon, and inventing the BEFLIX movie system (described later), Knowlton has also worked in collaboration

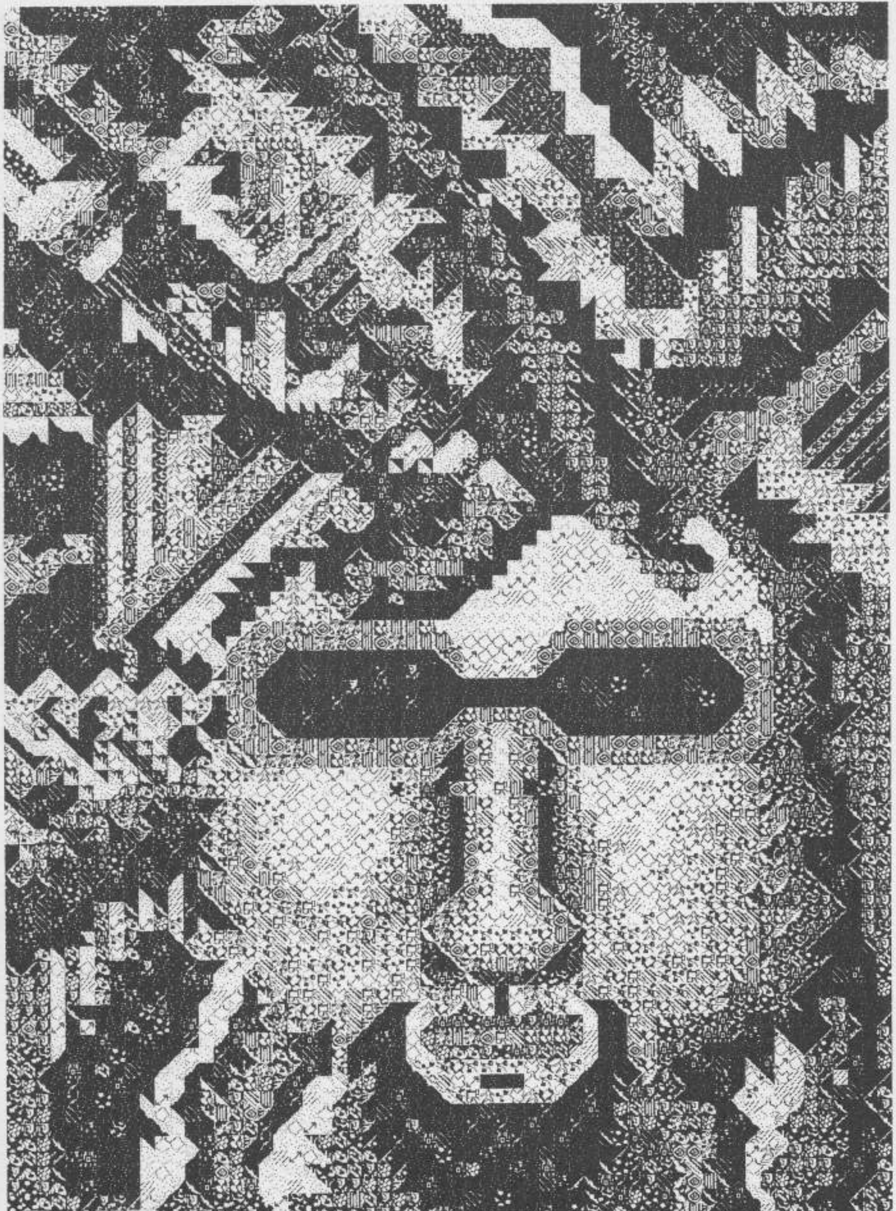


16. Leon D. Harmon and Kenneth C. Knowlton: *Gulls,* studies in perception II.

with artists. In the case of Lillian Schwartz, for instance, he developed computer pictures from her original paintings. Several of her portraits and still lifes were transformed into black and white computer-generated replicas, described by her as examples of 'technological pointillism'. Lillian Schwartz's attitude to the process is that the computer can merely complement the material provided in the first place by the artist, which should be made deliberately simple in order to allow for elaboration in the process itself.

Not all artist/technologist collaborations have been so successful however. A. Michael Noll, member of the research staff at the Bell Telephone Laboratories, having made one attempt at collaboration with an artist was discouraged to find that the artist had difficulties in verbalizing what he wanted to do.

Noll got involved in computer art by accident when his microfilm plotter went wrong and produced an unusual linear design. He became sufficiently interested in the possibilities of computer graphics to have taken part, together with Bela Julesz, in the first ever documented exhibition of computer



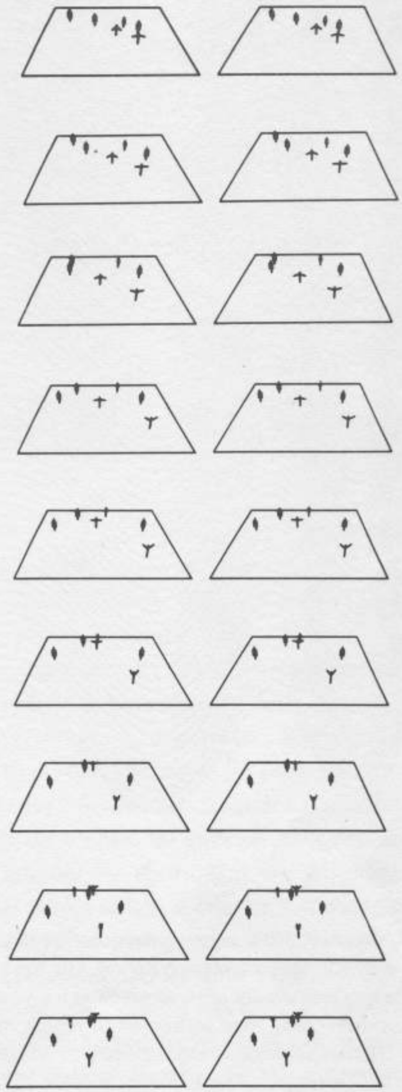
17. Kenneth C. Knowlton and Lillian Schwartz: a composite computer-generated picture which includes the heads of Leon Harmon, Kenneth Knowlton, John Vallard, as well as the gargoyle in figure 14.

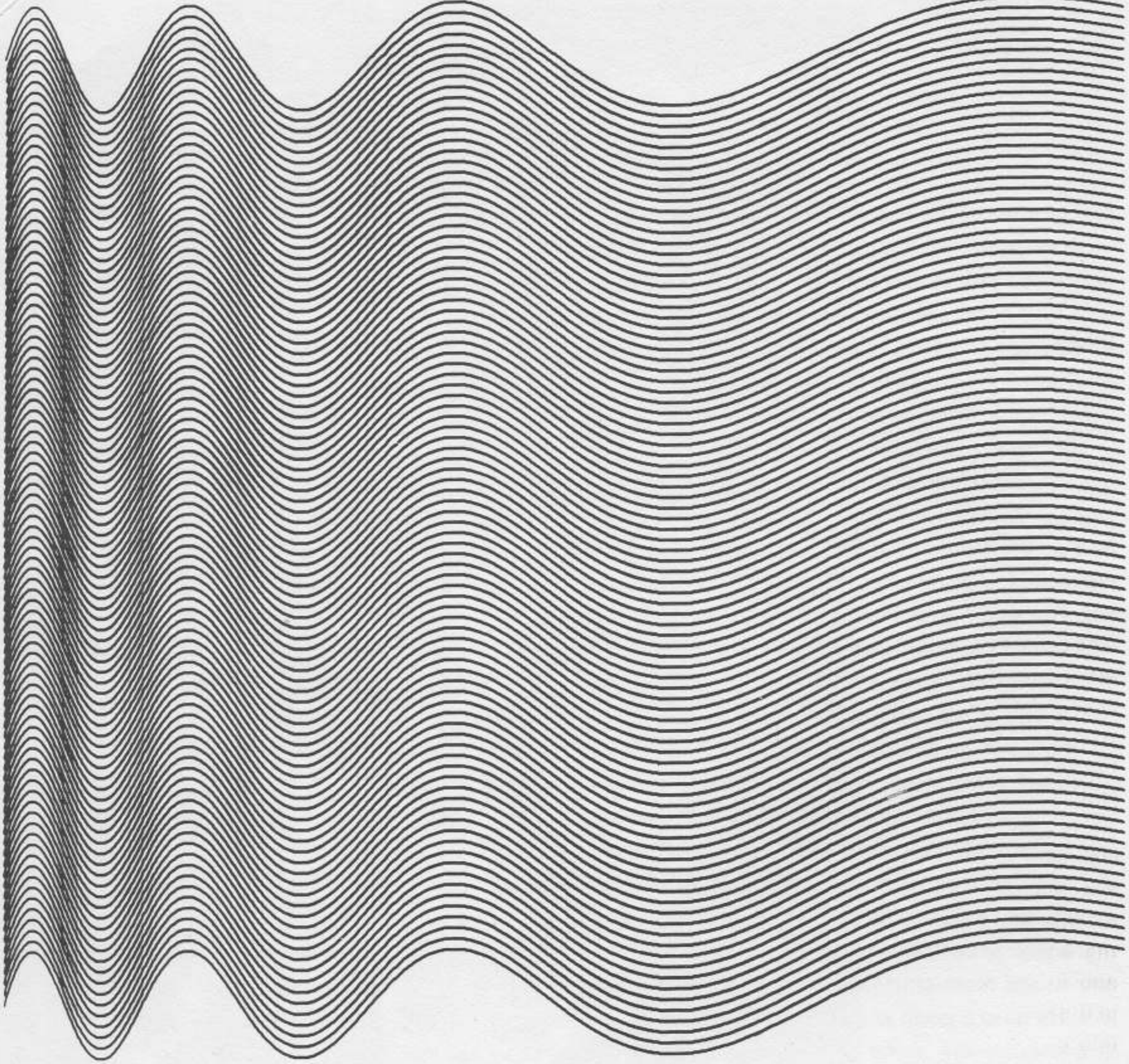
graphics at the Howard Wise Gallery in New York, in April 1965. Noll's graphics, which eventually developed into stereo pairs, his films, including an animated choreography with stick figures, and his studies on the 1917 *Plus and Minus* Mondrian drawing were thought of by him as exploratory experiments. They were intended to interest artists in the new capabilities of the computer but he himself had expressed no desire to seriously make computer art himself.

Noll points out that the computer could be used to great advantage for producing the sort of art which, like Op Art, has a mathematical component, or which, like permutational or serial art, depends on the making of versions based on set parameters. Noll is one of the few people involved in computer art from the technological end who has always claimed that the roles of the artist and engineer are not only *not* interchangeable, but that beyond making his techniques available and accessible, the engineer has no role in that area of creative activity generally called art. Pioneer, nevertheless, in the field of computer generated art, Noll has been one of the most articulate exponents on the subject. He gave a good example of the way in which, in computer art, order and randomness can be combined:

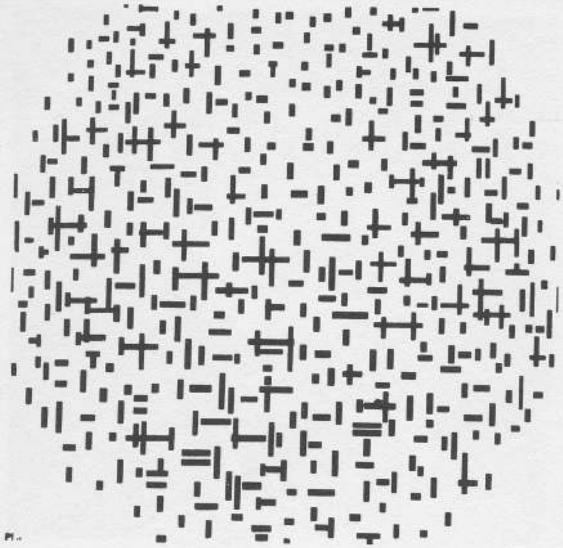
The computer was programmed to generate its version of Richard Lippold's sculpture *Orpheus and Apollo* which hangs in the lobby of New York City's Philharmonic Hall. This work consists of long flat plates of brass that have been hung from the ceiling by thin wires. For all practical purposes, the plates can be represented by single straight lines. When Lippold's work is so visualized, it becomes

18. A Michael Noll: example of stick figure representation of human motion. The positions of the stick figures on the stage are chosen at random, and the figures move at uniform rates. Arm motion has also been programmed into the figures. The real goal of this project was to draw a complicated stick figure which could be used in computer investigations and optimization of human movement.

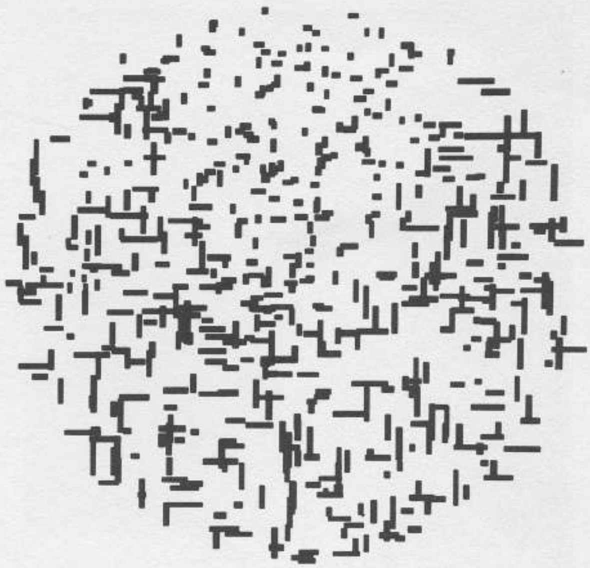




19. A. Michael Noll: ninety computer-generated sinusoids with a linearly increasing period. The top line of this picture was mathematically expressed as a sinusoid curve. The computer was then instructed to repeat the line 90 times. The result approximates closely to Bridget Riley's painting *Current*.



20. Mondrian: *Composition with Lines* 1917, was used for a subjective comparison with a computer-generated picture by Michael Noll.



21. A. Michael Noll: *Computer Composition with Lines* 1965, based on the composition by Mondrian.

possible to describe the sculpture in terms of imaginary trend lines about which the bars have been placed. The computer approach was to specify each trend line by giving the coordinates of its end points, and the computer then distributed lines randomly about this trend line, and also had random angular positions in space. In the result, a total of six such trend lines is used.

The three-dimensional projection program has the flexibility of specifying any viewing position. In this way it is possible to obtain views of a computer sculpture from any specified position without the necessity of actually constructing the sculpture. The facility should be valuable in visualizing complicated sculptures before the expense of final construction.

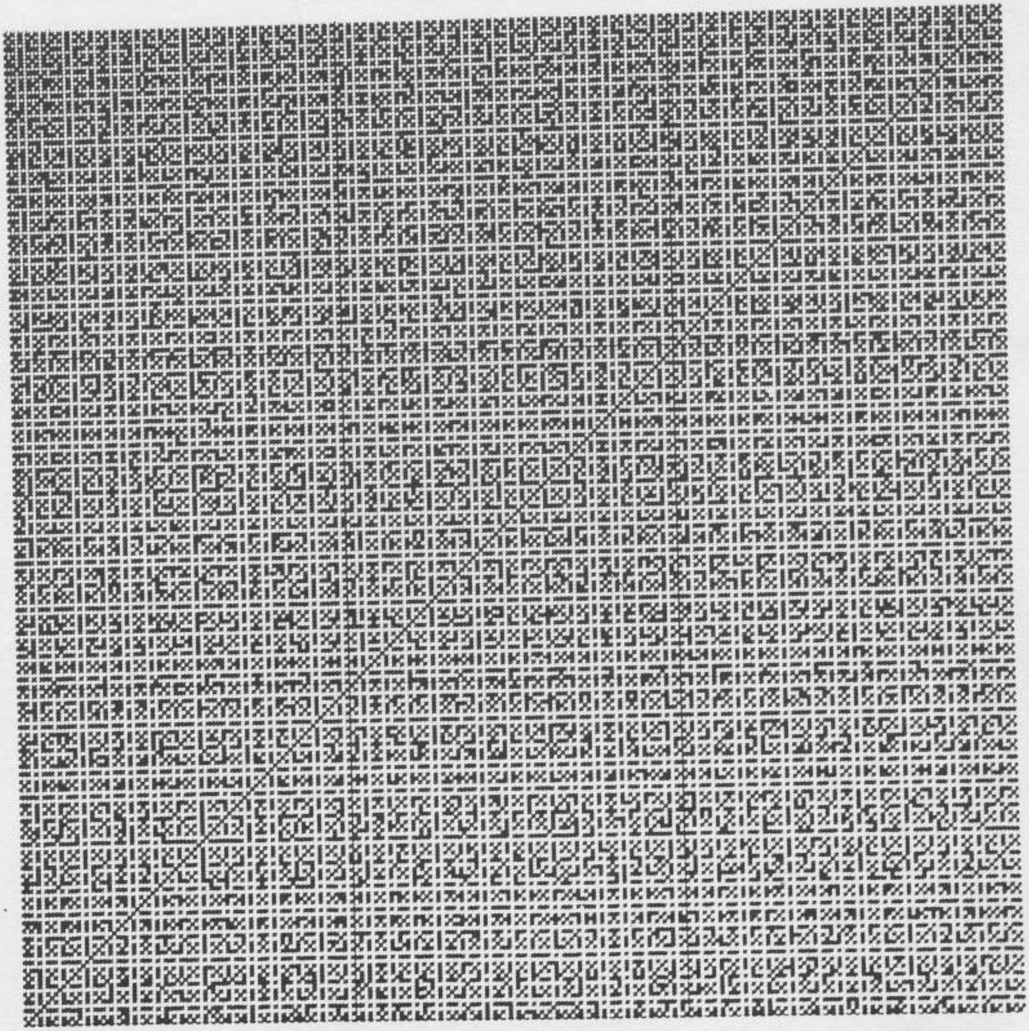
The simulation of computer sculpture also has other implications. As we shall see with attitudes towards computer art currently prevalent in Japan, proposals have been made for an art form that will be projected and manipulated on the cathode ray tube display, but never realized.

M. R. Schroeder, also from the Bell Telephone Laboratories, has used the computer in conjunction with microfilm plotters and has employed special programming techniques to produce half-tone renditions of any given image. Since microfilm plotters in current use make no provision for half-tone images, Schroeder turned to the process originally developed for making spectrograms of speech sounds by controlling the brightness of individual points which appear on the phosphorescent screen. The points appear successively and can be photographed in time-exposure so as to make a complete image in due course. Intermediate grey values, achieved by multiple exposure, result in different optical densities on the microfilm.

22. M. R. Schroeder: ordinary photograph of a girl.

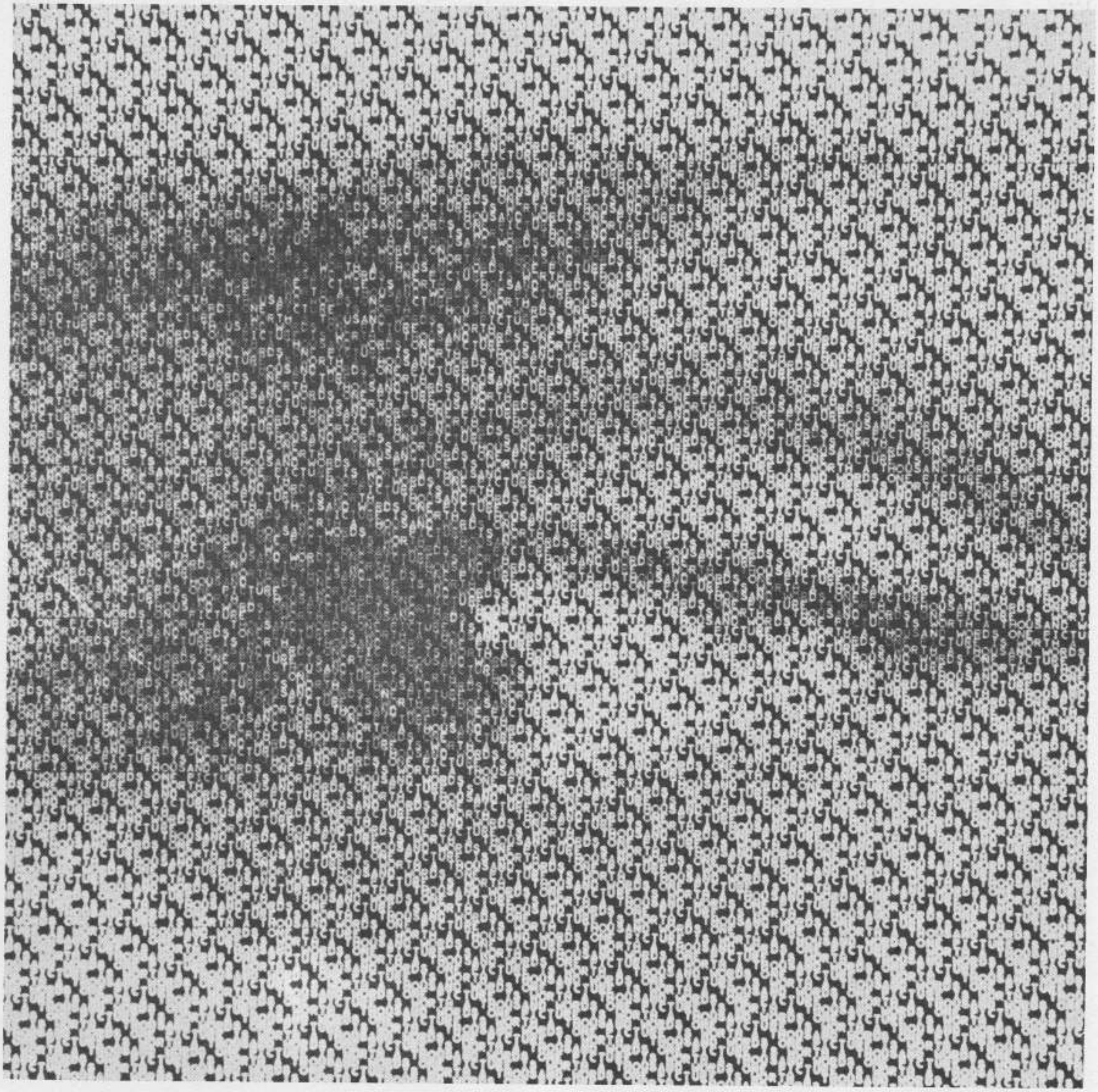
23. M. R. Schroeder: microfilm plotter output obtained from figure 22 by plotting only points whose brightness exceeded a fixed threshold. There are only 'blacks' and 'whites', no intermediate gray tones, reflecting the limitations of existing microfilm plotters which were designed for producing graphs, alphanumeric characters and other high-contrast material.

24. M. R. Schroeder: instead of each point in the image being exposed exactly once (or not at all) as in figure 23, the number of exposures for each point is variable depending on the corresponding brightness value of the original photograph. The resulting contours reflect the discreteness of this 'overwriting' exposure technique.

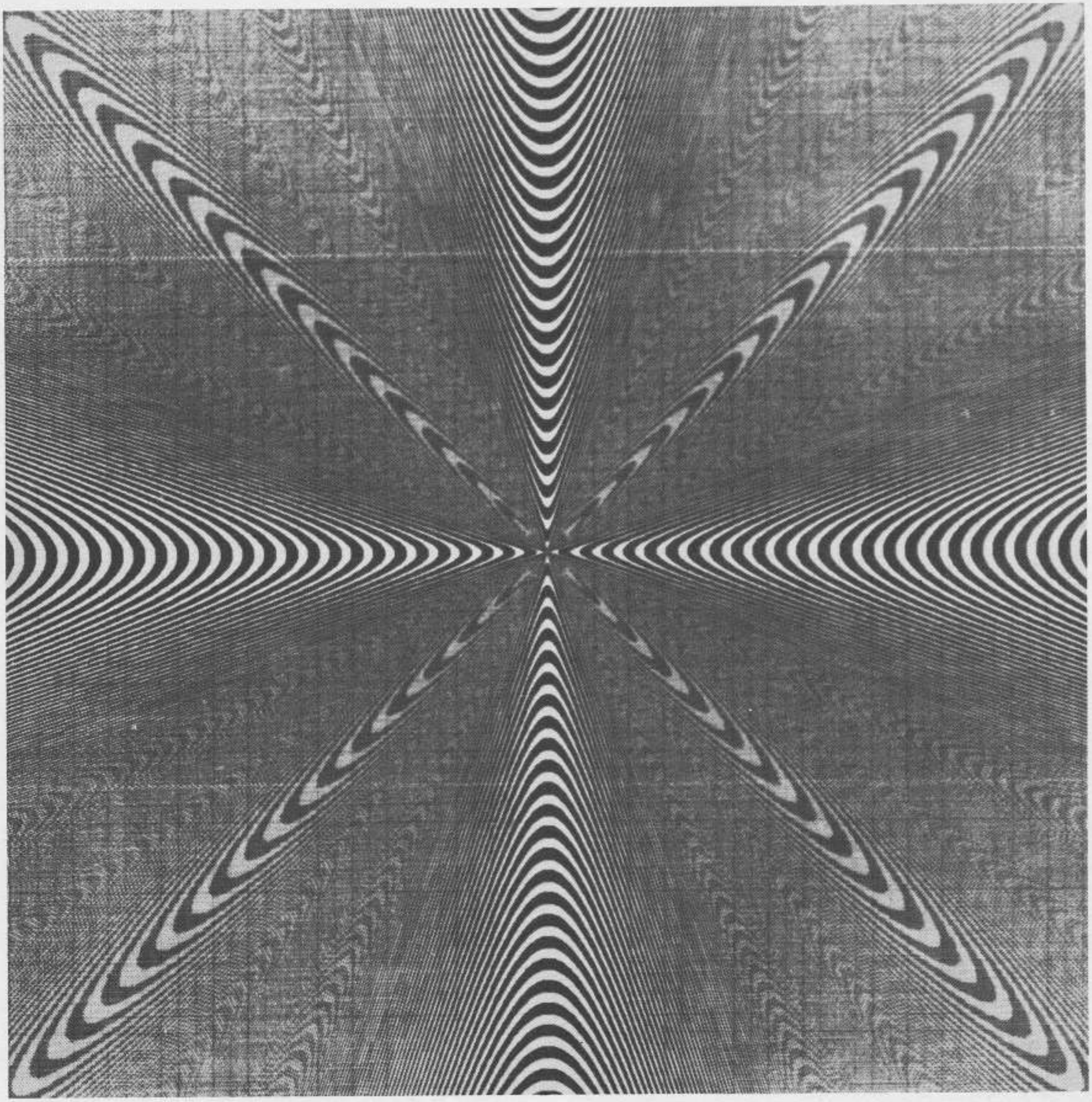


25. M. R. Schroeder: half-tone rendition of the original photograph obtained by the same microfilm plotter used for figure 23. The half-tones are realized by a special program which makes local spatial averages of the brightness values in the replica equal to the brightness values of corresponding points in the original.

