COMPUTER ART

COMPUTER ART
Edited by Dr. Laxmi P. Sihare

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Acknowledgments:

Acknowledgments:

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Catalogue No. 4   Beckmann, Otto and   Computer Drawing, 1969
                      Grassl, Alfred   12" x 7"

Computer Art: Possibilities and Limitations

Dr. Laxmi P. Sihare

In the present state of computer technology, a computer, on its own cannot create works of art; however, under the guidance of creative artists, sculptors, architects, poets and musicians, its artistic manifestations excel in technique, variety and complexity of forms and their amalgamation. 157 works of art—graphics, computer poems, computer music and computer films—included in this exhibition amply testify to this, refuting reservations expressed by conservative critics. Evidently, under precise instructions, a computer comprehends at least some of the main principles of Neo-Plasticism (catalogue nos. 78, 79 and 84)[1], Constructivism and Structure (catalogue nos. 7, 10, 101, 136 and 137)[2], Optical Art (catalogue nos. 86 and 102)[3], and "Moire" pattern (catalogue nos. 40, 41 and 132)[4]. This becomes even clearer as one examines some of these computer creations in the light of the fundamental tenets of these art movements. While explaining the basic principles of Neo-Plasticism, Piet Mondrian wrote:

"The fundamental law of dynamic equilibrium gives rise to a number of other laws which relate to the constructive elements and their relations. These laws determine the manner in which dynamic equilibrium is achieved. The relations of position and those of dimension both have their own laws."[5] Elsewhere Mondrian stated:

"Pure Plastic manifestation is not a reproduction of life. It is its opposite. It is the unchangeable, absolute, in opposition to the capricious, the changeable. The absolute is expressed by the straight line. Painting and architecture, according to the new aesthetics, are the consistent realization of a composition of straight lines in neutralizing opposition and therefore a multitude of the duality of the unchangeable rectangular position."[6]

Similarly, Naum Gabo explains his Constructivist manifestations:

"They are a factual force and their impact on our senses is as real as the impact of light or of an electric shock. This impact can be verified just as any other natural phenomenon. Shapes, colours, and lines speak their own language. They are events in themselves and in an organized construction they become beings—their psychological force is immediate, irresistible and universal

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to all species of mankind; not being the result of a convention, as words are, they are unambiguous, and it is for that reason that their impact can influence the human psyche; it can break or mould it; it exults, it depresses, elates or makes desperate; it can bring order where there was confusion and it can disturb and exasperate where there was an order." [7]

Finally, George Rickey discusses the fundamentals of "Op" Art:

"The optical properties of lines (distinct from their descriptive function as maps or depictions), and of such relational situations as convergence, tangents, super-imposed grids and ambiguous or multiple images are hard to explain but, explained or not, they become extra-ordinarily powerful tools in the hands of an experienced and sensitive artist . . . . A work by Bridget Riley or Anuskiewicz can make one feel dizzy or sick: beauty and integration are not their purpose; sensation is . . . . Optical phenomenon can also be used to warp space, to bend it, fracture it, force it back or forward from the picture plane. Vasarely was a master of this . . . . Moire is the commonest of the devices employed for optical impact. It originated in the Orient and came to Europe in the Middle Ages. Two layers of ribbed silk were pressed together with the ribs very slightly crossed, which gave a watery effect. When two thin lines are seen crossing one another, a thickening—like a bead—appears at the intersection where both lines gain by the width of the other at that point. This bead appears to move along the lines as the point of intersection changes. When grids of many parallel lines are superimposed, successive inter-sections become a secondary pattern which changes as the spectator moves." [8]

Computer's greatest gift to the creative artist is speed, especially in exploring instantaneous variations and alternatives. A computer is an accurate, fast and tireless technician. Once the data is provided, the computer's role is to calculate and display the results pictorially on a film or on the glass screen of a cathode–ray–tube. The artist could edit the image or could simultaneously interact with the machine while it is working. He can order a computer to make the necessary changes, such as "delete the line" or

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"move that line over