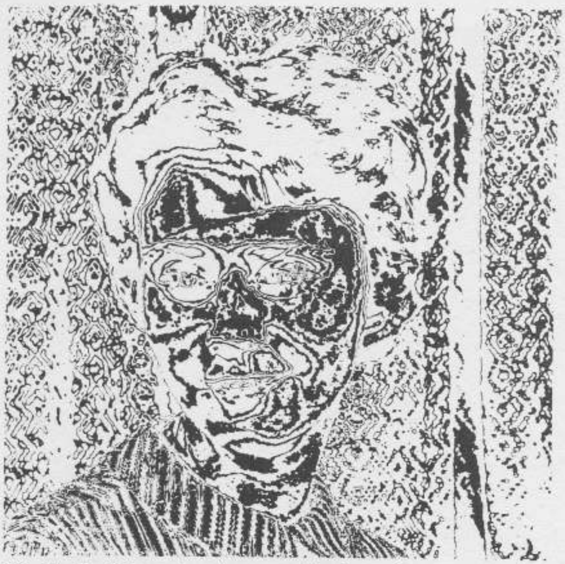
26. M. R. Schroeder: the plane of integers x = 1 to 256 and y = 1 to 256. A point is plotted if its two coordinates x and y are relative primes, that is if they have no common divisor. This is an example of using a digital computer and microfilm plotter to 'view' number-theoric relationships. It shows the intriguing combination of regularity and randomness which characterizes the distribution of prime numbers and the property of joint divisibility. This picture can also be interpreted as consisting of all those points that can be seen from the origin (x = y = o) or that would be coloured if a pellet of paint were exploded at the origin.



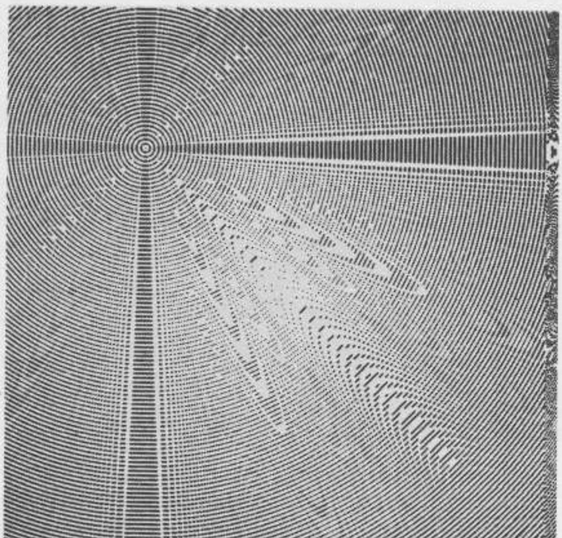
27. M. R. Schroeder: *Wordy Eye*. A human eye (the left eye from the original photograph in figure 22) composed of individual letters and spaces forming the English sentence 'ONE PICTURE IS WORTH A THOUSAND WORDS' repeated over and over again. Each letter was exposed in the microfilm plotter from one to forty times according to the brightness level in the original eye. Four kinds of information or patterns are visible: the individual letters, the words and sentences, the periodic design pattern resulting from the repetition of the sentence and, finally, the eye.



28. M. R. Schroeder: moiré pattern obtained from a program for plotting narrow concentric circles. Because of the discrete point grid of the microfilm plotter, a spatial beat, or moiré pattern, is seen instead.



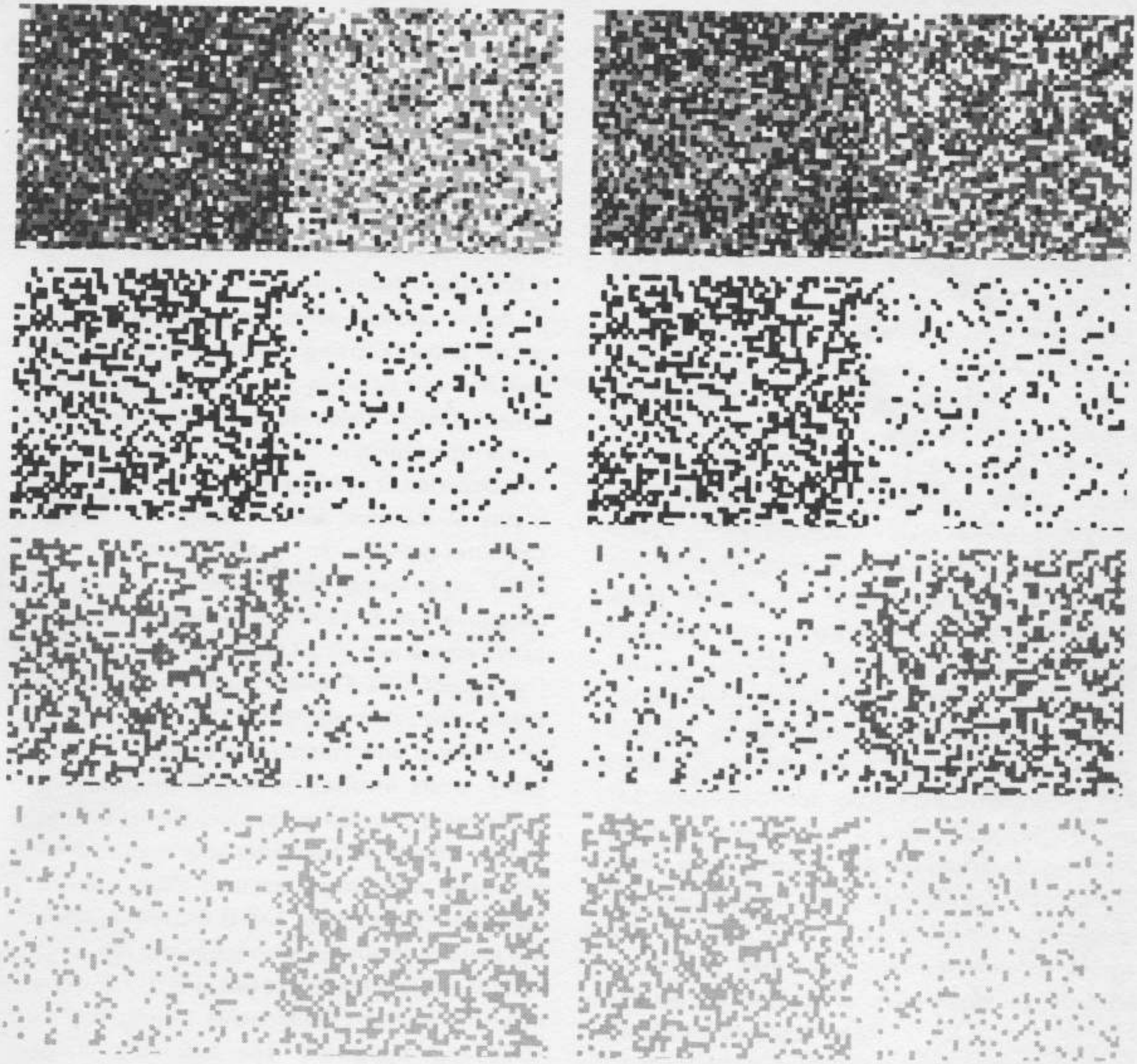
29. M. R. Schroeder: *Leprosy*. Contour lines connecting points of equal brightness in the original photographs. The width of these lines is modulated to reflect the different brightness levels. Two kinds of information are combined: connectivity and black-white area ratio. An example of the bizarre images obtainable on microfilm plotters.



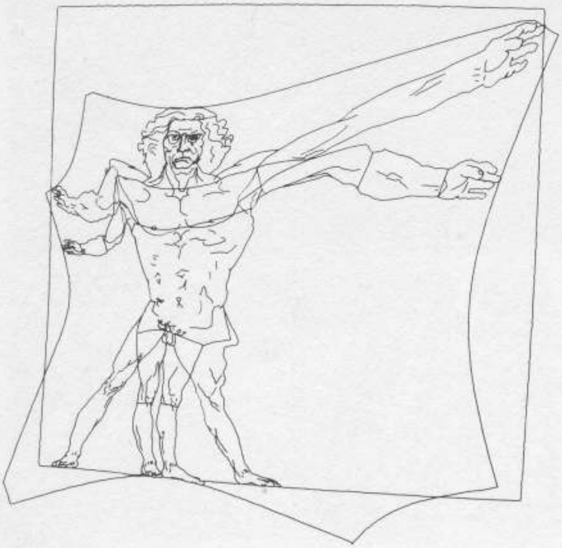
30. M. R. Schroeder: one of the many patterns which are the result of programming errors and which are often as visually attractive as those made strictly on purpose.

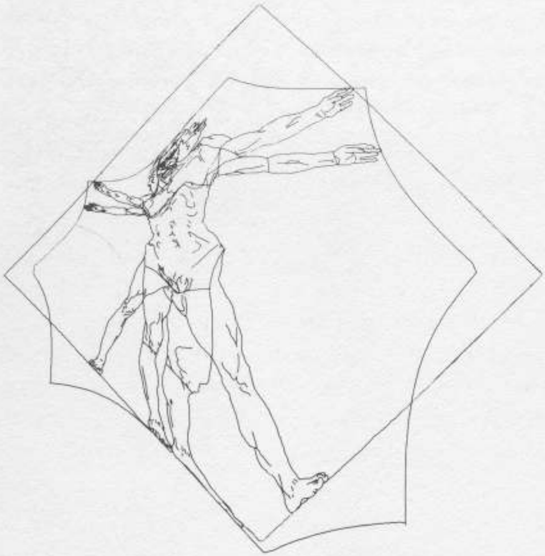
The sequence which demonstrates the half-tone process used by Schroeder starts with an original photograph of a girl. The brightness values in this portrait were sampled at 1024 × 1024 points, quantized to 4096 discrete levels and fed into a digital computer. The sampled and quantized picture information was recorded on digital magnetic tape and fed into the computer. The computer was programmed to expose a point in the grid of the microfilm plotter if the corresponding optical transmittance in the original exceeded a fixed threshold. The variously transformed brightness data were reconverted into photographic images by means of a microfilm plotter under computer control. The resulting picture consists of areas of black and white without any intermediate grey values.

Activities in the field of computer graphics at Bell Telephone Laboratories also include Bela Julesz's experiments with texture and visual perception, in which he used the techniques employed in the random generation of patterns. Random-dot patterns generated by computers have shown that the recognition of familiar shapes is not needed for the discrimination of textures, or even for the binocular perception of depth. Julesz used random fields of coloured dots. He discovered that texture discrimination is highly dependent on the way the component colours are paired, with, for instance, red and yellow giving a higher degree of discrimination than blue and yellow or blue and green. The objective was to determine those pattern properties that make it impossible to distinguish immediately two adjacent displays. He found that it is the



31. Bela Julesz: an experiment with texture and visual perception. Where the randomly distributed dots form clusters of the same brightness levels, the areas are much easier to discriminate, particularly if they are dark or black. When the dark colours are reversed the patterns are more difficult to discriminate. The randomly distributed dots were computer generated.





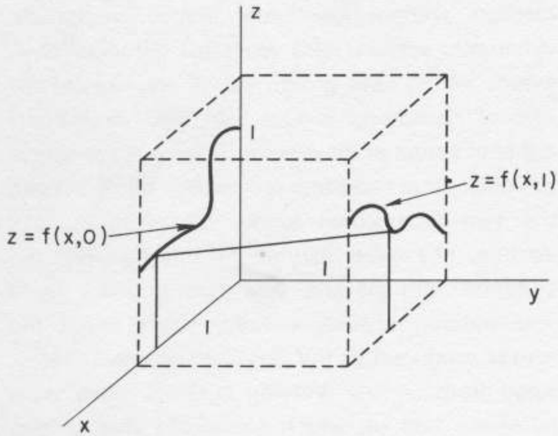
32 and 33. Charles Csuri: circle to square transformations, based on Leonardo's *Vitruvius Man*. If the original image were on a circular rubber sheet which was then stretched into a square, the image would be similar. These images were produced using this transformation and rotating the pre-image through increments of 45 degrees.

statistical properties of patterns that allow for spontaneous discrimination. This is independent of brightness distribution but relies on the isolation of darker clusters which could be said to form certain patterns. Using stereo pairs, Julesz found that one can perceive camouflaged objects with binocular vision which are invisible in a two-dimensional representation.

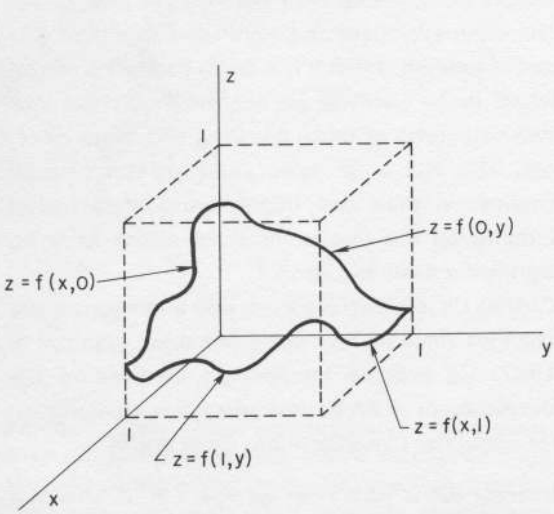
The Department of Art at the Ohio State University is one of the most active centres in the field of computer graphics, computer-animated films and allied experiments. The university celebrated its centennial year in 1970 with an exhibition of interactive sound and visual systems. The man behind the project was Charles Csuri, one of the few artists to be extremely active in the field of computer graphics and computer animation. Unlike so many artists involved in the development of a relationship between art and technology who have to rely entirely on help from engineers and technicians in order to realize their ideas, Csuri is a competent programmer and is capable of designing systems to suit his own purposes. His centennial project was the first of this kind in a university, involving fourteen departments contributing their skills and equipment. The exhibition involved decision-making on the part of the audience in the form of evaluation and participation. Csuri has gone beyond that area of computer graphics which is limited to transformations from one image to another, or indeed transformations of a single image according to a set of predetermined principles. As we shall see later, it is no longer possible to talk about computer-generated graphics as an art medium without mentioning environmental art, cybernetic systems and spectator participation – events which have grown out of and around the idea of converting images into their equivalents either in sound or movement. Typical of the sort of possibility that computer technology offers beyond the two-dimensional works on paper, Csuri's venture, like other exhibitions dealing with the computer and the arts, was open-ended – there was nothing absolutely finite either about the results produced or the possibilities encountered. Apart from on-line drawing controls, there were television sets on which one could alter colour, movement and shape, screen projection of pictures controlled by signals from the spectator's body, as well as an electronic sound laboratory where visitors could make their own sound sequences. The other important and significant aspect of this sort of venture is that it is a do-it-yourself platform where those involved are not strictly divided into two categories of those admiring and those admired. This has a far more important sociological implication than one might immediately realize judging by the results, most of which have no significant aesthetic value.

Charles Csuri's own work has also undergone some changes since he first made computer graphics in 1967. He became increasingly involved in the development of a real-time interactive environment for computer film animation. Csuri writes:

Basically this is what I can do now, I sit in front of a cathode ray tube display and draw images upon the screen with a light pen. The drawing routine has been designed with an artist in mind rather than an engineer. These

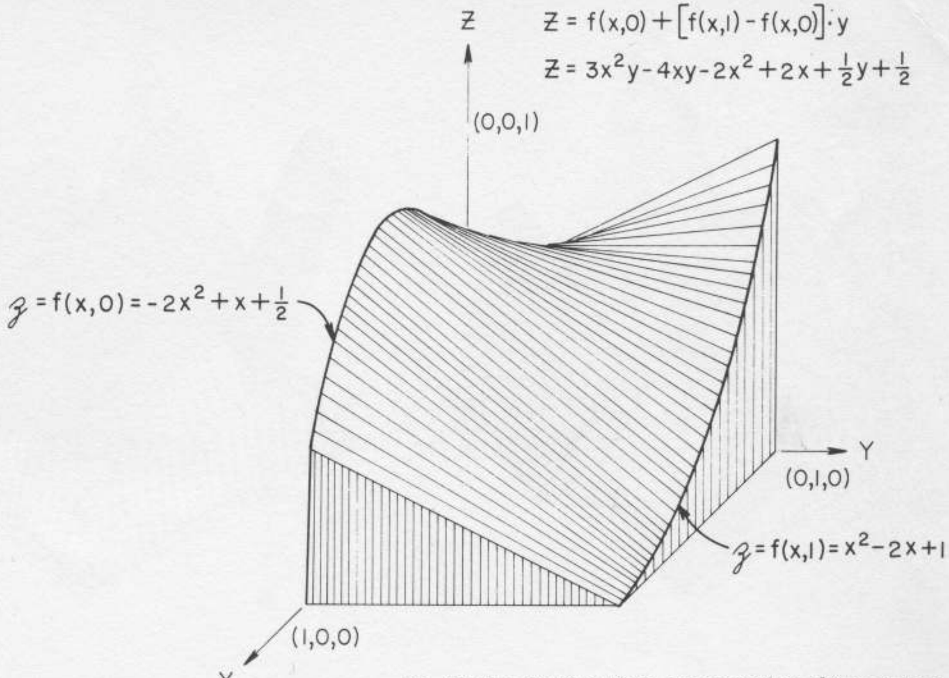


34. Charles Csuri: the unit cube, with curves on two opposite faces. Drawn by hand.



35. Charles Csuri: the unit cube, with curves on each of the four faces. Drawn by hand.

cathode ray tube drawings can be background images and abstract structures as well as representational images. A computer program stores the data which represents drawings on a disc, and I can, through program control, read them into animation programs also stored on the disc. With the light pen I draw the path I wish a drawing to follow, in fact I can draw several paths for several drawings on the same screen. Then I type in the parameters which control speed, rotation and transformation changes (permutations) of each drawing on the screen. The computer reacts so quickly that once I depress the last key of my message, the images move like a motion picture display on a television set. All the calculations representing the hundreds of individual frames for moving pictures are done so rapidly that it appears like a film. If I don't like the result I can change it within a few seconds and see the new result again to judge time, speed, shape and position. For a zoom effect I draw the path which can be any path and press a function key to witness the effect. I can try out several dozen combinations within one hour. Through a switch on the control panel of the computer I can have the images generated for a stop action filming. We have built some electronic circuitry to automatically control the camera. The computer keeps track of my frame count which is very useful if I want to back up the film on the motion picture camera and overlay one moving image upon another one. It also calculates the number of frames required, say 2 per second, 10 per second, 31 per second, and so forth for smooth real-time motion. Recently we also developed a three-dimensional computer animation program for rotation, projection and translation. I can take a three-dimensional drawing (x, y, z, coordinates) and move it along a path in three dimensions and change its shape and size as it is in motion. From my point of view a program to control three-dimensional moving images (a real-time environment) is a significant one. This program represents quite an achievement for the project. In another program I can animate any part of a drawing independent of the other parts. For example, if I use a line drawing representing a face, I can move an eye, eyebrow, nose, ear, mouth, and so forth in real-time. There are



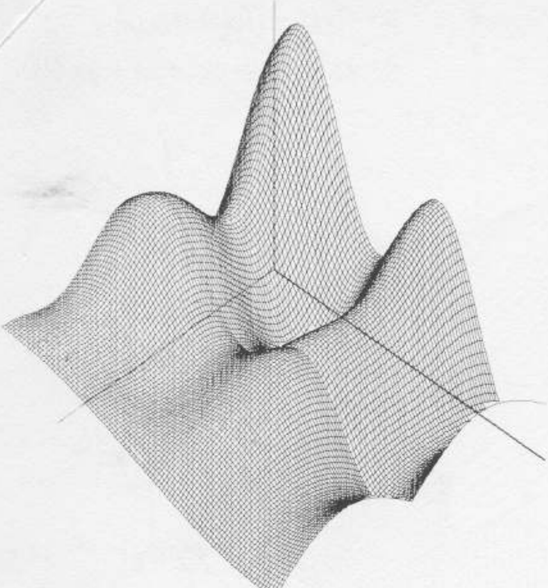
36. Charles Csuri: surface representation of two curves. Drawn by hand.

several other things we can do in computer animation but it would take considerable detail to explain them.
My computer-animated film *Hummingbird* cost about $12,000 in computer time to make and that was in 1967. By comparison that is, assuming 10 minutes of animation, I am now making more complex films in a spontaneous manner in living colour for $120, and that includes costs of computer time, film and film processing.

More recently Csuri has turned to computer sculpture, of which by the end of 1969 there were only a few examples. Csuri describes a technique for creating a computer sculpture:

This approach to computer sculpture involves two basic procedures. One procedure is mathematical and involves a computer technique to generate x, y, z, coordinates which represent a three-dimensional form. The second requires a comprehensive set of computer programs which analyse the form for a continuous path, 3 axis milling machine.

Procedure 1
A unit cube was used in the mathematical technique to develop a three-dimensional surface (fig. 34), which with values between 0 and 1 has certain computational advantages and is a convenient module that permits the development of complicated forms. A modular concept permits the juxtaposition of many unit cubes to achieve a desired aesthetic result. The artist has the option to define the boundary curves on each of the four faces of the unit cube. Once the boundary curves are established they are approximated by equations. These equations generate 100 points along each boundary curve, and the computer program takes an average from all four sides of the cube. An alternative approach is to define the boundary curves on graph paper and then 'read in' their coordinates into the computer program. In figure 36, the two opposite faces with boundary curves, the simple case of how a surface can be defined is demonstrated. As one views figure 35 it is difficult to visualize the interior of the unit cube based on the four boundary curves indicated in the illustration.



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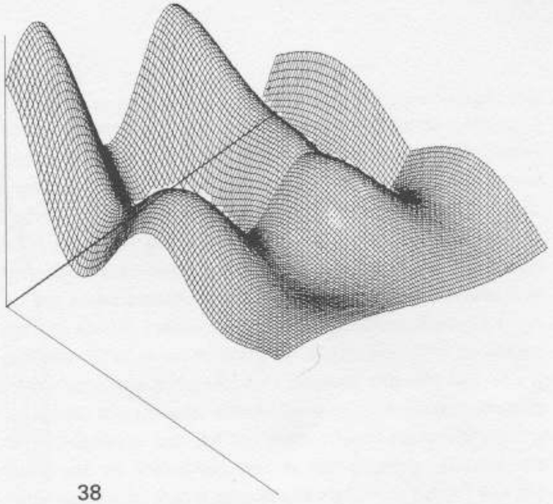

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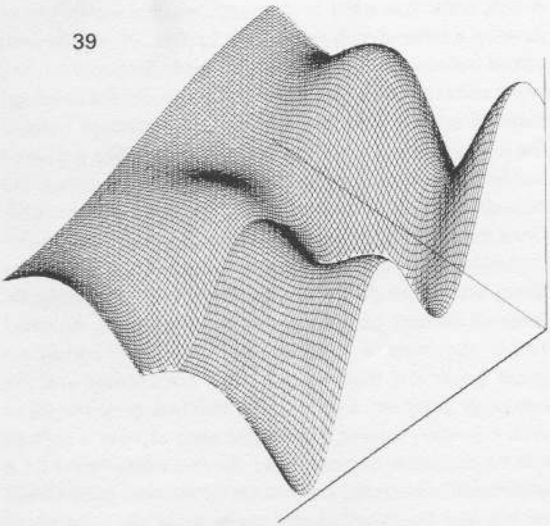
37, 38, 39 and 40. Charles Csuri: computer drawings of a surface which was based on four boundary curves. Four different views of the same surface are represented.

39



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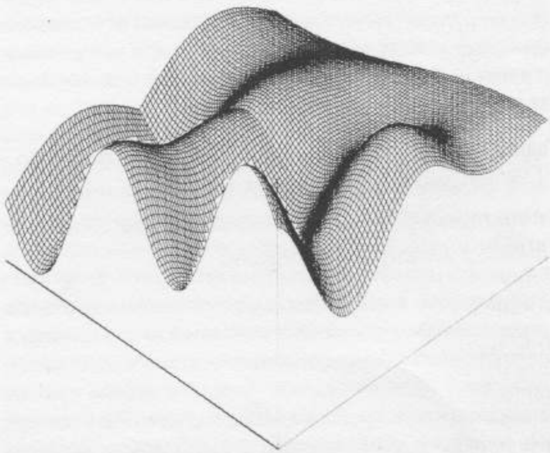
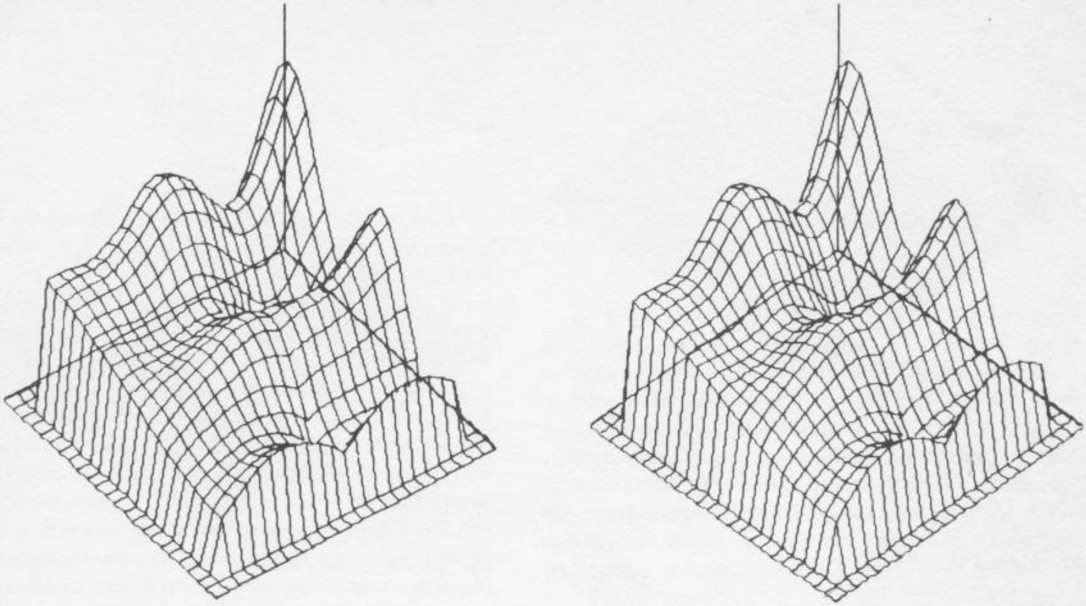
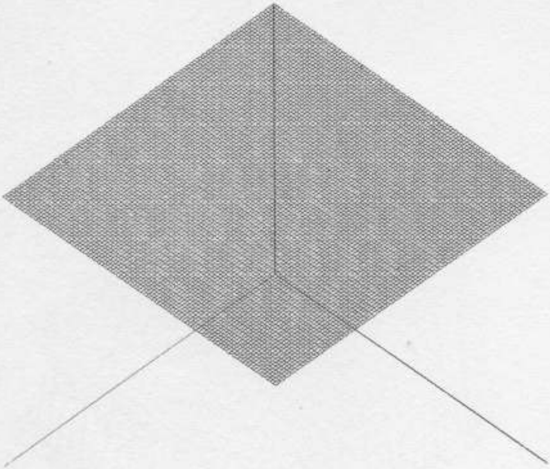
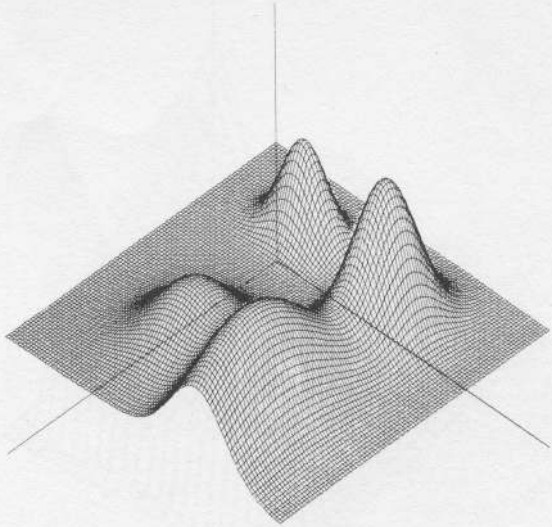




41. Charles Csuri: stereo pairs.

In those instances where lines from opposite curves intersect in the x-y plane but do not meet in the z plane, a mathematical technique was used averaging out the two zs to establish the three-dimensional coordinates of the surface, at the same time preserving the artist's original boundary curves.
In the next step a computer program takes the coordinates, which represent the surface, and makes the necessary calculations for computer drawings. It is a three-dimensional perspective routine that eliminates hidden lines from a specified viewing angle. The artist can indicate his viewing angle and the computer program with a graphic plotter will give him a representation of the form. Figures 37 to 40 are an example in which a viewing angle of 45° was specified and the form was rotated in four steps through 360°. The hidden line routine also permits the representation of stereo pairs based on the data set, so that the artist can have some feeling for the three-dimensional experience (fig. 41).



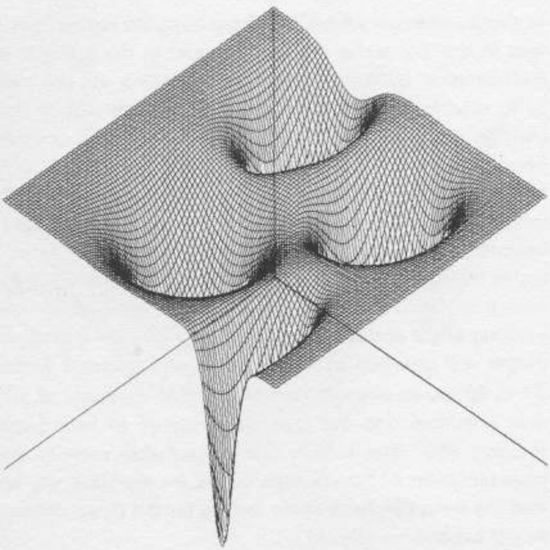


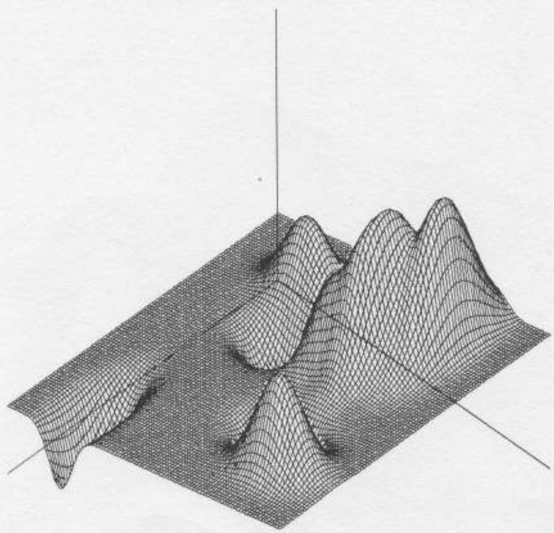
42. Charles Csuri: x – y plane.

43. Charles Csuri: *Peaks*.

44. Charles Csuri: *Valleys*.

45. Charles Csuri: combination of *Peaks* and *Valleys*.





There are other interesting options available to the artist which permit further experimentation. At an operational level, peaks and valleys can be used to manipulate the surface which was developed through the technique of the unit cube. Figure 42 shows an x-y plane, while figure 43 is a representation of several peaks which have been added to the x-y plane. The artist needs only to specify an x, y, z, coordinate (a location on the plane plus a height or depth) for each peak and a computer program handles the problem. There are options in the program to specify the angle of the slope of a peak with variation on each side of the peak. It is also possible to establish a relationship between each of the peaks to give smooth continuity. Valleys or depressions can be made in the same way as peaks, as shown in figure 44. Figure 45 illustrates a combination of peaks and valleys.

Procedure 2

Once the artist has decided that the graphic representations are acceptable for sculpture, then the x, y, z, coordinates which represent the object are given to the computer milling programs. There are 24 subroutines which had to be developed for this phase of the problem. Numerically controlled milling for artistic purposes is an exceedingly difficult task. When the z axis, or the third dimension, is introduced, the software requirement to have an operating system on an IBM 360 is tremendous. It is beyond the scope of this report to indicate many important technical details. The following basic programs were used but many sub-programs are not indicated.

1\. A. SURFACE CONVERSION PROGRAM. Program which changes the original x, y, z, coordinates into a surface description in terms of triangles. Any surface which can be developed can be approximated with small, but finite triangles. Another reason for using triangles is that three points always determine a plane. In this case many results from geometry and linear algebra have attractive forms for computation.

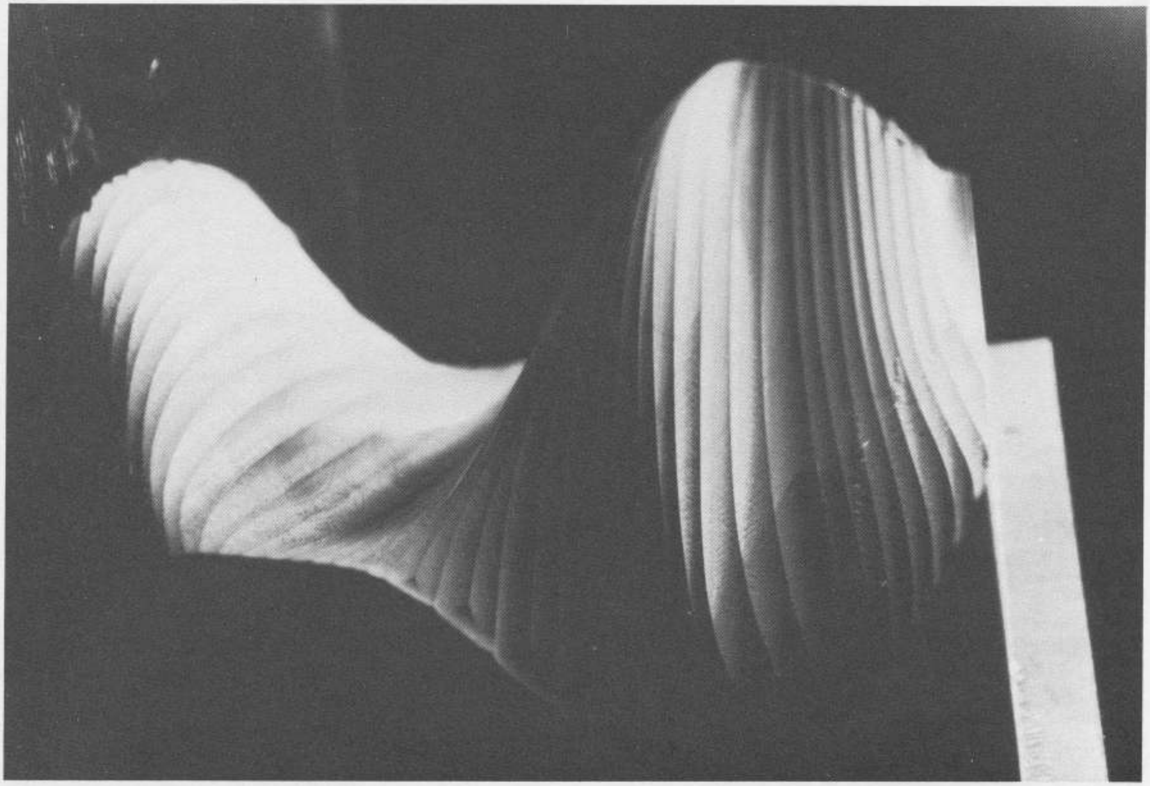
B. MILL PATH DESCRIPTION SUBROUTINE

a. Decision about the mill path, such as contour, spiral, rectangular pattern, or another mathematical function.
b. Subroutine also includes the domain or boundary check and 'quill up' and 'quill down'.
c. Once a position on the surface is specified an efficient guide is provided as to the next position of the tool, and the direction it should move next. The direction is first specified on the plane by the subroutine which calculates the x and y components.

2\. SURFACE DESCRIPTION CHECK. The main program checks the triangles on the surface to calculate a z component. It then checks the surface description and decides whether or not the move can be made by the cutting tool and how far it can move. An accounting of the angle of the tool in relationship to the slope of the surface is one critical task of the milling routine.
a. It might be of interest to mention that data for the surface is stored on disc and it is the direct-access feature of the disc that permits rapid location of data to be manipulated by the program. That is, there is no need for lengthy tape searches.
b. There are also controlling parameters for the tool size and the depth of cut on any given pass.

3\. PAPER TAPE ROUTINE. This routine takes the data from cards and punches a paper tape on the 1130 computer. The tape has the commands with the format for the 3 axis milling machine.

4\. SURFACE RECOVERY PROGRAM. Coordinates are read from the paper tape and returned to the 'hidden line' routine for another drawing. This drawing is compared to the original drawing before a commitment is made to the final step.

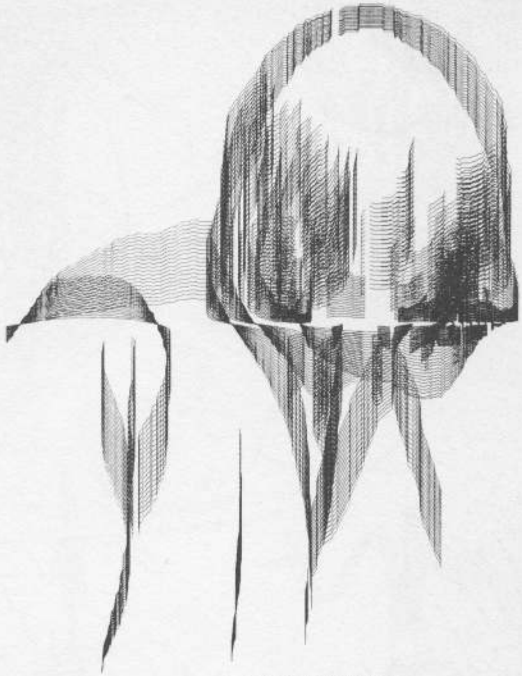


46. Charles Csuri: prototype model for a sculpture.

5. PARABOLIC INTERPOLATION. The control unit for the milling machine has parabolic interpolation in 3 space as a hardware feature.

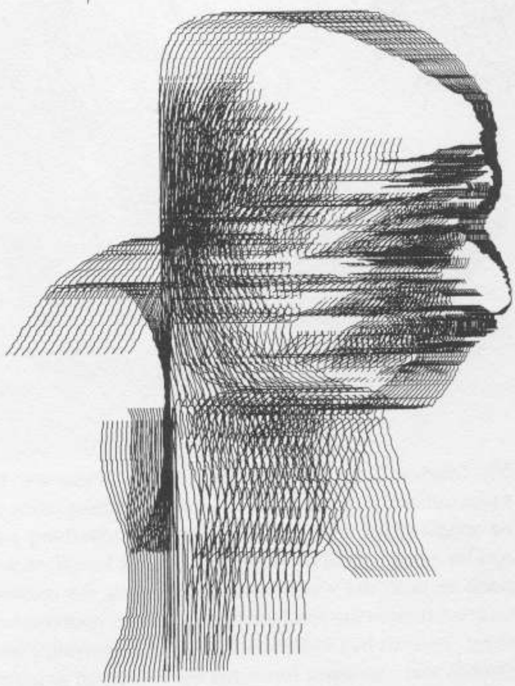
Computer time for this system on the IBM 360 computer model 75 can involve five minutes to one hour of computation time. After the paper tape has been checked by the Surface Recovery Program and there are no errors, then the milling machine completes the problem. The electronics of the milling machine are controlled by the paper tape with its set of instructions and coordinates. Figure 46 is an example or prototype of sculpture which was done on a continuous path, 3 axis milling machine. This model was done in wood but there are options of plastic and metal.[1]

[1] Computer sculpture is a cooperative effort between mathematicians, programmers, engineers, and an artist. Charles Csuri was helped by Samuel Cardman responsible for the mathematical analysis and the computer program logic for the milling routines; by Dr Leslie Miller who developed the ingenious mathematical technique with the unit cube and solved the mathematical requirement for peaks and valleys; by Gerald Shifrin who did the computer programming for the graphics and several important programs for the milling problem; and by James Shaffer who helped to coordinate the many complicated parts of the project.

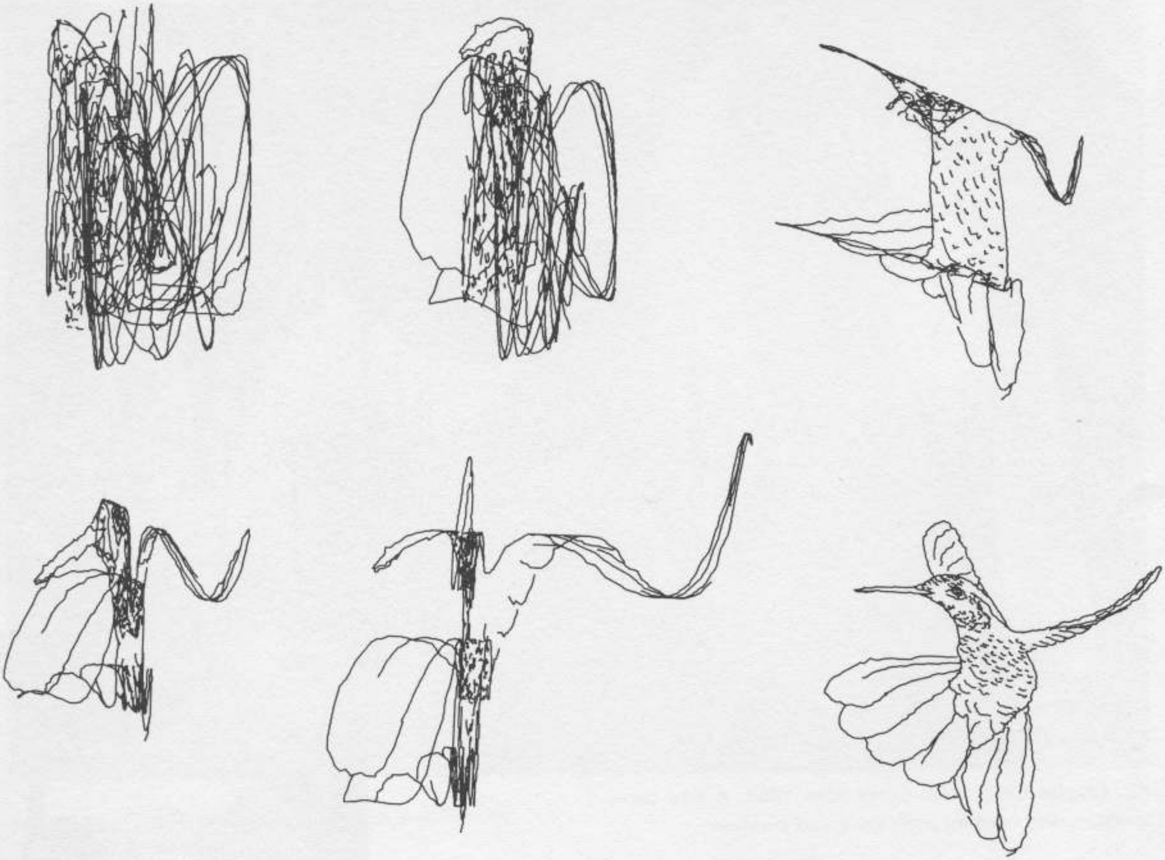


47. Charles Csuri: data deck of the old man used for figures 48 and 49. This is a digitized drawing made with a graphic plotter.

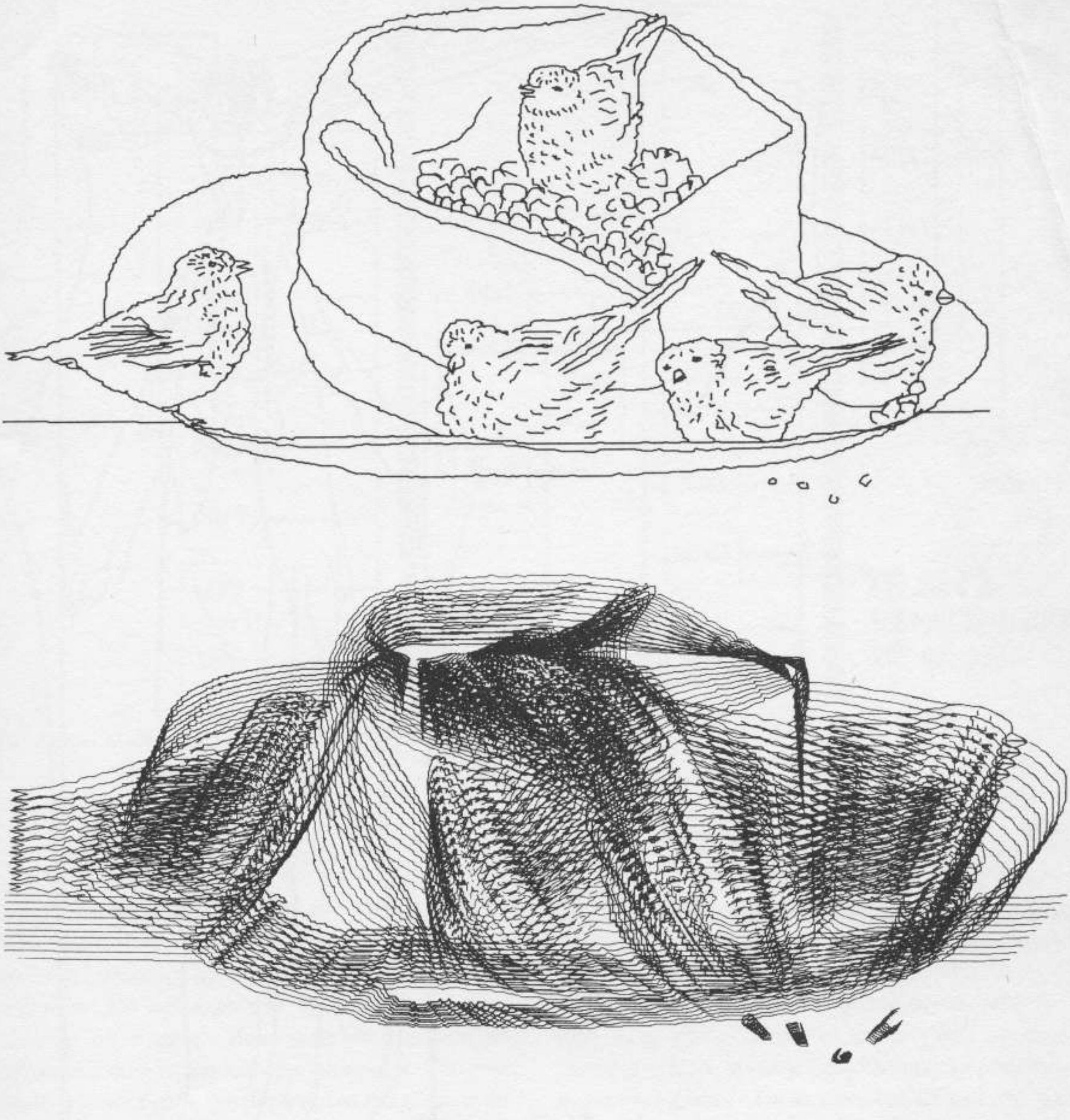
48. Charles Csuri: *Sine Curve Man* 1968. A sine curve function was used on both the x and y values.



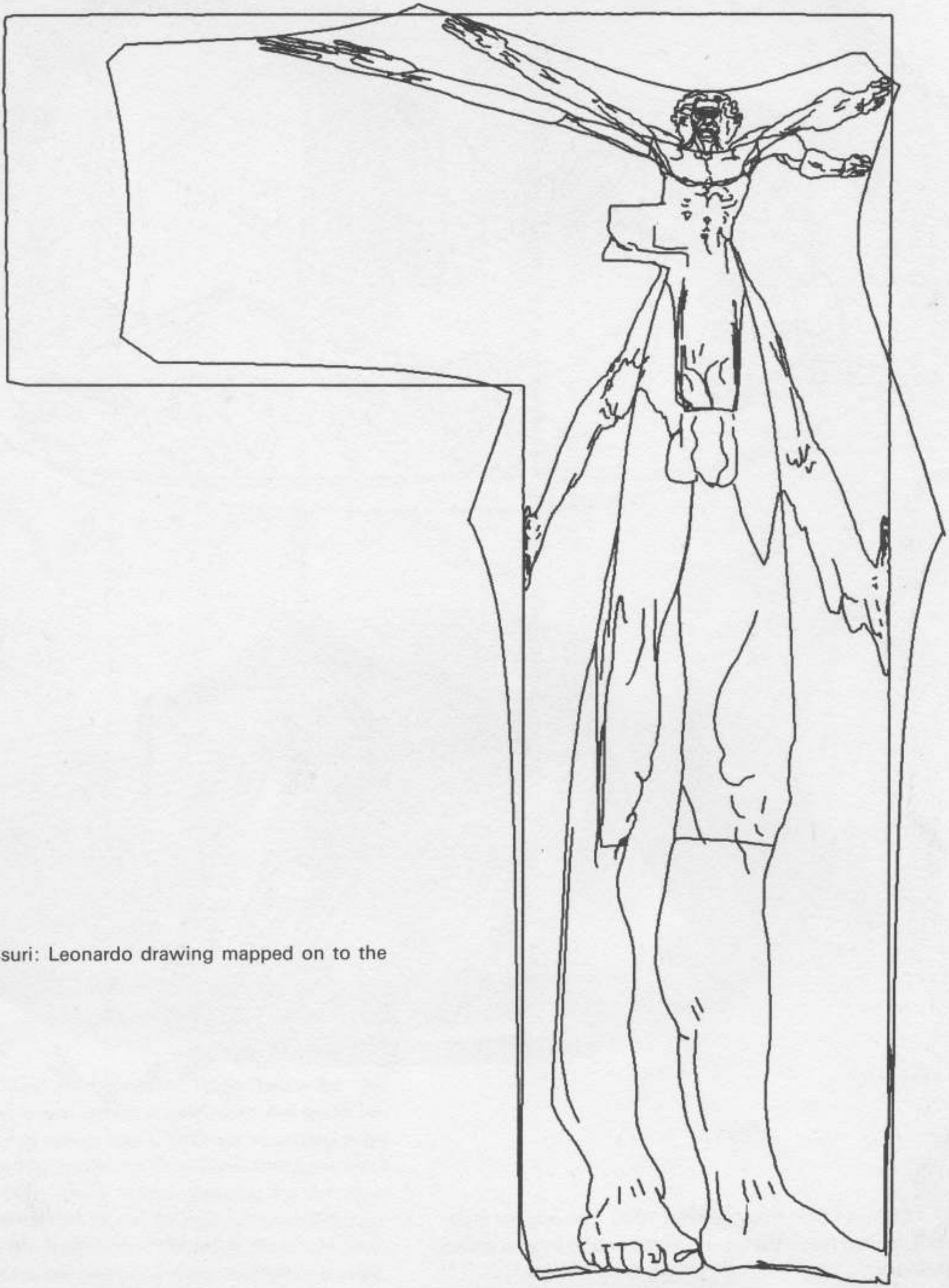
49. Charles Csuri: *Sine Curve Man* 1969, a version of figure 48.



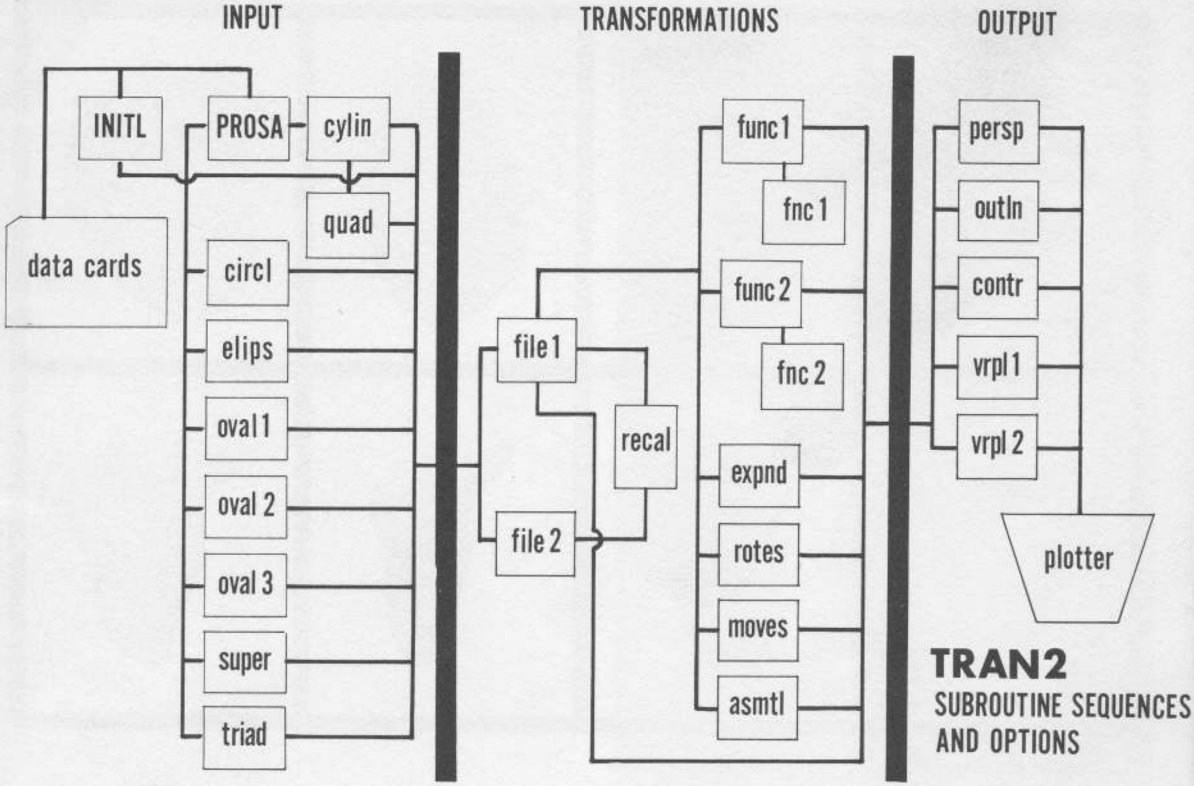
50. Charles Csuri: *Hummingbird* 1968. There are two basic options in this program: a new vanishing point can be specified for drawing, and a different vanishing point can be indicated for each line. Sine curve functions were used on both the x and y values. Reading the drawings from left to right the first represents the maximum displacement. Then in five incremental steps the drawing's perspective and sine wave functions were returned to normal.



51. Charles Csuri: *Birds in a Hat* 1969. The original digitized drawing (top); the transformation made by sine waves (below).

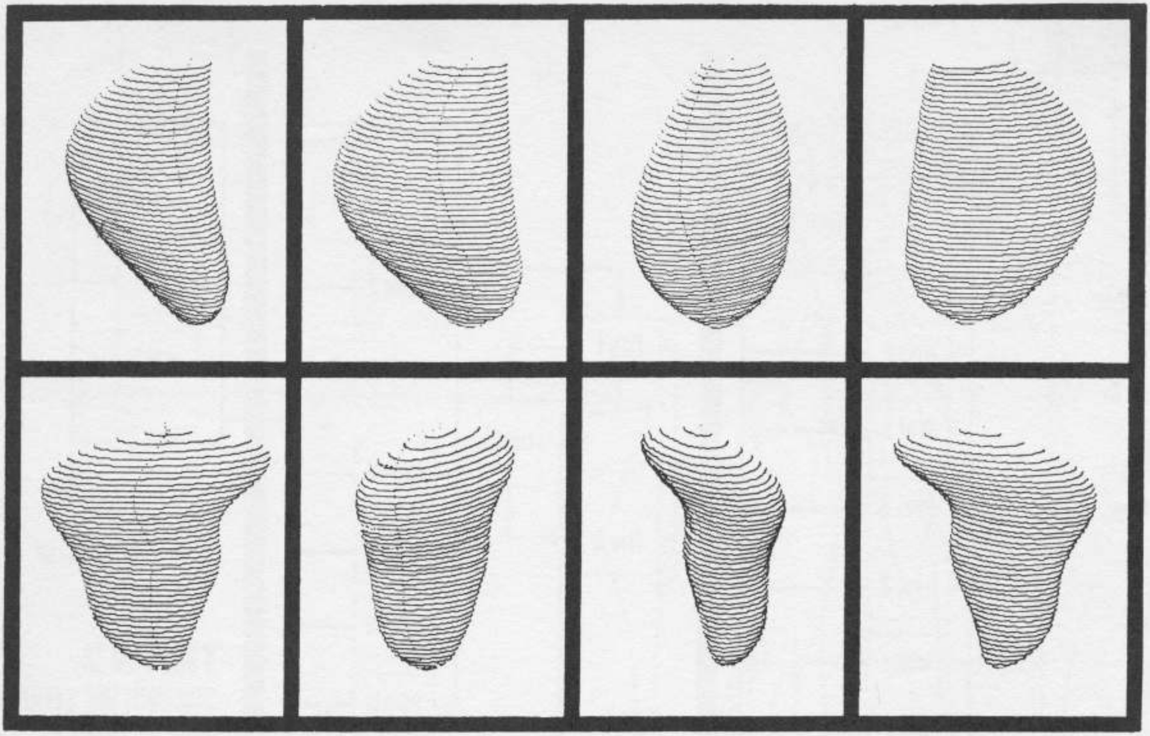


52. Charles Csuri: Leonardo drawing mapped on to the letter L, 1968.

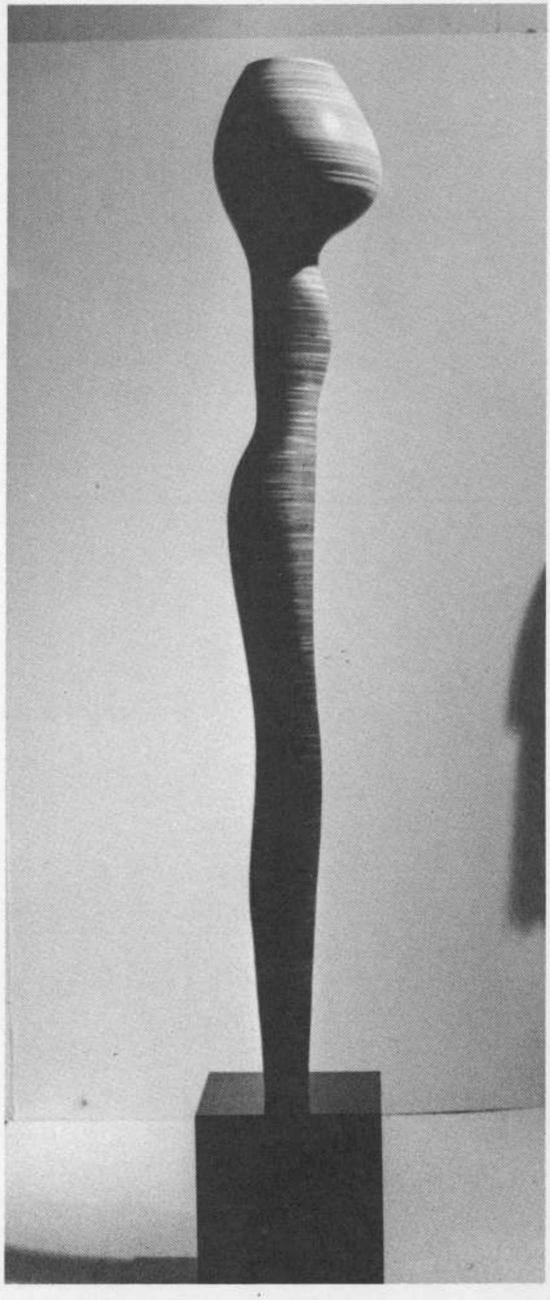


53. Robert Mallary: TRAN 2 schematic block diagram.

Robert Mallary, Professor of the Department of Art at the University of Massachusetts developed a computer graphics program, TRAN 2, to generate sculpture. He achieves this by making transformations on a given three-dimensional form of which the data is fed into the computer. The end result is arrived at by breaking down the given solid form into a regular series of parallel cross sections, or contour slices. The information of these contour slices is eventually transferred to computer punch cards. The slices undergo a series of mathematical transformations which reshape the contours into a new range of forms resulting finally in a completely new overall outline. The plotter reproduces a series of perspective views of the overall form, as well as a complete set of transformed contour sections which Mallary calls 'computer transformation templates'. These are used as patterns for making the sculpture in some appropriate material such as laminated wood or plastic. So far the only sculptures produced with this program have been based on a central axis.



54. Robert Mallary: TRAN 2 computer drawings for sculpture.



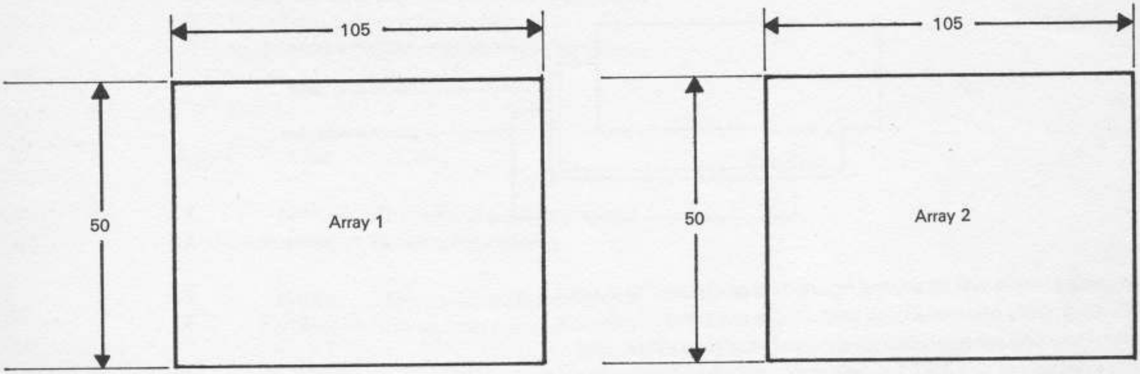
55. Robert Mallary: *Quad III* 1968. TRAN 2 computer sculpture in laminated veneer.

Computers in art education

Both Csuri and Mallary have been involved in using the computer in the course of teaching as well as in their own work. The students learn to use the available computer programs in graphics, animation, as well as various other projects which are later realized with the aid of conventional art techniques and materials.

Among those using the computer in teaching art is Katherine Nash, Professor of Art at the University of New Mexico. She believes that the computer will inevitably become an artist's tool in the future and with this in mind she has been using a computer language ART 1 devised by Professor Richard Williams at the University, to teach students to make simple computer graphics. Referred to as the Williams Computer Art Language, it is notable for its simplicity and is intended primarily as an introduction to the use of computers for those without any technological background. With a few guide lines the student uses a key-punch machine to punch holes in cards. To make a computer graphic, once the ART 1 program is stored in the computer, all one needs to do is to type a few Data Cards specifying what lines and shapes are to be used, where on the page they are to be placed and the dimensions. By using more than one array the artist can overprint one shape on another in a great number of combinations and permutations. In order to explain how ART 1 program works, the students are given the following notes:

ART 1, briefly, is a computer program that permits a person to assemble designs in each of two arrays. Each array is 105 columns by 50 rows. The designs as finally assembled in the arrays are printed one over the other using the computer's off-line printer.



In general a program is made of three parts:

1. The program itself.
2. Data to which a program may refer.
3. Program management cards; they begin with a slash (/).

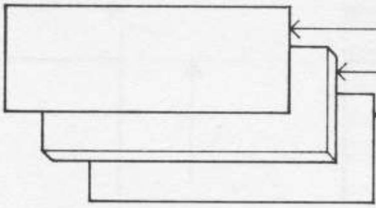
```
/IDbbbbbbbbRAXbS.S.NUMBR,AR701bbbbbbbbbb'NAME
/JOB TIME=02,GO
/FTC NAME=ART 1
            Program
/DATA
            Data
/END
```

ART 1 program stored in the computer

```
/ID ...
/INCLUDE ART 1
            Data
/END
```

The data cards for ART 1

There are three types of data cards used with ART 1:



In general there will be several figure data cards used to make a drawing. Only one initializing data card is used and it is always first. Only one sentinal data card is used. It is always last, and it is used to 'tell' the ART 1 program that all other data cards have been read and that the computer drawing is to be printed.

The sentinal data card

columns

1–2	01 should be entered in columns 1 and 2.
3–80	All remaining columns should be left blank.

The figure data cards

The figure data cards will be described in detail on the following pages. In brief, however, each figure data card begins with a number to specify what type of figure is desired:

02 Line
03 Solid rectangle
04 Open rectangle
05 Triangle
06 Ellipse
07 Quadrants
08 Exponential

The initializing data card

The initializing data card is used to:

1. Set up the arrays in some desired initial state.
2. Print a title below the drawing.
3. Specify the number of drawings to be printed.

columns	type	purpose	example
1	symbol	The symbol goes into array 1	L
2	number, n	in every nth column	2
3	symbol	The symbol goes into array 2	/
4	number, m	in every mth column	5
5	number	The number of drawings to be printed, 1 to 6	1
6–10		Not used	
11–70	symbols	Reproduced exactly below the drawing as a title, etc.	(Make any 60 symbols)
71–80		Not used	

Notes a) If the columns 2, 4, or 5 are left blank then the ART 1 program will change the numbers to one (1). If the number in column 5 is greater than 6 the ART 1 program will change the number to 6.

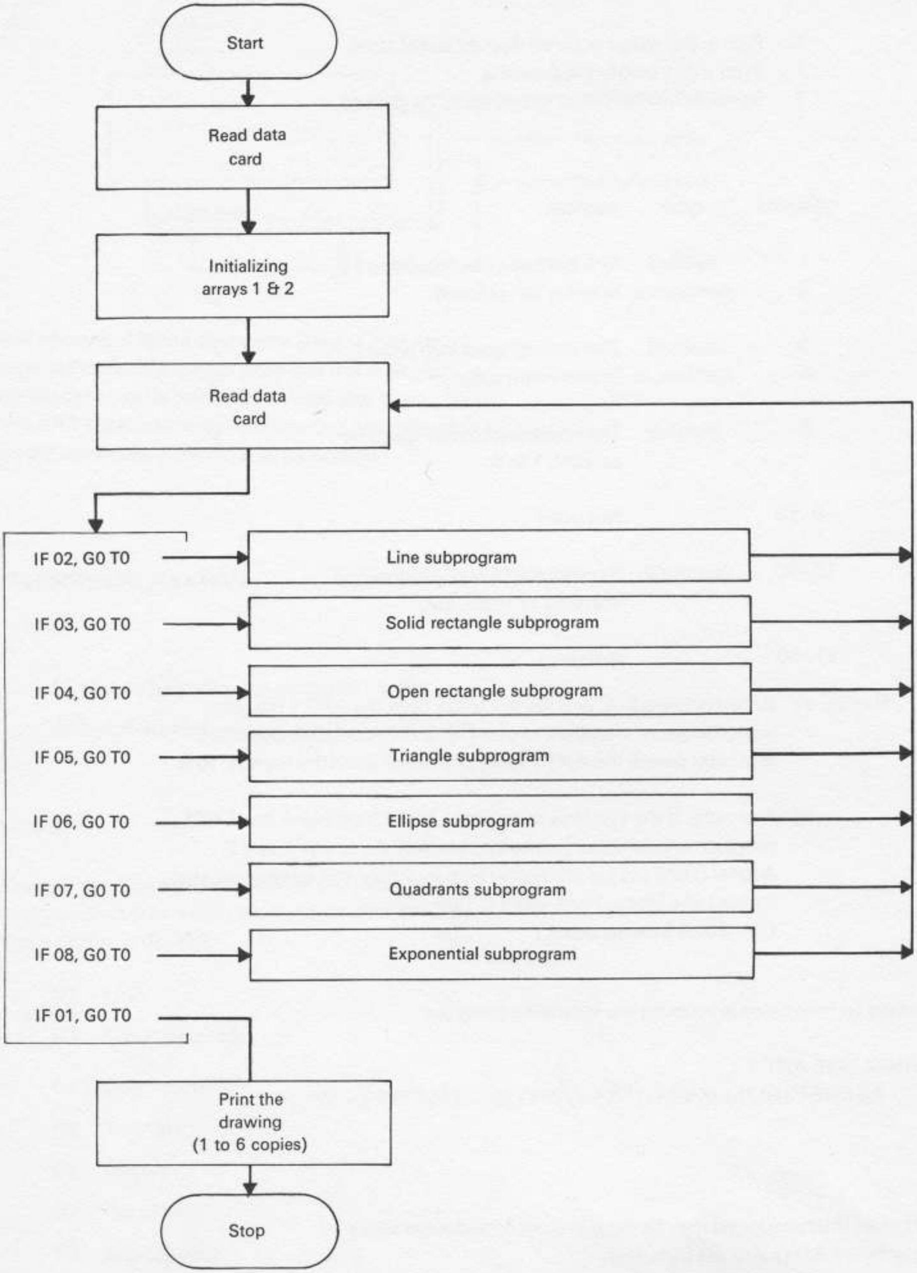
b) Normally, if the symbols in columns 1 and 3 are blank the ART 1 program would erase (make into blanks) the arrays 1 and 2. A local UNM printer difficulty requires a non-printable character instead of a blank. Here, use a (") for a blank. ("= 7 and 8 overprinted.)

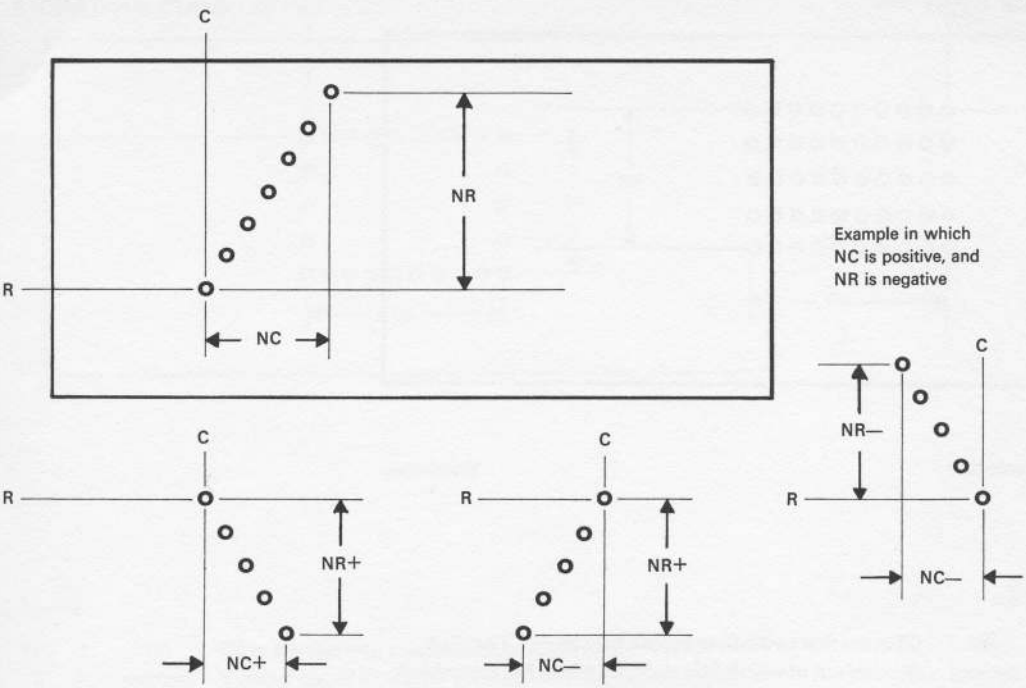
The user may be interested in running the following program:

```
/ID ... /INCLUDE ART 1
.2"16      ABCDEFGHIJKLMNOPQRSTUVWXYZ0123456789+-*/=.,'()$
01
/END
```

The six figures thus produced may be used in sketching design ideas before any figure data cards are punched.

A simplified flowchart of the ART 1 program

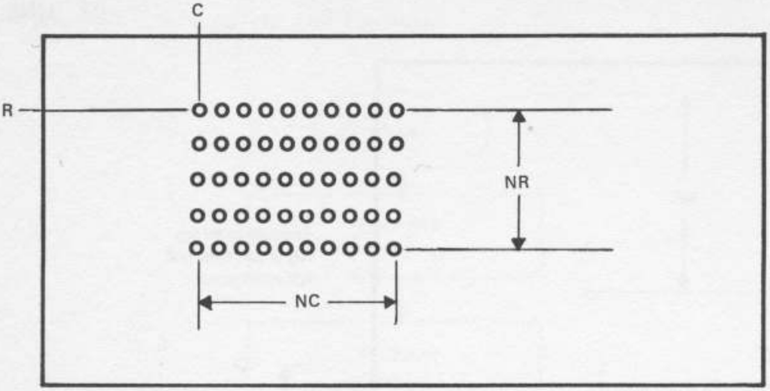




columns

1–2	02	02 in the first two columns calls LINE
3	symbol	Symbol out of which LINE is assembled
4	array	Array 1 or 2
5–6	R	Row at which LINE starts
7–9	C	Column at which LINE starts
10–12	NR	Number of rows in LINE, + is downward and — is upward
13–16	NC	Number of columns in LINE, + is right and — is left
17–20		Not used
21–25		Row/column (2/3) for the first repeated LINE
26–30		" 2nd "
31–35		" 3rd "
36–40		" 4th "
41–45		" 5th "
46–50		" 6th "
51–55		" 7th "
56–60		" 8th "
61–65		" 9th "
66–70		" 10th "

03 SOLID RECTANGLE



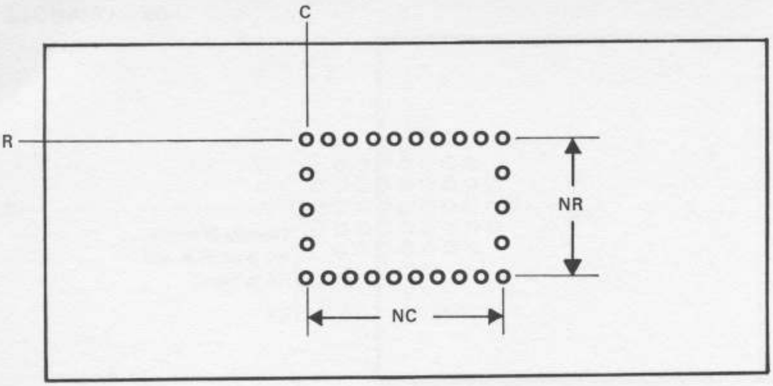
03×120200050010

3004040050

columns

1–2	03	03 in the first two columns calls SOLID RECTANGLE
3	symbol	Symbol out of which SOLID RECTANGLE is assembled
4	array	Array 1 or 2
5–6	R	Row of the upper-left starting point
7–9	C	Column of the upper-left starting point
10–12	NR	Number of rows in SOLID RECTANGLE
13–16	NC	Number of columns in SOLID RECTANGLE
17–20		Not used
21–25		Row/column (2/3) for the first repeated SOLID RECTANGLE
26–30		,, 2nd ,,
31–35		,, 3rd ,,
36–40		,, 4th ,,
41–45		,, 5th ,,
46–50		,, 6th ,,
51–55		,, 7th ,,
56–60		,, 8th ,,
61–65		,, 9th ,,
66–70		,, 10th ,,

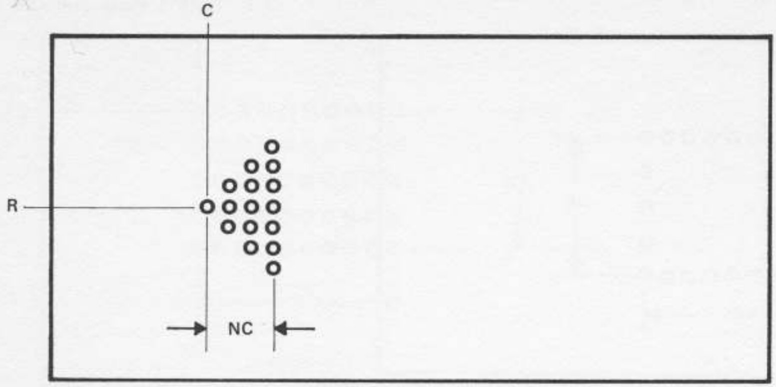
Note If NR is 'blank', ART 1 automatically changes the 'blank' to 1
If NC is 'blank', ART 1 automatically changes the 'blank' to 1.



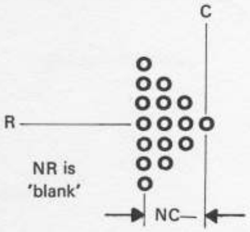
columns

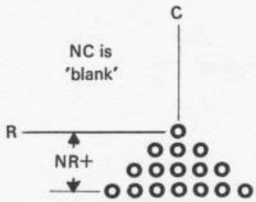
1–2	04	04 in the first two columns calls OPEN RECTANGLE
3	symbol	Symbol out of which OPEN RECTANGLE is assembled
4	array	Array 1 or 2
5–6	R	Row of the upper-left starting point
7–9	C	Column of the upper-left starting point
10–12	NR	Number of rows in OPEN RECTANGLE
13–16	NC	Number of columns in OPEN RECTANGLE
17–20		Not used
21–25		Row/column (2/3) for the first repeated OPEN RECTANGLE
26–30		″ 2nd ″
31–35		″ 3rd ″
36–40		″ 4th ″
41–50		″ 5th ″
46–50		″ 6th ″
51–55		″ 7th ″
56–60		″ 8th ″
61–65		″ 9th ″
66–70		″ 10th ″

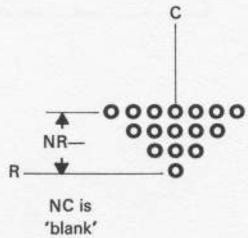
Note If NR is 'blank', ART 1 automatically changes the 'blank' to 1.
If NC is 'blank', ART 1 automatically changes the 'blank' to 1.



Example in which NC is positive, and NR is 'blank'

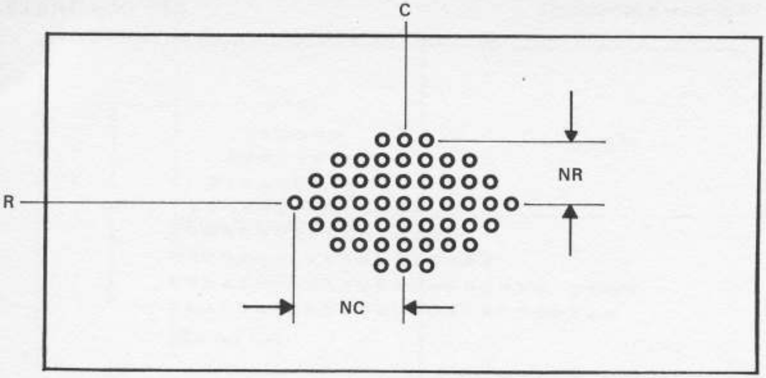






columns

1–2	05	05 in the first two columns calls TRIANGLE
3	symbol	Symbol out of which TRIANGLE is assembled
4	array	Array 1 or 2
5–6	R	Apex of TRIANGLE is at row R
7–9	C	Apex of TRIANGLE is at column C
10–12	NR	Number of rows in TRIANGLE, + is downward and — is upward Or '**blank**'
13–16	NC	Number of columns in TRIANGLE, + is right and — is left Or '**blank**'
17–20		Not used
21–25		Row/column (2/3) for the first repeated TRIANGLE
26–30		″ 2nd ″
31–35		″ 3rd ″
36–40		″ 4th ″
41–45		″ 5th ″
46–50		″ 6th ″
51–55		″ 7th ″
56–60		″ 8th ″
61–65		″ 9th ″
66–70		″ 10th ″

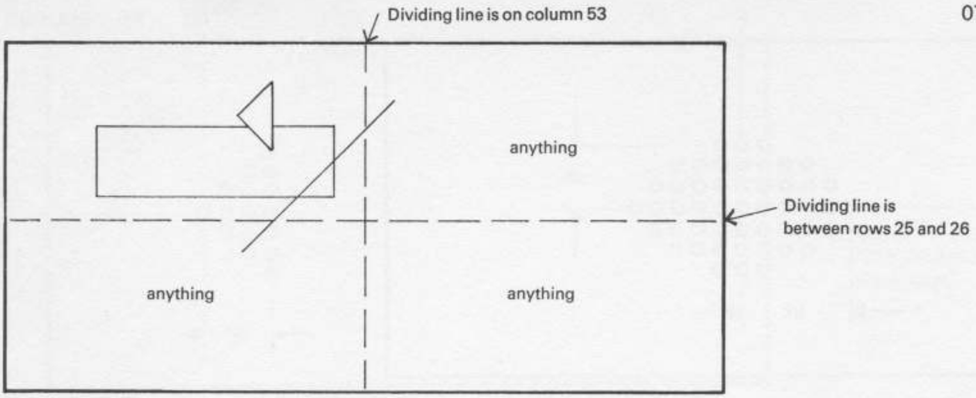


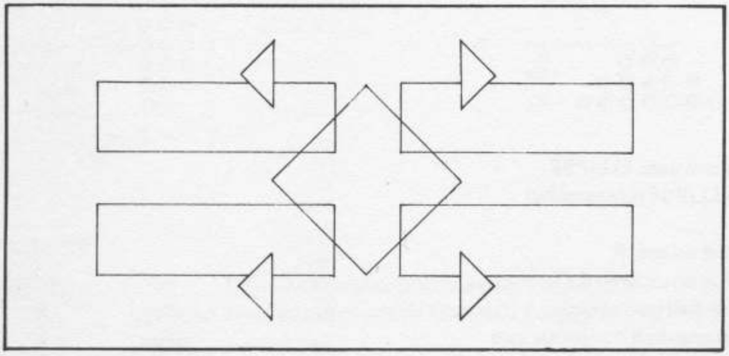
columns

1–2	06	06 in the first two columns calls ELLIPSE
3	symbol	Symbol out of which ELLIPSE is assembled
4	array	Array 1 or 2
5–6	R	The centre of ELLIPSE is on row R
7–9	C	The centre of ELLIPSE is on column C
10–12	NR	Number of rows on one-half vertical axis
13–16	NC	Number of columns on one-half horizontal axis
17–20		Not used
21–25		Row/column (2/3) for the first repeated ELLIPSE
26–30		" 2nd "
31–35		" 3rd "
36–40		" 4th "
41–45		" 5th "
46–50		" 6th "
51–55		" 7th "
56–60		" 8th "
61–65		" 9th "
66–70		" 10th "

Note NR may be greater than, equal to, or less than NC as desired.

If NC is 'blank', ART 1 automatically computes NC so as to make the ELLIPSE look as much as possible like a CIRCLE.

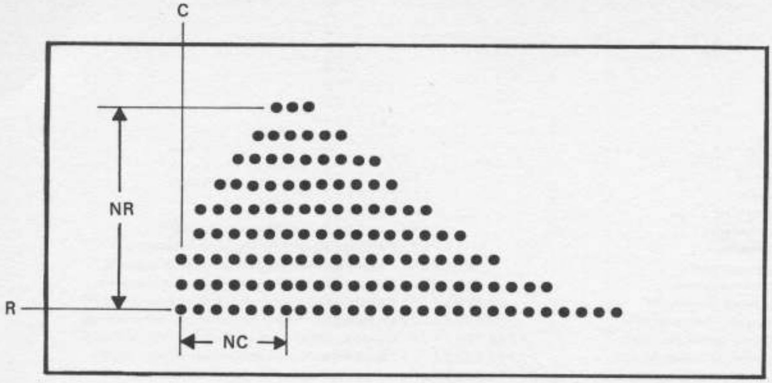




In QUADRANT, all designs assembled in the three quadrants other than the upper-left are replaced by the design in the upper-left quadrant rotated about the vertical and horizontal axes.

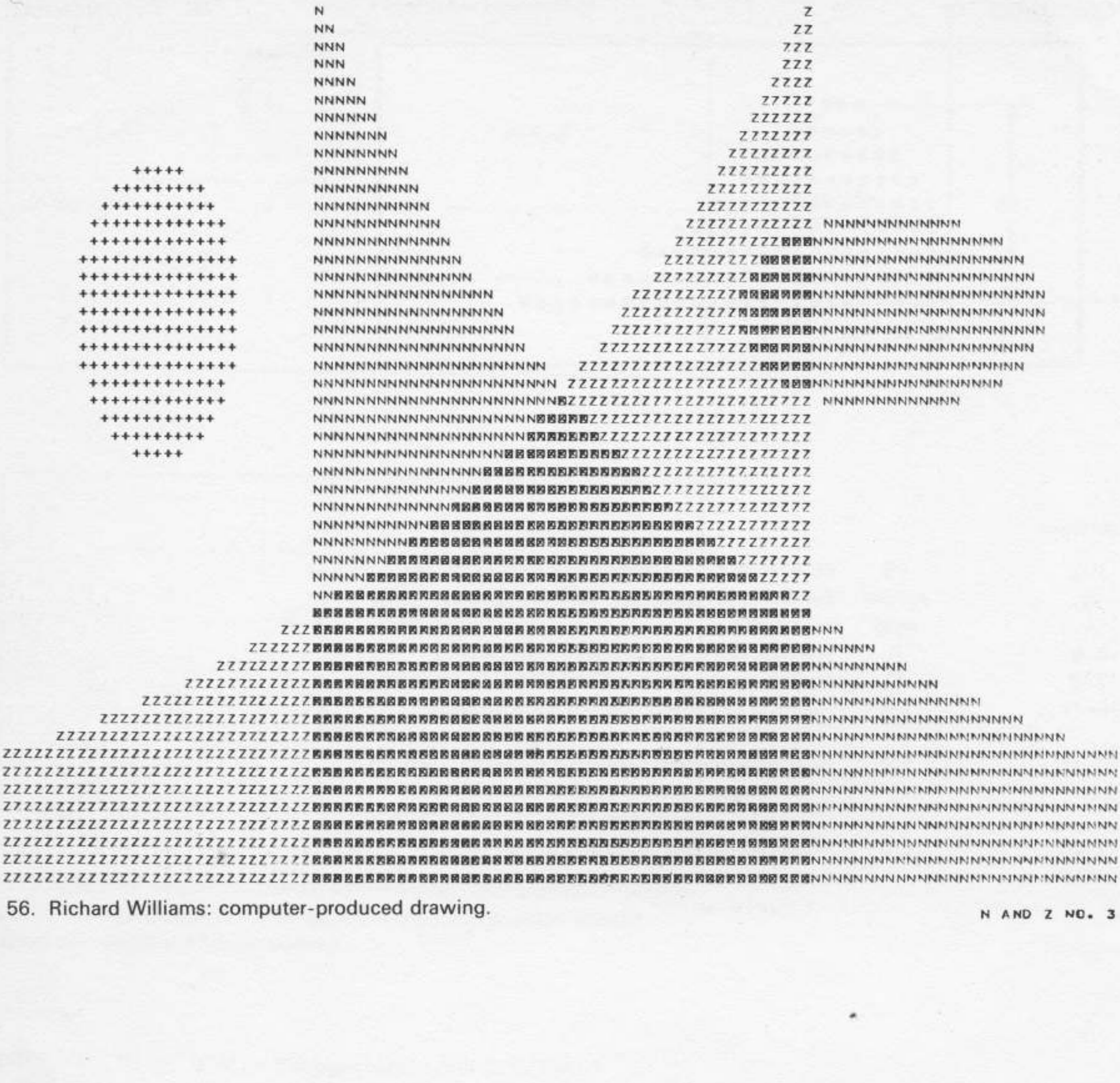
columns

1–2	07	07 in the first two columns calls QUADRANT
3–80		All remaining columns should be left 'blank'.



columns

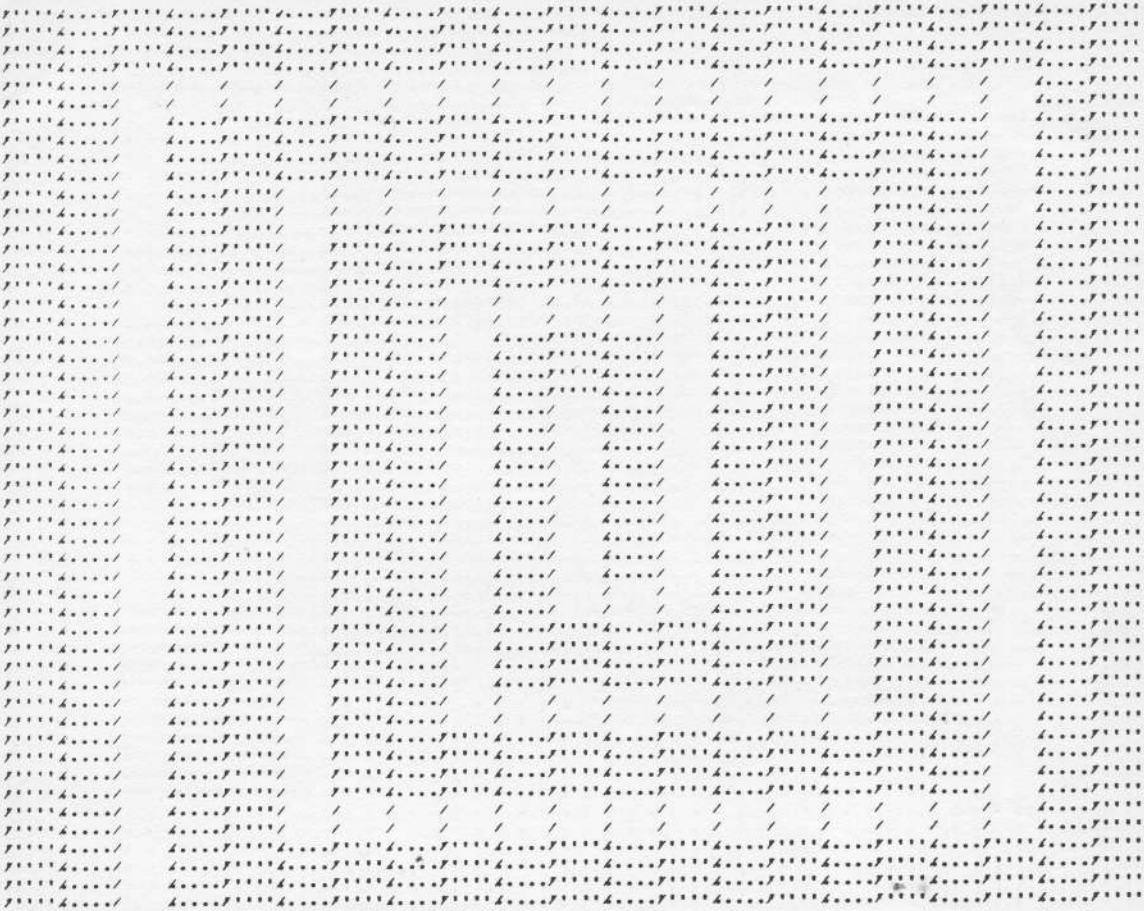
1–2	08	08 in the first two columns calls EXPONENTIAL
3	symbol	Symbol out of which EXPONENTIAL is assembled
4	array	Array 1 or 2
5–6	R	The base row of EXPONENTIAL is row R
7–9	C	The left-most column in EXPONENTIAL is column C
10–12	NR	Height of EXPONENTIAL – If NR is negative EXPONENTIAL will appear rotated about row R
13–16	NC	Number of columns between the column C and the maximum height of EXPONENTIAL
17–80		All remaining columns should be left 'blank'



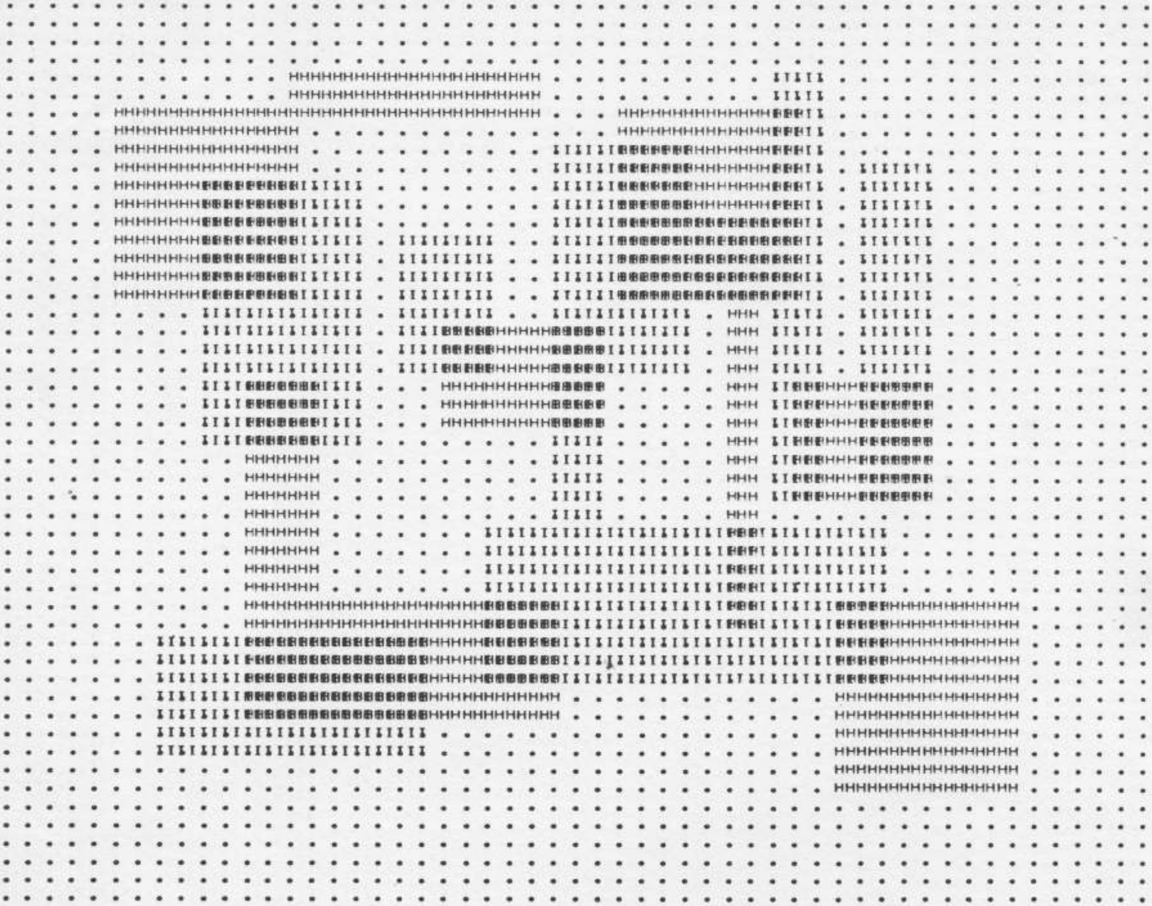
56. Richard Williams: computer-produced drawing.

N AND Z NO. 3

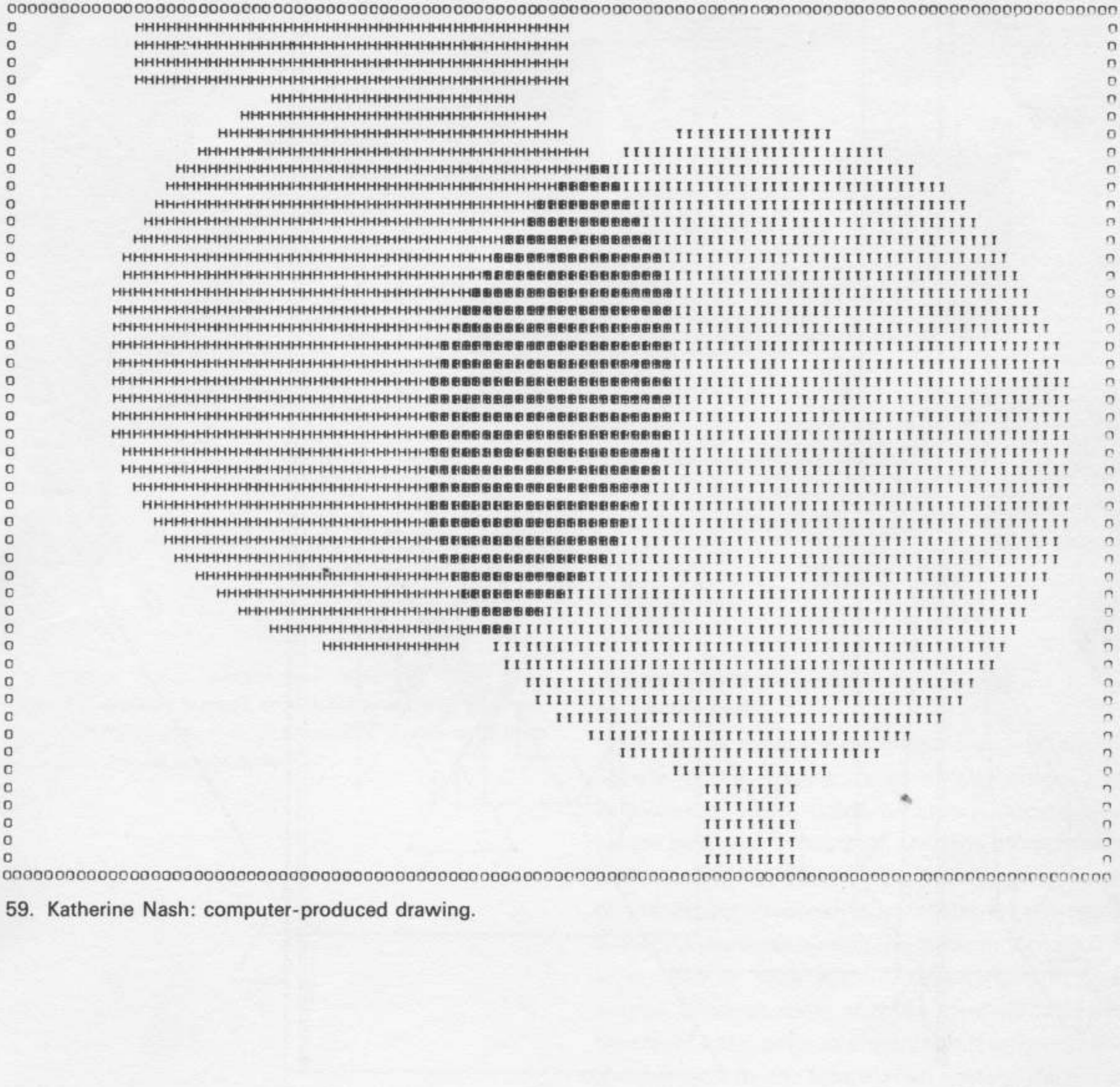
The results of ART 1, although attractive, are limited in scope. It is nevertheless quite clear that the art students leaving the University of New Mexico in the 1970s will be familiar with the computer as a tool which adds another dimension to the traditional concept of art education.



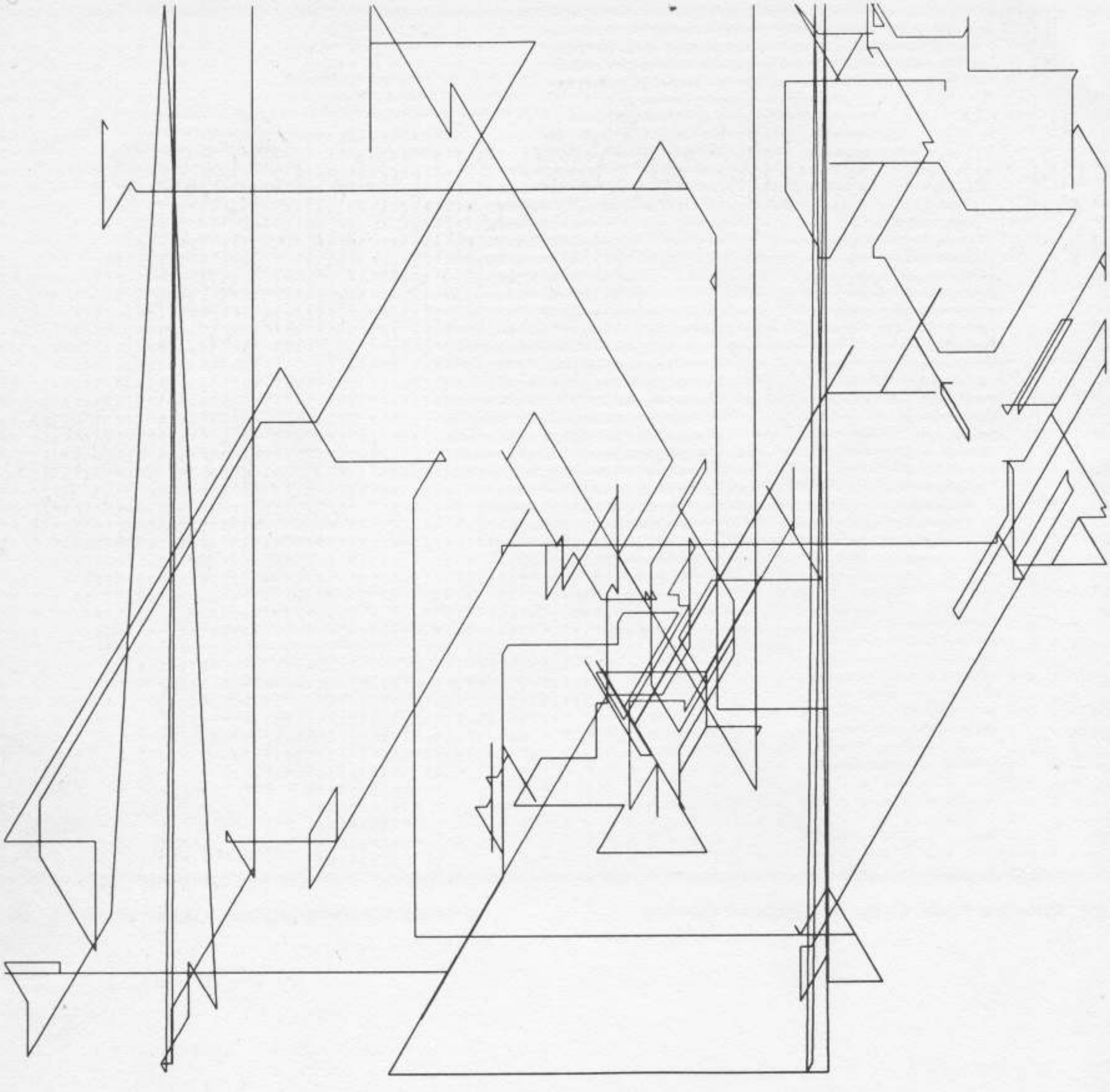
57. F. Hammersley: computer-produced drawing.



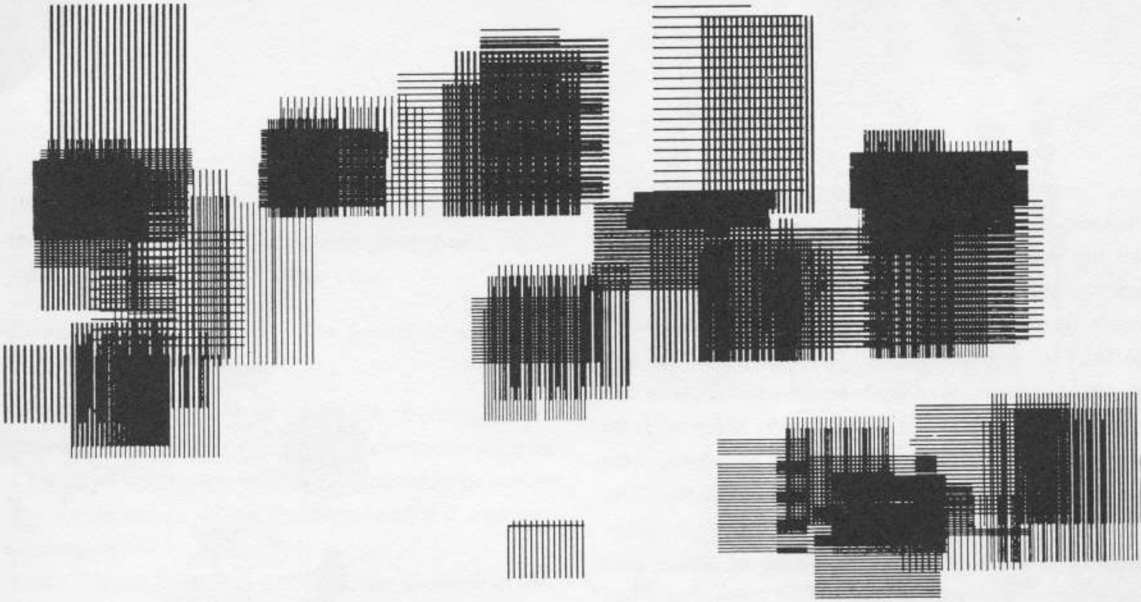
58. Katherine Nash: computer-produced drawing.



59. Katherine Nash: computer-produced drawing.



60. Frieder Nake: *Polygonal Course No. 7* 1965. Random elements include: number of polygonal angles, direction of each polygonal side and length of each polygonal side.



61. Frieder Nake: *Rectangular Hatchings* 1965. The random elements include: total number of rectangles, position of rectangles, size of rectangles, direction of lines and selection of drawing pen.

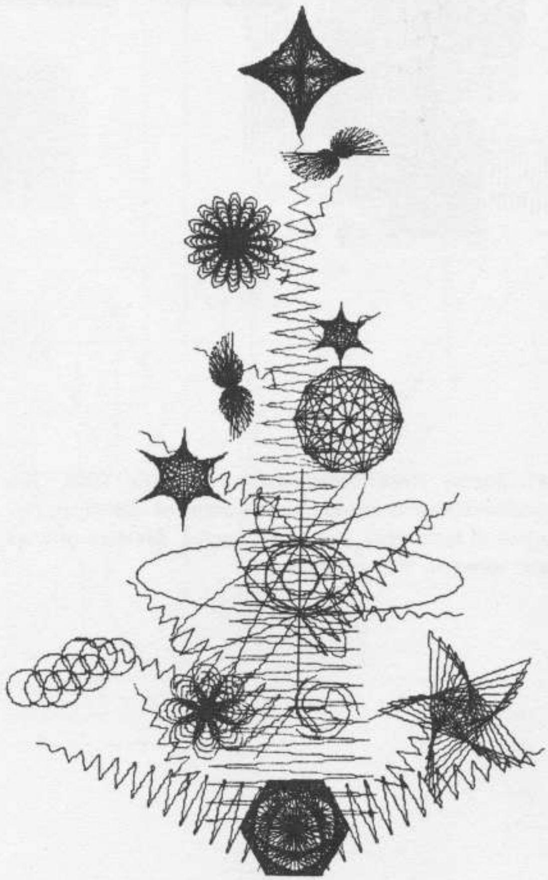
Assessments of computer graphics as an art form

Many of the computer-produced drawings which appear in the August issues of *Computers and Automation,* which holds an annual competition for the best work in this field, are done by engineers and artists whose work rarely appears again. Many of the people involved in computer art represent a floating population using the medium for a period of months or even years, abandoning it in due course. Whereas some of those involved feel that the use of a computer to produce art is an inevitable development for the future when some of the basic questions have been sorted out and when the technical possibilities of interactive display systems have filtered down to the working designers and artists, others hesitate to make speculations. Frieder Nake, who during the 1960s produced in Stuttgart some of the best and most intelligently conceived computer graphics to have been done anywhere, has very deep reservations. Nake's graphics involved the working through of the entire scope of a particular visual theme. He used a series of elements each of which in turn, or in combination, was subjected to randomization. In this instance, the random element was seen as an equivalent to the intuitive element in the artist's work. More recently the computer-plotted results were translated into shapes on a canvas and painted manually. The main concern in these pictures was with the distribution of areas of colour, the ratio of which was determined according to specified rules. Nake has concluded that much work done with the aid of computers does not justify, by the effects produced, the use of a tool of such great complexity. However, this initial stage is almost inevitable if one is to accept that computer graphics as an art form is experimental in every way. Whereas some exponents have grave doubts, others set about their work with unshakeable confidence.

Among the latter is Lloyd Sumner, one of the first artists to exploit computer graphics commercially under the name of a firm 'Computer Creations' with its head office in Charlottesville, Virginia. A leaflet advertising Christmas cards sent out by Computer Creations in the autumn of 1969 baldly stated:

> These Christmas cards were designed by Lloyd Sumner, one of the first computer artists in the world. Each of the cards contains an appropriate original verse that is 'of today' and in the spirit of Christmas.

The multicoloured cards printed from computer line drawings were given suitably seasonal titles like 'Conspired abstract of the Xmas spirit', and



62. Lloyd Sumner: *My Christmas Tree*.

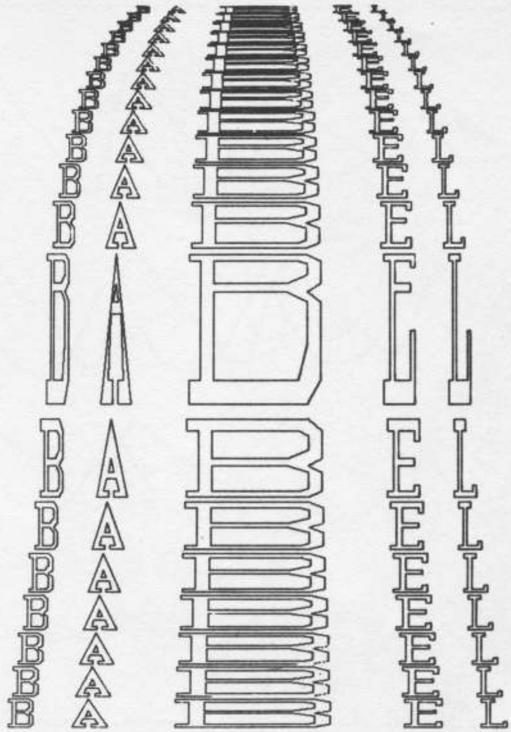
included poems and messages to which the knowledge that the card was an embodiment of a technological process added very little.

I hope someday we live a life as beautifully unique as snowflakes,

writes Sumner on one of the cards, drawing attention to the fact that his venture is a demonstration of a personal and rather arbitrary relationship between the implications of his medium and the content conveyed.

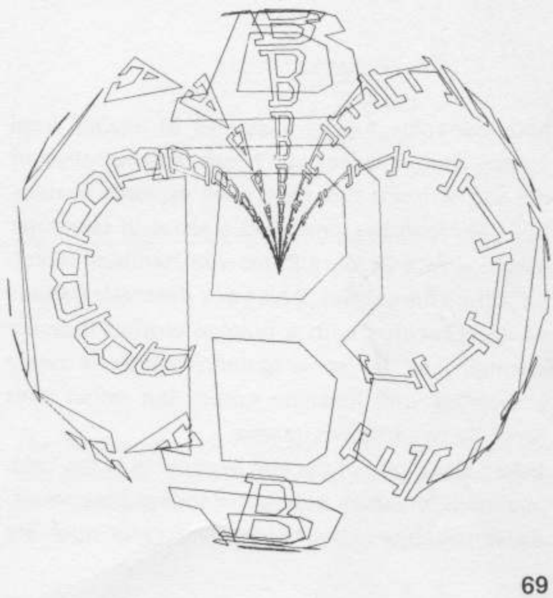
Leslie Mezei, Professor of Computer Science at the University of Toronto, and one of the very few people to produce a written survey of the scene of computer art as early as 1964, believes that the computer will never replace the traditional media of pen and brushes, but can transcend them by offering the possibility of the convenient introduction of modification. The three-dimensional simulation of sculpture is one of the most radically useful developments in the use of computers for creative purposes. Certainly, apart from building and altering scaled models, this is perhaps the only way of controlling the outcome by prediction. Mezei himself has done some interesting transformations on various themes by allowing a degree of random deviation within repeated patterns. He has used the images of figures, faces, animals, symbols and letters. His series of graphics on the theme of the tower of Babel was inspired by a concrete poem by Pedro Xisto (B)ABEL.

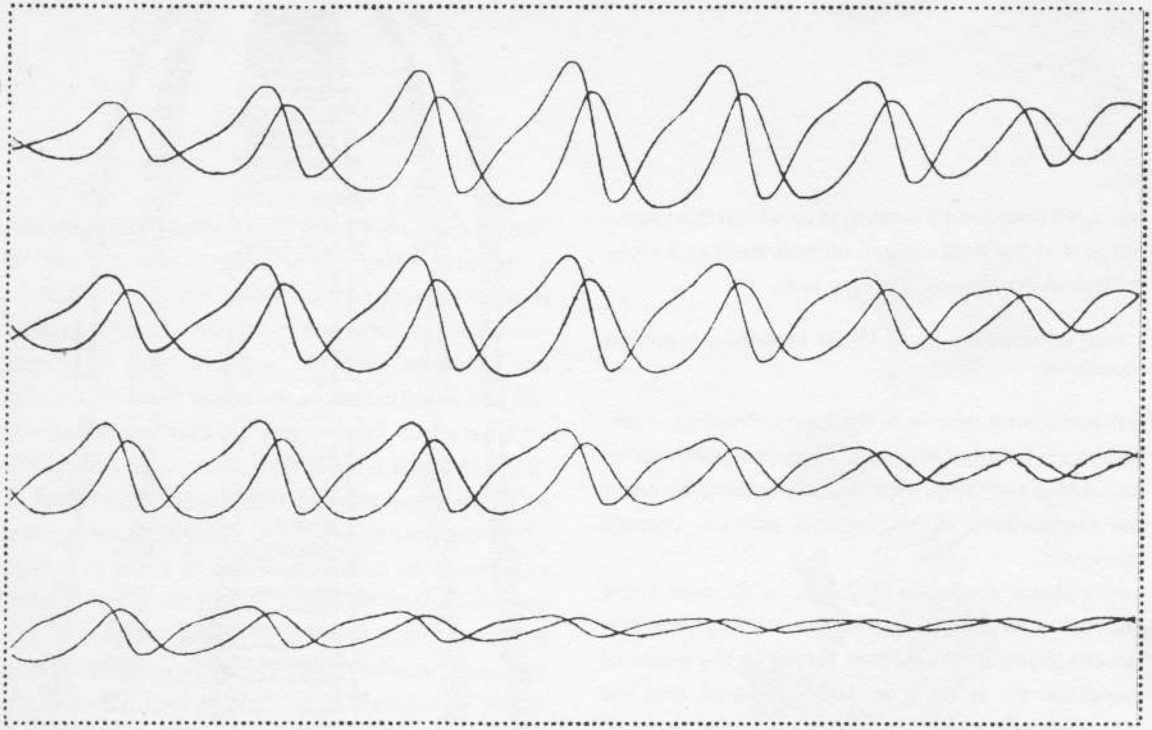
It is difficult to convey the entire range of work accomplished so far in the realm of computer graphics with acknowledged artistic intent, but



63. Leslie Mezei: *Tower of Babel* 1967.

64. Leslie Mezei: *Babel Exploded* 1967.





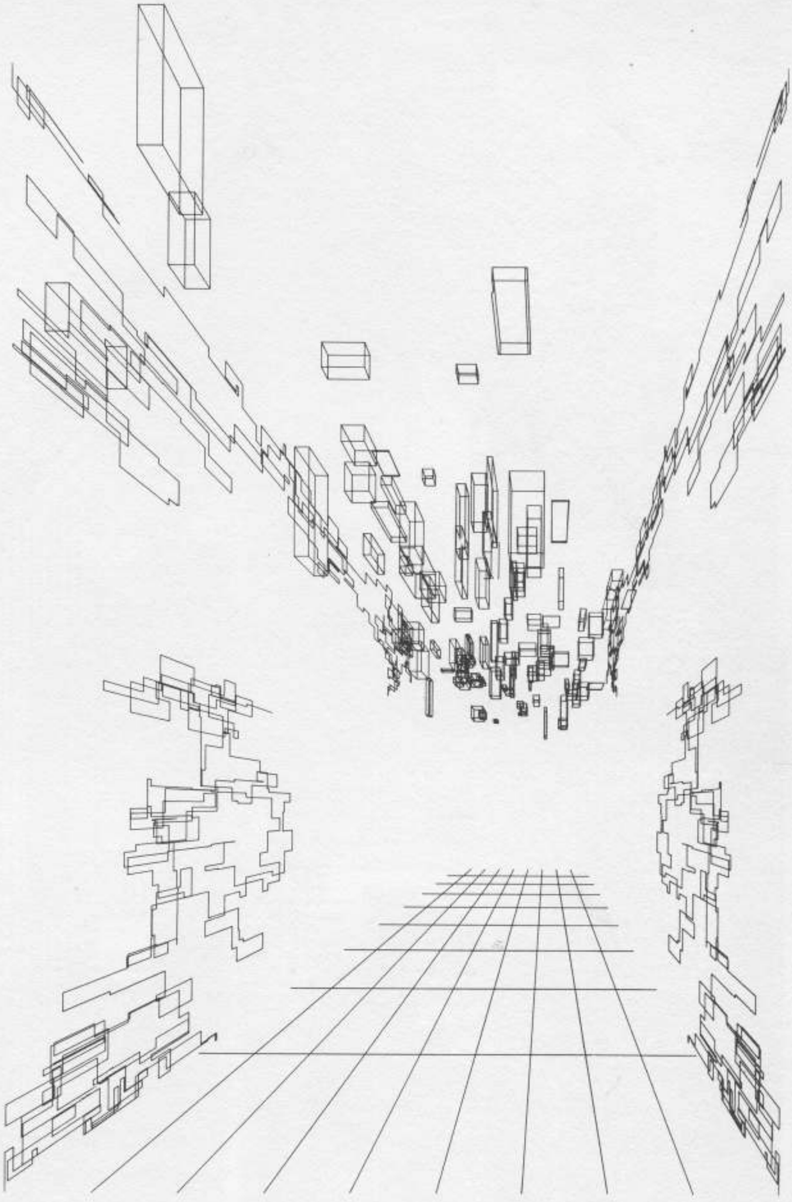
65. Kurd Alsleben and Cord Passow: *Computergrafik 4* 1960.

here are some further examples of images from Europe and America which are representative of the sort of forms that have been explored to date. Kurd Alsleben has produced a series of computer graphics with Dr Cord Passow in Hamburg which constitute the subject of his book *Aesthetic Redundancy*. Executed with a graphic plotter, they are distinguished by an irregularity which is rarely associated with machine output but rather with carefully hand-drawn images.

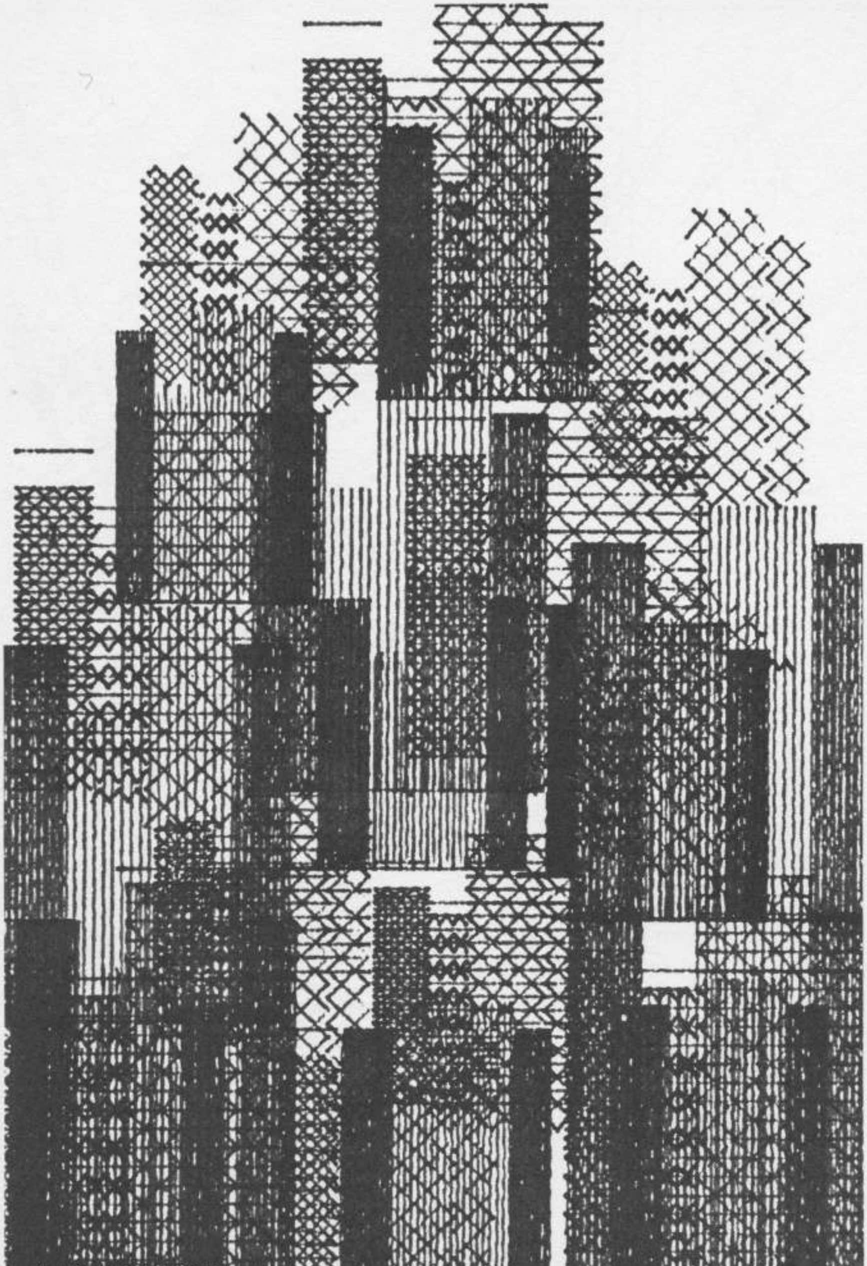
Georg Nees, one of the first exponents in the field, has made graphics based on random parameters, developing one or two themes with great ingenuity and using repetition as his subject.

Replacing the graphic plotter pen with felt pens and brushes carrying coloured inks, Grace Hertlein from the Chico State College in California, is one of the comparatively few artists to have learned computer programming. Her images consist of a variety of precise linear forms made more informal through the use of colour and texture.

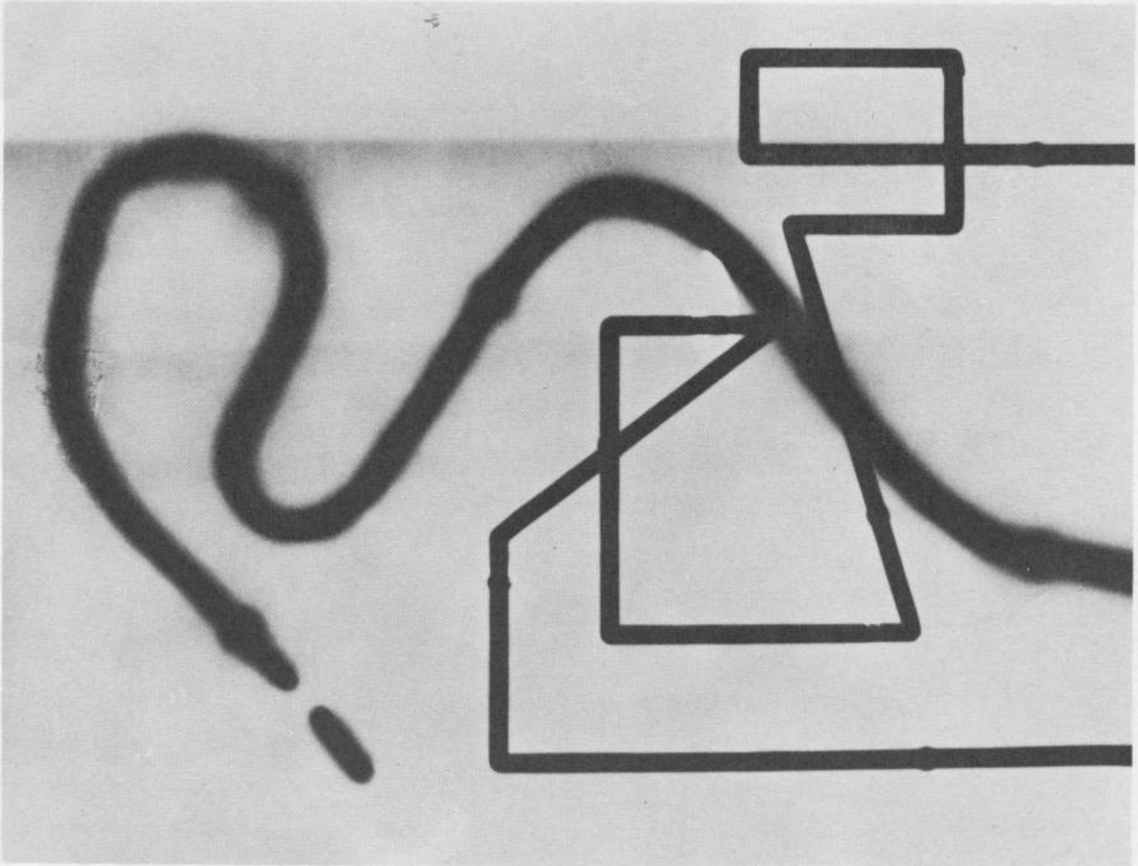
Computer-driven plotters have long used light sources for technical purposes in which a light spot is focused on to a photographic plate. Indeed this process is standard in the manufacture of computers themselves. Gustav Metzger has worked out a



66. Georg Nees: *Corridor*. The program for this picture was constructed as follows: two separate linear-rectangular progressions were generated on the left wall. This pattern was then copied symmetrically on the right wall. Then a set of cubes with randomly determined side lengths was generated. The cubes were spaced at random on the ceiling and the floor pattern was drawn.



67. Grace Hertlein: *City Painting,* a computer-produced picture made with a flow pen in brown ink. The image is based on a series of modules used by Hertlein in other city paintings.

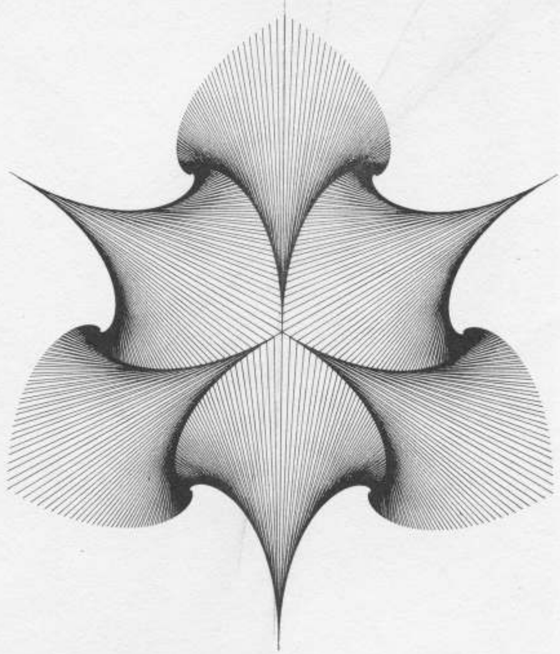


68. Gustav Metzger: third of four drawings produced with light in March 1970. It was made on a Calcomp 563 with magnetic tape. The movement of the plotter was continuous. The drawing was started at the bottom left-hand corner with the end of the light guide about a quarter of an inch away from the paper. When the line was completed, the guide moved outside the paper; it was then pressed down and the drawing was continued. The computer room was not completely dark with the result that some background tones are visible. The program was done by D. E. Evans of Imperial College Computer Unit.

particularly simple method of putting a light source on a graphic plotter, in which an optical fibre is used as a light conductor instead of a plotter pen. By varying the distance of the light source from the paper one can conveniently achieve the effects of light and shade, giving a rather painterly result. There is no reason why such a system should not be extended to colour by using, for example, three coloured light sources and a colour film.

In 1968 CalComp (California Computer Products) held a competition for the best computer graphics, under the title 'Computer Plotter Art', offering scholarships from $2,000 to $5,000, as well as cash

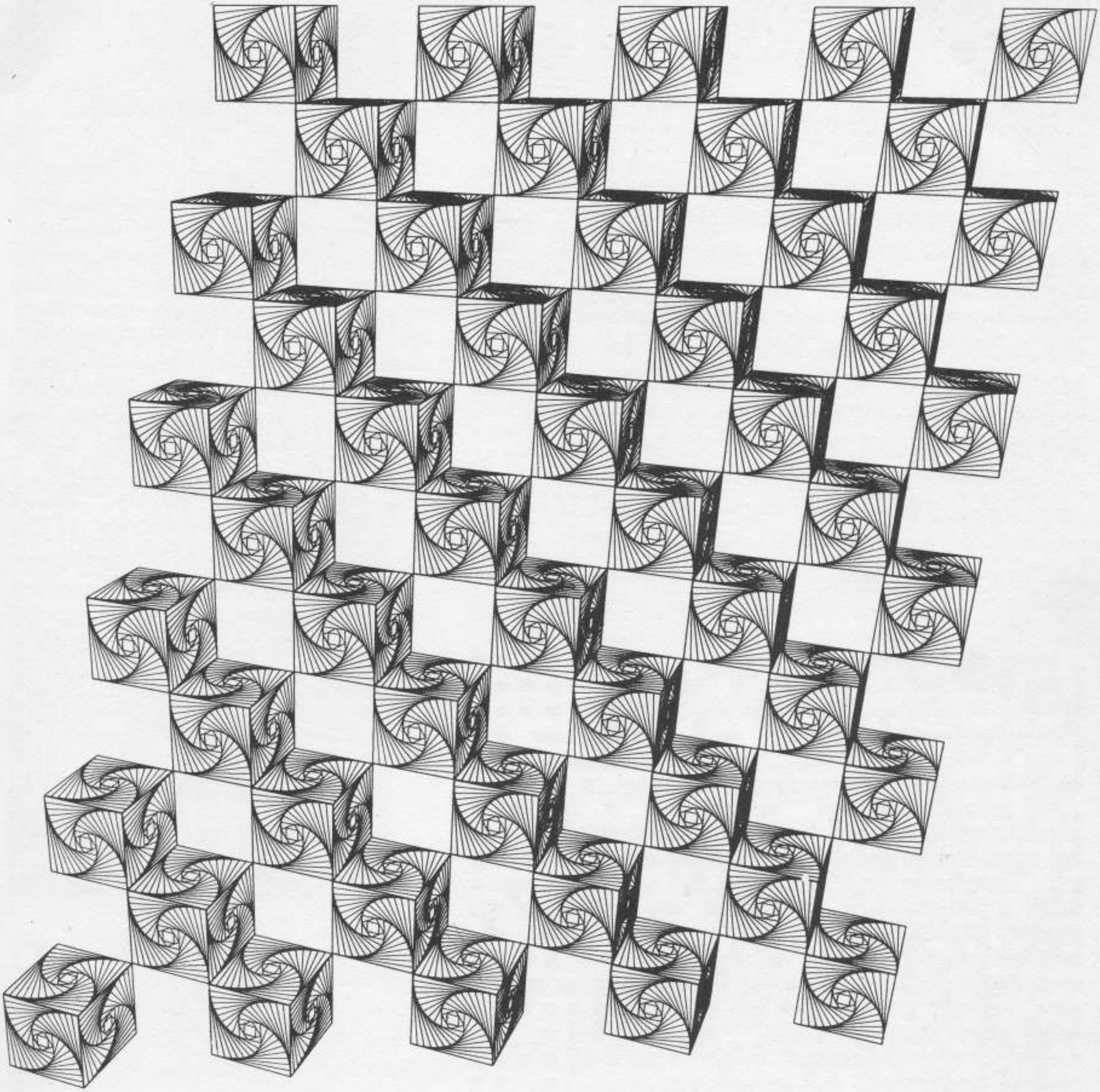
69. Drawing executed on a CalComp plotter from a woodcut by Utamaro.



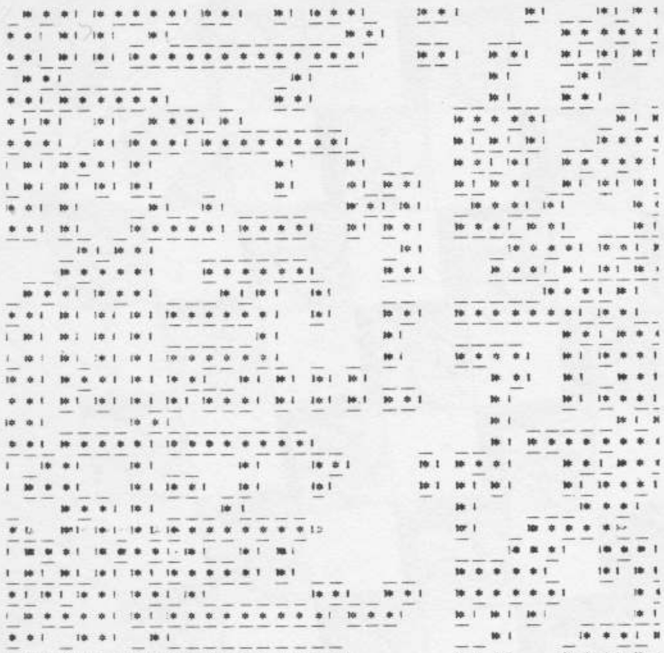
70. Figure approximating to a crest, drawn with a CalComp plotter.

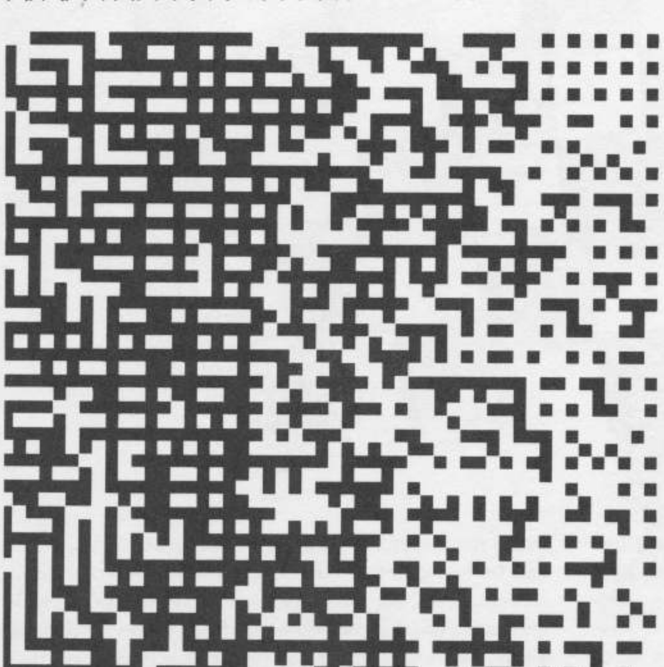
awards. CalComp, manufacturers of graphic plotters, sent examples of what can be achieved with this technique, with every entry form. They issued a statement to the effect that they were convinced that computer/plotter art would be accepted as a recognized art form 'if only because it gives a humanizing aura to machinery'.

The computerized copy of an Utamaro woodcut is composed entirely of tiny straight lines – the steps of the plotter – although these do not show in a reduced reproduction.

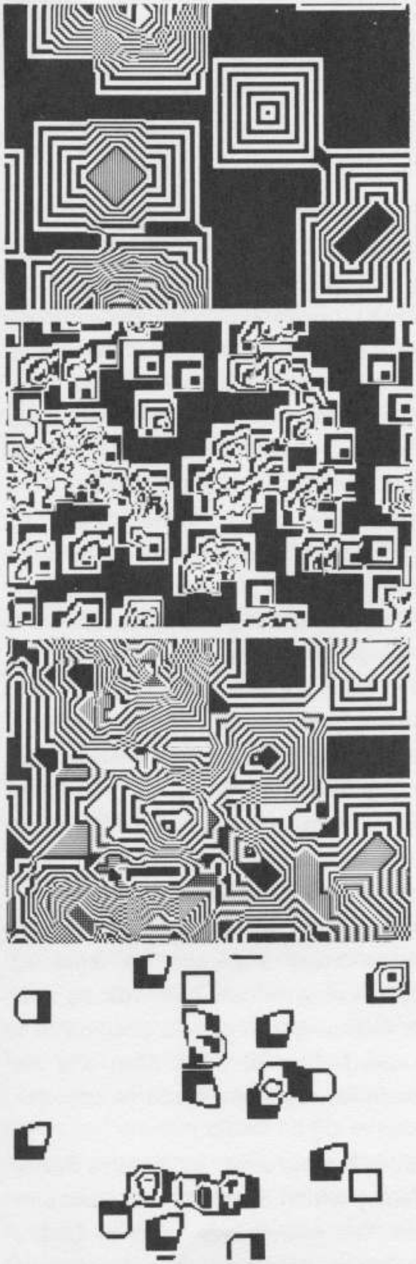


71. Donald K. Robbins: *Checkerboard Pattern*. One of the traditional problems in calculus is the so-called bug problem: if four bugs start on the corners of a square and start crawling towards each other, what path will they follow? If you take a picture of their lines you get a spiral effect. On a digital computer it is easy to put the bug's path into a portion of the program, called a subroutine, which can be manipulated. The checkerboard pattern shows a replication of the basic pattern. A further progression shows the checker-board revealed as a three-dimensional entity, with a shape distorted (or perhaps made more real) by the perspective transformation.





72 and 73. Peter Struycken has used the computer to establish the distribution of predetermined elements according to certain rules. The computer serves as a tool for solving formal visual problems, such as those of establishing surfaces, spaces, limits, saturation, movement and so on. The computer drawings composed of asterisks and lines are then translated into solid black and white areas painted with lacquer on perspex.



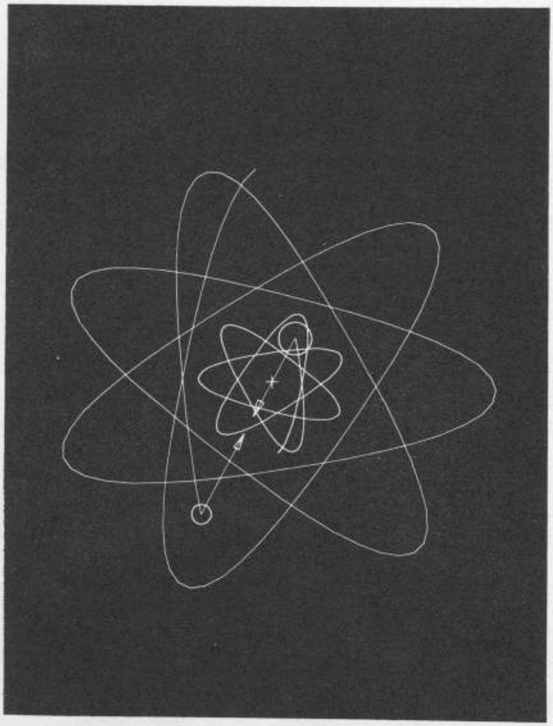
74. Stills from *Pixillation,* a computer-animated film by Kenneth C. Knowlton and Lillian Schwartz. The programming language here was a development of BEFLIX.

Computer-generated films

An electronic microfilm recorder in conjunction with a computer, can plot points and draw lines a million times faster than a human draftsman. Electron beams may also be used directly to form a picture on a film. The microfilm recorder consists basically of a display tube and a camera. It can be instructed to advance the film, display a spot or alphanumeric character at specified coordinates, or draw a line from one point to another. From this simple repertoire, the machine can compose complex pictures from a large number of basic elements, drawing 10,000 to 100,000 points, lines, or characters, per second. Literally in a matter of seconds this device can produce a television-quality image made up of a fine mosaic of closely spaced dots or simple line drawings at a rate of several frames per second.

Using the microfilm technique, a series of computer-produced movies was made at Bell Telephone Laboratories during the sixties, using an IBM 7094 computer and the Stromberg-Carlson 4020 microfilm recorder. The mosaic picture system devised by Kenneth C. Knowlton was used to produce both educational and research films. The other main programming language used was FORTRAN. Knowlton used the computer in two specific and distinct ways: always as a high-powered drafting machine and sometimes as a calculating machine which could determine the consequences of mathematical and logical statements.

With the mosaic system or BEFLIX (corruption of Bell Flicks) the pictures are made up of 252 × 184 arrays of spots of different shades of grey, or as



75. A frame from *Force, Mass and Motion,* an educational film made by F. W. Siden. The computer display shows what would happen under fictitious gravitational forces. In this case the paths show the motion of two massive bodies under a force of attraction that varies directly as the cube of the separating distance. The arrow lengths indicate the degree of the force of attraction.

numbers 0 to 7, indicating light intensity at that point. Pictures are built up and modified within the computer by appropriate manipulation of these numbers. BEFLIX is not a complex language mathematically since it does things that could literally be done by hand, although it performs this task more easily (not to mention faster) since some of the patterns are 'logically simple' although graphically complex. The instructions in the BEFLIX language permit drawing straight lines consisting of dots, or drawing arcs and other curves, or copying one area on to another, or filling the inside of an area with a solid shade of grey, or shifting the contents of one area up, down, right, or left, a specified number of raster positions. There are also operations for automatically filling an outline with a specific shade of grey, for enlarging part of a picture or a whole one, and for gradually dissolving one picture into another. The BEFLIX films were produced at approximately $500 per minute.

Apart from a film which demonstrated how the BEFLIX system works, Knowlton together with Stan Vanderbeek made a number of films for pleasure, with pulsating colours and intricate cascades of dots changing colour and position at a phenomenal speed. One of them *Man and his World,* was made for the world fair in Montreal in 1967.

Among educational films are F. W. Siden's *Force, Mass and Motion* which demonstrates Newton's law of motion. The film shows paths of bodies mutually attracted by a force which varies directly as the cube of the separating distance. The total effect of the motion of the linear images could simply not be realized in a physics class on a blackboard. Indeed, it has even been possible to make perfectly comprehensible instructional films on physics without a single word of commentary.

The first computer-animated film at Bell Telephone Laboratories was made by E. E. Zajac in 1963 which showed the result of a simulation of the motion of a communication satellite. The film showed the earth, a box-shaped satellite and a clock which counted the orbits.

A film based on 'noise' from a pseudo-random number generator was made by Bela Julesz and C. Bosche to study human vision and perception. The images, deliberately devoid of any familiar patterning, were used to determine precisely under what conditions subjects see three-dimensional effects, independent of the knowledge of the 'objects' seen, since there are no recognizable objects as such.

A. M. Noll was responsible for a stereo film of a mathematical construction. The image consisted of a four dimensional hyper-cube projected mathematically down on to three dimensions and then twice on to two dimensions. The experiment was an attempt to give people an intuitive feeling for four-dimensional objects. Noll has made other films, including one of stick figures performing a ballet and another based on his initials AMN.

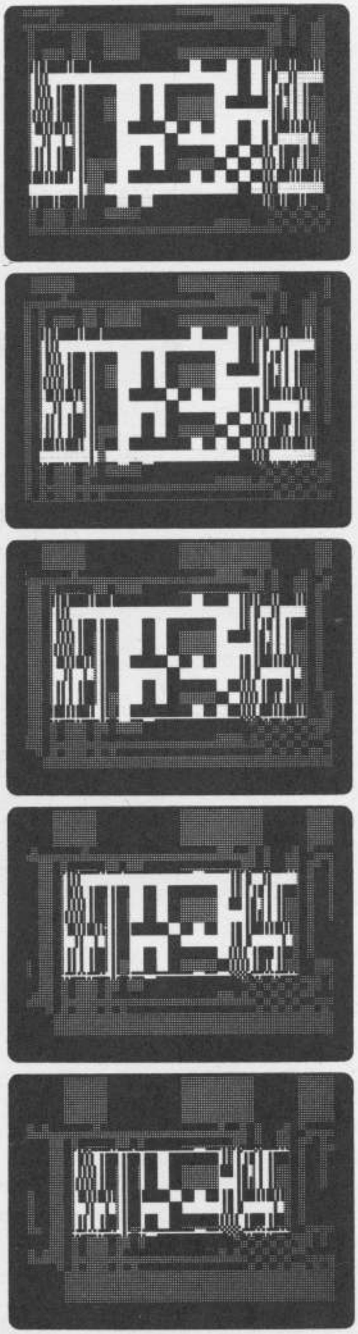
Among other films made during the early development of computer animation were those by Boeing dealing with aircraft design and cockpit visibility; the simulation of weather conditions at Lawrence Radiation laboratory, and the behaviour of fluids at Los Alamos Scientific Laboratory.

Computer-generated films are extremely useful for comparing mathematical models with reality and in depicting phenomena which are not directly observable, like the flow-rate of water under a dam. The computer's role in movie making is also significant in that one can make several versions of one scene with considerable ease, and choose the best version.

One of the most remarkable film makers using the BEFLIX mosiac system is Stan Vanderbeek who has created wildly exuberant and brilliantly coloured sequences. His own attitude to the computer as a creative medium is described in a short biographical note, which he wrote in 1969:

Over the past ten years, I have been working with a variety of media, starting with painting and graphics, polarized light, constructions, heat painting, collages, etc., developing an interest in motion pictures in 1957 I began work in animation . . . painting: stroke by stroke, animation: frame by frame . . . computers: on and off . . . and bit by bit . . . the sequence is inevitable, motion pictures as graphics in motion . . . computers came to my attention in 1965 with some of the graphic possibilities, I looked on the computer as a challenge . . . (a large blâck box: the memory of the world, a metaphysical printing press . . .) I was fortunate to meet Peter Neuman who was a programmer who helped me to meet other people working in scientific research with computers . . . gradually with the help of Carol Bosche and Ken Knowlton I was tutored in programming and began to work in the area of computer-generated animation . . . I consider the computer-logic systems and process of image making, a fast high speed car, that is difficult to learn how to drive . . . and like fast turns is somewhat dangerous and unpredictable . . . however, in time-speed-memory-ideas and forms, it is breathtaking . . . I expect driving a computer down the road of art and sensibilities, will lead to flying: i.e. analog systems . . . and that will be very lovely and full of surprises that defy gravity and expected images . . . my own perspective as an artist and my instincts, tell me that memory is the matrix of the human condition, and computers are the pertinent extension of the real-time-mind of man . . . hooray for art and life . . .

Vanderbeek's metaphysical approach may be at odds with what computer technology conjures up in most people's minds, yet it demonstrates an attitude which has been responsible for the realization of some of the most enchanting images in motion.



76. Stan Vanderbeek: stills from computer-animated films programmed with the BEFLIX mosaic system.

Computer Technique Group

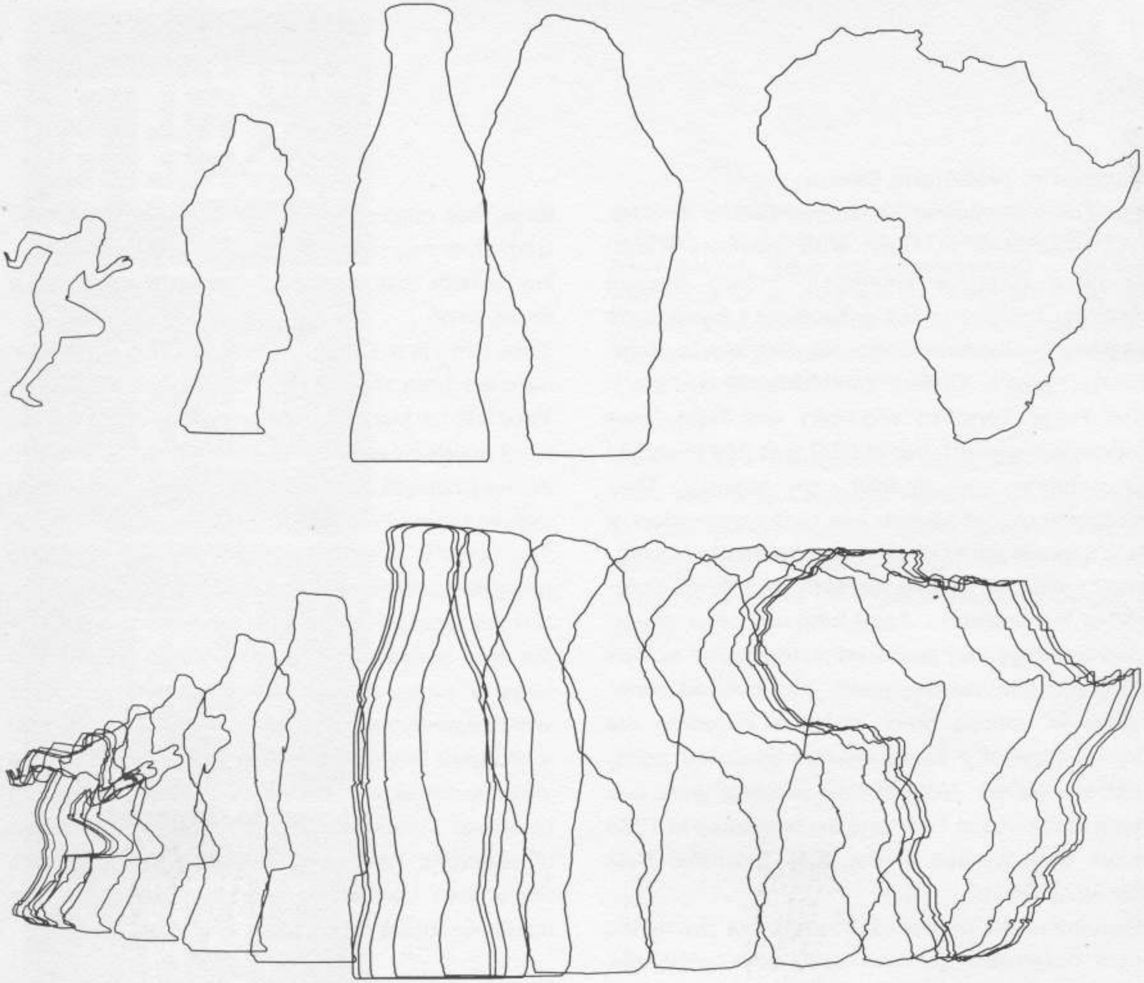
The Tokyo Computer Technique Group, or CTG, was established in 1967, with members Haruki Tsuchiya (systems engineer); Masao Komura (product designer); Kunio Yamanaka (aeronautic engineer); Junichiro Kakizaki (electronic engineer); Makoto Ohtake (architectural designer): Koji Fujino (systems engineer) and Fujio Niwa (systems engineer). When CTG was first launched its members were in their early twenties. Their manifesto described their aim as the restoration of man's innate rights of existence by means of computer control. They saw themselves as 'brain workers' of the operation. Apart from computer-generated drawings they produced mathematical models for community developments, and involved themselves in various other activities including the construction of a computer that produced paintings in a gallery. Most of their graphics work was done at the end of 1967 and the beginning of 1968 when they worked at the IBM Scientific Data Center in Tokyo.

Their computer-produced drawings are among the most imaginative to have been done anywhere. They have explored the potential of the computer in those fields of drawn images which cannot readily be done by any other means. In graphics they have explored the possibilities of transforming one image into another, as in *Running Cola is Africa,* or the distortions of a single image as in *Sharaku*. They have also developed single images in different ways such as the two versions of *The Return to Square* where one is programmed according to an arithmetical series and the other according to a geometrical progression. Their drawings tend to be less consistently formal than those of their German or American counterparts and it is interesting to note that on the CTG team there is not a single artist.

Their attitude to computer-aided work is somewhat different from that of their colleagues elsewhere. They felt, for instance, that one of the major underlying possibilities of computer art is that the 'artist' actually designs a system – a method of producing a given repertoire of forms and generating patterns. The 'artist's' work consists largely of envisaging possibilities rather than producing individual works. It is the program itself that is the work of art. As for the rest, the resulting works – these are, by and large, a series of near repetitions and variations which demonstrate intricate and subtle differences, with only a few of them possessing any remarkable visual qualities. A system in this context, according to Masao Komura, implies the specific association of materials, forms and techniques. As soon as these have been determined the content of the results becomes predictable:

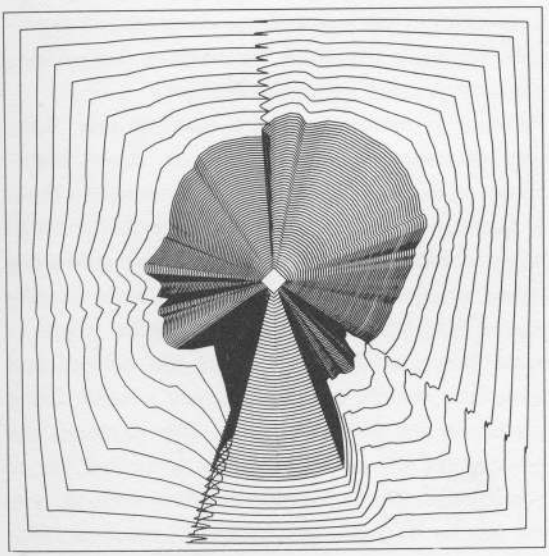
> Let us suppose, for instance, that oil paints and canvas are selected, and a palette knife to be used in Fauvist style. Now that we know this, the precise content of the resulting painting is not of such great interest, whether the subject be an apple or a person with a melancholy face . . . I should like to propose the thesis that art is the discovery of a system.

Hiroshi Kawano puts forward other ideas in relation to computer art. He sees the computer as an artistic medium of a real democracy. This can only be achieved if the medium of art itself can be, as he says, 'softened'. He defines a soft work of art as one

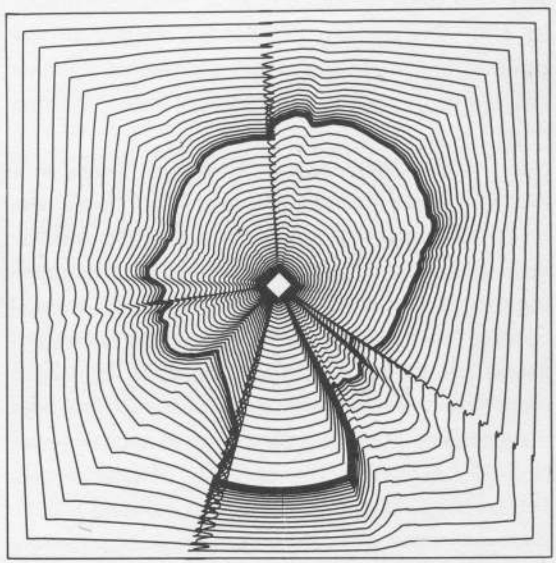


77. Computer Technique Group: *Running Cola is Africa*. A computer algorithm converts a running man into a bottle of cola, which in turn is converted into a map of Africa.

78. Computer Technique Group: *Deformation of Sharaku*. Five separate techniques of coordinate exchange are applied to original data.



79. Computer Technique Group: *Return to Square A*. A computer metamorphosis: a square is transformed into a profile of a woman and then back into a square.



80. Computer Technique Group: *Return to Square B*. Figure 79 is programmed according to an arithmetical series, this according to geometrical progression.

that can appear and disappear at will, with a built-in possibility of impermanence. Such 'soft' works of art will neither clutter up the attic nor accumulate prestige over the years. Kawano writes:

> Perhaps soft art will even creep into a person's dreams and change his personality before he knows it. The electron is surely the medium making such free 'soft' art a possibility.

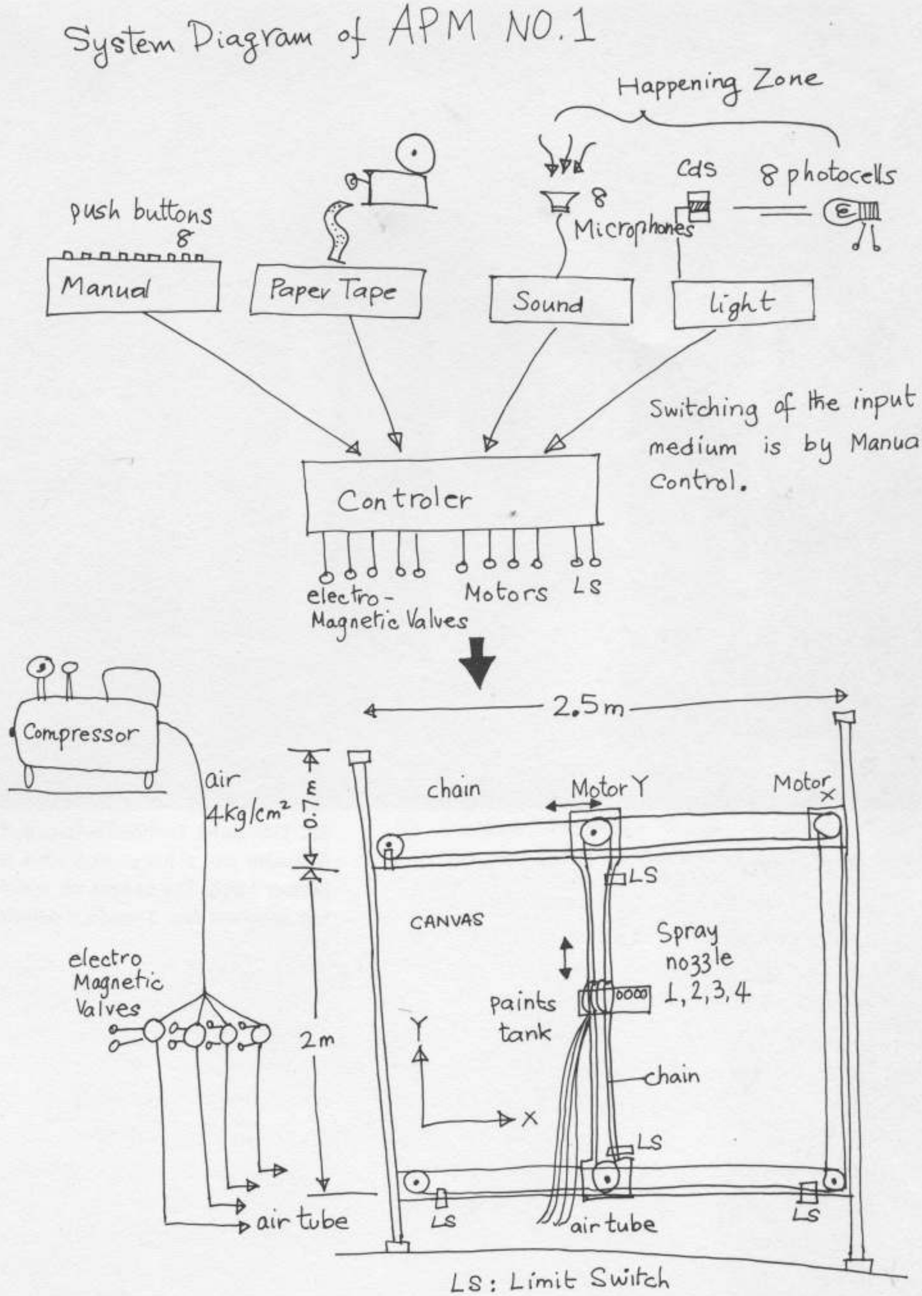
This new art form of which oscillographs and holograms (when used in an art context) are perhaps the first examples, need not necessarily be programmed in quite the same way as those computer graphics which have to fulfil some practical role. The making of abstract images on the cathode ray tubes and other interactive systems allows one to explore this notion of impermanence in art.

One of the CTG's most adventurous works was their *Automatic Painting Machine No. 1* (there was no No. 2), which consisted of a painting mechanism, control unit, paper tape reader and a happening zone. It was controlled in four ways: by manual control; with paper tape from a digital computer; sound input from the happening zone; and light input from the happening zone. The machine was capable of painting on a canvas up to approximately 2 × 1.5 meters. The principle of operation is shown in the diagram. The actual painting instrument consisted of four colour sprays operated by compressed air through electro-magnetic valves. When the machine was controlled manually it could be played like a piano to produce a picture. When controlled by paper tape, the result was no different from a computer-generated picture executed in four colours.

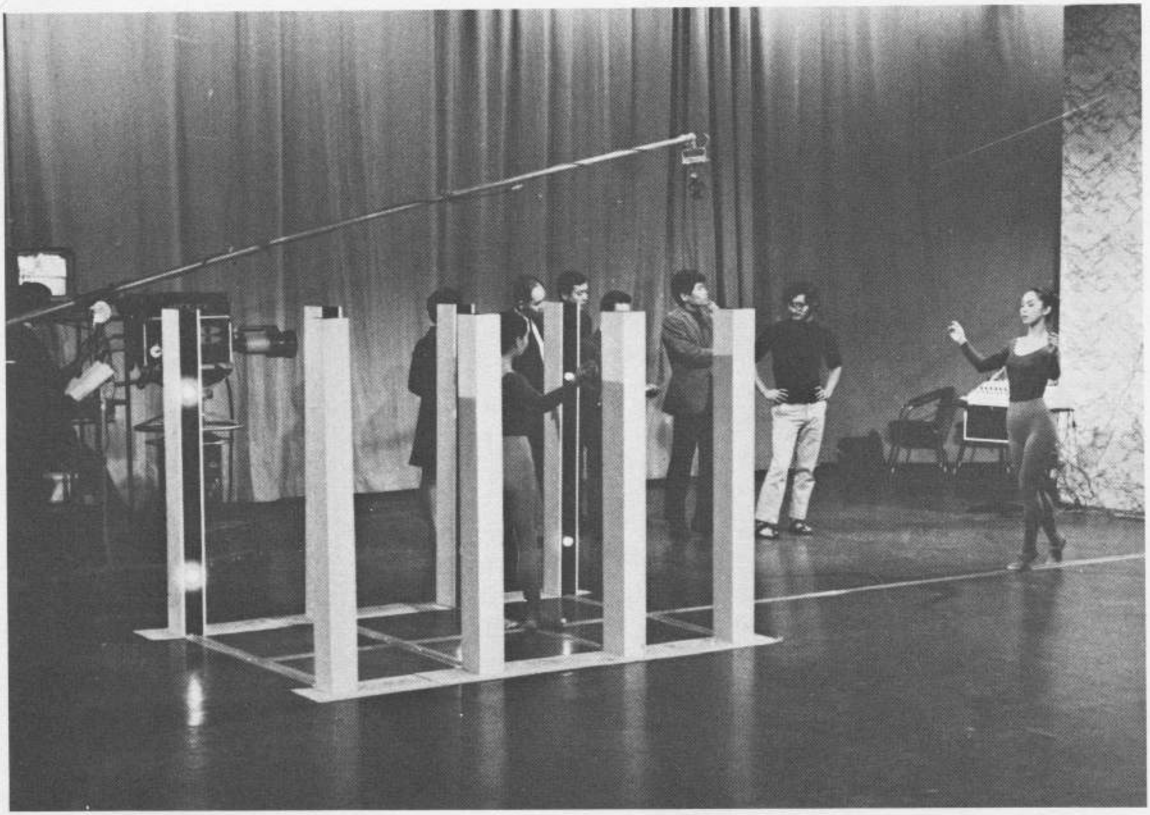
The ambient sound and light interference which are generated within the happening zone affect the picture being painted on the canvas. Thus the visitors to Tokyo Gallery where the machine was demonstrated, without being aware of it perhaps, affected the images produced if they passed through the happening zone.

To the members of CTG, the *Automatic Painting Machine No. 1* was a significant example of media transformation through electronics, as well as an innovation in the realm of computer art and cybernetic sculpture (to which the machine as a responsive environment naturally belongs).

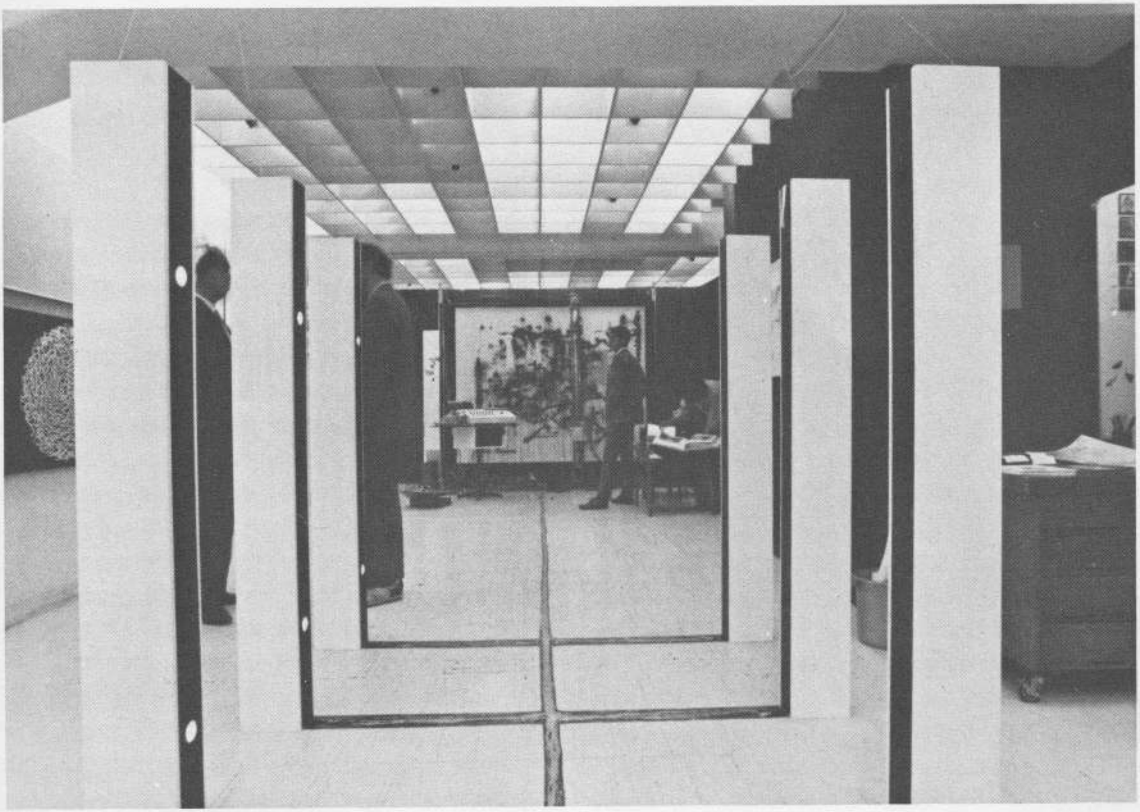
Painting by remote control is nothing new. Tinguely produced painting machines called Metamatics in the late 1950s. His machines held a sheet of paper and a moving arm with coloured pencils of one's choice, which was capable of producing rather predictable pictures. These were usually signed by both the viewer whose work it was in some measure, since he chose the colours and threw the switch, and by Tinguely himself. Other machines like harmonographs also explored the possibilities of variation within a limited set of possibilities. Of any painting machine made to date, the one by CTG is undoubtedly the most sophisticated.



81. Computer Technique Group: system diagram of the *Automatic Painting Machine No. 1*.



82. Computer Technique Group: The *Automatic Painting Machine No. 1* happening zone being televized in September 1968. The canvas on which the *Automatic Painting Machine No. 1* made a painting is on the right.



83. Computer Technique Group: *Automatic Painting Machine No. 1* and the happening zone at the Tokyo Gallery.

Computer-aided art

Computer graphics produced with intentional aesthetic results, are generally predictable, or rather, predictable in comparison with pictures which also involve randomness but which are produced manually, like action paintings, where sequences, patterns and media can be changed in mid-stream. There are no computer-generated pictures in evidence where the idiom, materials or technique are changed in the course of work. Consider for instance a painting by Alan Davie which is being done on the floor and which involves the pouring of paint and free-hand drawing. Suddenly a cat runs into the studio and across the half-painted canvas, Davie's reaction is to paint the word 'cat' and later on the word 'mouse'. Even if the computer can be programmed to incorporate a word or a sentence which would be unpredictable in the middle of a picture, it cannot react to the entry of an animal into a room from which animals, together with other unforseeable interruptions, are barred. It is true that there are other stimuli which might provoke an equivalent response but in the clinical conditions in which computers are usually used there is only a small range of these in comparison to what might happen in an artist's studio. The fundamental difference is very simple. With computer art, at least that which is produced by writing a program, the artist must know exactly what it is he wants to do and in what areas he is permitting randomness to occur. All this has to be done before the actual image emerges. With action painting, the program is being written as the work on the picture proceeds. This is true to a lesser or greater extent of most pictures, although it is the element of chance in action painting that is always stressed, as indeed it is also the one which is emphatically pointed out by those who produce drawings with the aid of computers.

Professor Max Bense, whose theory of generative aesthetics has been based on computing procedures, has pointed out that randomness involved in computer graphics replaces that aspect in art which is described as intuitive. Thus the randomizing procedures in computer technology are analogous to an artist's intuition. This theory is questionable but it shows that attempts are being made to find equivalence between human activities in the sphere of creativity and the realization of those activities with the aid of a cybernetic device.

An experiment yet to be conducted is that of analysing the preoccupations, interests, capabilities and skills of an imaginary artist and then seeing what sort of output a person of this type might produce. Alternatively one could feed into the computer information about various artists working in a particular style in order to find those images which epitomize it.

The psychologist Michael J. Apter pointed out that a major relevance of cybernetics to art is that:

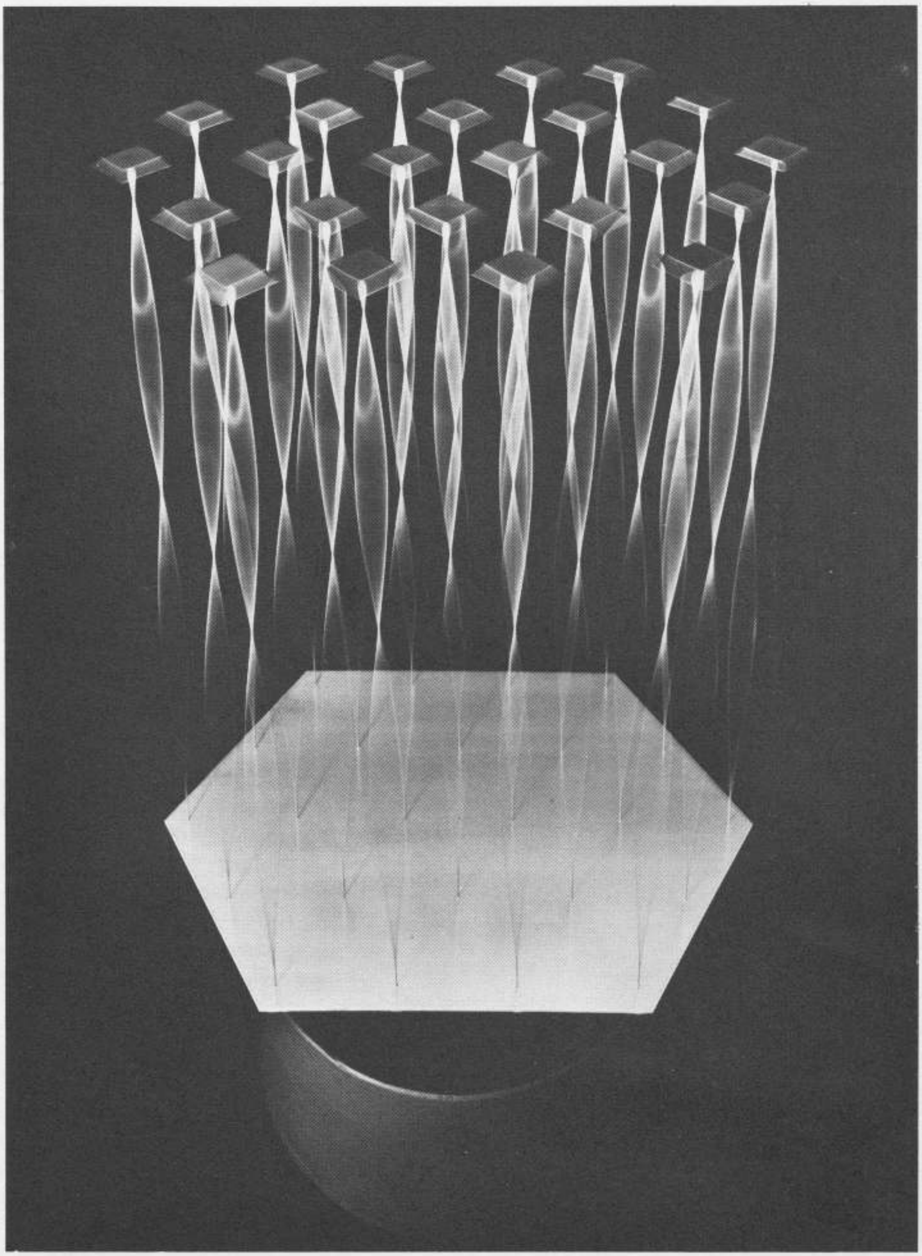
> cybernetics, in its quest to understand complex human behaviour may be able to throw light in due course on that highly complex type of behaviour called 'artistic' – a type of behaviour clearly involving control and communication.

Such analysis may be purely speculative at the moment, but meanwhile the use of computers in art has captured in a general way the imagination of artists and stimulated the pursuit of certain idioms, styles and forms of art. Among them must be counted permutational and serial pictures, as well as those which convey the spirit of computer technology like constructions which incorporate computer tape, electronic circuitry, computer typefaces and other bits of hardware. The notion of feedback has entered the world of happenings as well as various environmental constructions, where audience participation and reaction can alter the appearance and even the content of the work in due course. One could say, for instance, that cybernetic sculptures such as those by Tsai are the extension or bridge between computer art and kinetic art. Tsai's sculpture, illustrated on page 91, consists of rods surmounted by polished metal plates vibrating in harmonic motion. There are two stroboscopic lights directed on to the sculpture. Clapping or other sound disturbance affects the frequency of the flashing lights and the vibrating rods suddenly appear to move with a gentle undulating motion. Other cybernetic sculptures produce sounds as the visitors cast shadows on a series of photo-electric cells, or move across a room; others still, react with movement or flashing lights. These works, however, are more specifically involved with the notion of cybernetics at large than the role of the computer, as such, in the visual arts.

The involvement of artists with cybernetics in particular, and technology in general, has been responsible for the foundation of a number of groups and societies whose aim is to provide a link between those conventionally called artists and the others conventionally called engineers and technologists. One such organization in Argentina is the Centre of Art and Communication of the Foundation of Interdisciplinary Research, or CEAC for short. Like many similar groups CEAC is concerned with the means and techniques of communication as a link between the social, creative, and technological aspects of contemporary life. What is interesting in this context is that the stress is laid on the means of communication rather than the content. CEAC is concerned above all with universality of communication which is encouraged by the fact that computer languages are international.

In England the Computer Arts Society was started in 1968 after the initial impetus of the Cybernetic Serendipity exhibition at the Institute of Contemporary Arts, London, which dealt with the computer and the arts. It is the only group of this sort whose efforts have been directed specifically towards the popularization of computer technology and acquainting artists in a practical way with the new possibilities offered. CAS has held demonstrations, symposia, and exhibitions designed to demonstrate the computer as a tool for creative activity, in the visual arts as well as in music and poetry. In two years CAS has become an international body with 500 members throughout the world.

The oldest organization attempting to make links between creativity and technology is the American Experiments in Art and Technology, or EAT for short, which was set up in New York in 1966 to encourage collaboration between artists and engineers which involves the sort of technology which is not accessible to the layman. The organizers described it as:



84. Wen Ying Tsai: cybernetic system 1969. Harmonic sculpture of stainless steel with concrete base, stroboscopic light, audio-amplifier and multi-vibrator. Collection: Addison Gallery of American Art, Andover, Mass.

an international network of experimental services and activities designed to catalyze the physical, economic, and social conditions necessary for the inevitable cooperation between artists, engineers and scientists, and members of industry and labour. We see the EAT network as a new form of university and laboratory to which any individual has access for experience and experimentation. The aim of the network is to create possibilities for mutual contact between individuals in a live, responsive society.

One of the ideas was to enrol both artists and engineers as members of the organization, and thus put artists in touch with engineers whose specialized knowledge would help them with projects they were unable to realize on their own. Proposals ranged from those that still seem impossible to create, such as a walk-through mirror and objects that disappear, to others that seemed impossible at first but for which an eventual solution was found. Here are a few proposals submitted to EAT which give an idea of the range of interests:

1. A disappearing paint;
a. I am interested in encouraging teenagers to paint designs, decorations and murals on the outside of certain buildings to release the inhuman rectangular drabness of so many modern cities.
b. However, a major objection will always come to such decorations from people who will say, 'How will we ever get rid of them?', and they are quite right. One of the big problems with all art is how to get rid of it.
c. Therefore, I propose inventing a type of paint which can be painted on bricks or cinderblock, but which will change chemically with the first freezing weather, disintegrate to a powder and blow away completely. As soon as such paint is invented, I foresee a large use for it.

2. I would like to work with a technician on devising a new way to use the hologram in order to create interchangeable circuits that could be grafted. While a process of grafting is taking place, another machine would compute the data and duplicate this data into a three-dimensional structure. This machine would be free and available to any artist or technician as a new tool.

3. My technical problem is the development of a hand-held radar-type device, which will function by alterations in sound when it encounters an object within a certain practical range. The persons released into the room will be able to guide themselves to the appropriate exit.

4. I have two projects:
a. Electromagnetics: the construction of a variable participation sculpture, a non-compositional work of art (open-ended). I have been using a light bulb as a resistor to a soft iron hand-wound electromagnet (with AC/DC rectifier which I haven't got into the system yet). Results are disappointing so far. I need help.
b. This project involves the use of a laser hologram unit for a growing sculpture. Kinetics in a different sense than is usual – would mean a variable film unit and might result in something usable within technology. I have an idea for making the diffraction plate variable.

5. I am a painter, sculptor and a musician. I would like to develop a human-scaled electronic keyboard to be played solo and with a group, in a spontaneous conversation. I would like to investigate laser beam projections and other light phenomena for drawing in space with light. I would also like to study grid structures with a computer. I would like to be a representative for a number of downtown Manhattan-based artists centred around Park Place Gallery in order to merge the idea of the artist and engineer with our own projects involving architects and city planners.

EAT held a competition for works produced as a result of artist/engineer collaboration. These were shown in The Machine exhibition at the Museum of Modern Art in New York in 1968. EAT has also been responsible for a number of exhibitions, projects for world fairs, performances, as well as lectures, meetings and publications. During the latter part of the 1960s it has become increasingly clear that organizations such as EAT fulfil a very real need of both technologists and artists in their desire to extend their individual activities.

The effect of the computer on the arts

The role of the computer in the realm of the visual arts is not limited to the production of graphics, sculptures, computer-aided action paintings, films and cybernetic devices. There are other functions involved which, by being more generalized, are likely to affect society at large in a more fundamental way. Among others, the computer can help to bring about two very specific things: first of all the *musée imaginaire* – the museum without walls, and secondly an entire range of multiple originals in quantities and at prices which would bring them into the orbit of the supermarket. In both cases the computer could be the tool for the democratization of art in its availability, even if it could do very little about making art more comprehensible or desirable to a wider public.

The *musée imaginaire* is a museum of an infinite number of reproductions. Professor Abraham Moles, the champion of the project, when asked about the discrepancy between the quality of an original work of art and its reproduction, said that what was important was what the viewer could gain from the object, be it genuine or a copy, and not its innate value. He referred to the authenticity of the occasion in the confrontation of the viewer and the work of art or its copy. The possibility that the reproduction might in fact have a greater appeal than the original work of art, Moles found quite irrelevant and admitted that this is more likely to be the case than not. Michael Noll's experiment with a computerized version of a Mondrian drawing is one of the instances which prove this point. In the case of the real Mondrian only a small percentage were able to identify the original, and the greater number of those who saw both preferred the computer version. Whereas Noll found these results discouraging, Moles would tend to see them as support for the case that, providing that there is such a thing as an art experience, it is not significant what brings it about.

The *musée imaginaire* poses the problem of deciding whether the original work has a more important function than that of being a model for the unlimited copies on which they are based. And if indeed it is merely a prototype or matrix for a multiple, beyond this does it have any role or value at all? While the copies can be made in lasting colours and lasting materials, the original will continue to fade and disintegrate however imperceptibly. This issue is likely to raise more dissent than the mere fact of production of computer-aided unlimited multiples which are not copies.

Multiples can be made in such a way that each one could be slightly different from the others. According to Moles, this would mean that each buyer would in fact have an original. The price would still be very low since the computer can be programmed to make a single adjustment each time with the use of a random number generator. The multiples can then be manufactured from the nearly infinite number of drawings provided.

If this does come about, and our supermarkets become flooded with objects serving no other than spiritual functions, at low prices and in great variety, a foreseeable reaction is likely to set in. The differences between a run of individual computerized multiples are likely to be insignificant. The notion of possessing a work of art as something unique will not be so easily replaced with a multiple which is common by the mere fact that it is one of many. The possibility of seeing a copy or a version of a multiple, which one owns, not only in other people's homes but in the supermarkets and offices, cannot but devalue in most people's eyes the multiple in question. Democratization of art has many important justifications – availability and access to art is a human prerogative, but this does not cater for the instinctive desire to possess something unique and the urge to be different. The very fact that a cheap chain-store, such as Woolworth, despite modern techniques of reproduction, sells original hand-painted pictures in oil on canvas, is significant. This may be only a pointer but there is no doubt that these pictures fulfil a need which education and sophistication are unlikely to alter radically.

Computer art in context; comments at large

Computer art is the last stance of abstract art. The development of abstract art can be divided into several clearly defined stages. The first could be considered the discovery of the possibility of creating non-objective models in a spirit other than that of decoration. Among the artists who belong to this particular section are Gabo, Mondrian and

Kandinsky. The heroic advance which implied a departure from the accepted cannons of mainstream modernism by creating a mainstream abstract movement is illustrated by abstract expressionism. This was followed by the concentration on the pure relationship of form and colour without any obvious sociological and ideological implications, as in the work of Stella and Kelly. Today, in the early 1970s, abstract art as such is no longer the tool or the means of experiment.
Computer art has brought about the possibility of unidentifiable and impersonal abstraction, even to the extent that those who have programmed the computer have on occasion failed to recognize their own output. Because pre-programmed computer art is an extreme departure from work controlled by hand, from it will undoubtedly spring something quite different and unexpected. It may be merely the basis on which a new art form will be reformulated. It is not a dead-end, but a manifestation which is sufficiently new and, to date, sufficiently unexplored in art's known realm, to become an influential force in the future.

The relationship between art and technology has given rise to comments which are sometimes heroically nonsensical, and at other times pinpoint the essence of this relationship and its possibilities.

Creative collaboration is possible between the designer and the new computer technology,

was one of the comments from the proceedings of a conference on design.

Oliver Selfridge of MIT Lincoln Laboratories defined computer art as:

any visual output with artistic intent, where the ingredient of art may be very small indeed.

Some of the best comments on the subject were made by Nak June Paik, the Korean artist living in New York:

It is of historical necessity, if there is historical necessity in history, that a new decade of electronic television should follow the past decade of electronic music. Variability and indeterminism is as undeveloped in optical art as Parameter Sex is underdeveloped in music. As collage techniques replace oil paint, the cathode ray tube will replace the canvas. Some day artists will work with capacitors, resistors and semiconductors as they work today with brushes, violins, and junk.
There are 4,000,000 dots per second on one television screen, just think of the variety of images you can get. It's so cool. It's like going to the moon.

The most poignant comment arrived in the form of a letter from the Computer Technique Group in Tokyo, in December 1969:

Dear Miss Jasia Reichardt
How about your book *Computer Graphics?*[1]
We must report you many things.
First, we dismissed our Group on 1st October 1969. We are very much grateful for your kindness to us, and we will never forget it.
The reason why we dismissed our group is very much complexed. One reason is that so-called collaboration of

[1] When this book was first mooted in 1967, its title was to be *Computer Graphics*.

engineers and artists is not so easy as we had expected. They are different from each other. And one reason is that we must treat computer more deliberately, because the machine becomes more and more complicated existence in our life.

We can't live without seeing many things occur around us. We think that we must look at ourself over again including computer, art, science, student power, social revolution, andso.

Perhaps you may have seen our movies (16mm, colour) exhibited at 'On the New Eve of Tomorrow'. The movies are titled as follows:

1. 'Computer movie no. 2', 10 minutes
2. 'Computer + something', 9 minutes

The movies are produced by the aid of IBM 360 model 65, and IBM 2250 graphic display system. The programming language is FORTRAN. The movies were entirely produced by CTG, from programming to photographing, to editing.

I think computer art should be explored by artists, not by engineers, or someone who is not both.

I found out several things while producing computer a[rt]

1. Computer can treat only symbols not meanings
2. Through computer we can handle images, pattern[s and] symbols by means of symbols
3. Through computer, we can control images, patterns [and] symbols by means of logic
4. We must always be careful of the difference between symbols and meanings of the symbols, when we use computer.

In any way, computer can't understand the meanings of program, work, art and our life.

While producing computer art, I found myself staying sti[ll] as an engineer, but not the same as before.

I must think everything over again.

Thank you for your kindness

Yours sincerely

Haruki Tsuchiya

The final word of affirmation that the world goes on, with or without computers, also came from Haruki Tsuchiya in the form of a Christmas card.

Best Wishes for A Merry Christmas

and

A Happy New Year

I married on 23, November. I would like to be a man, not artist, not engineer. a man.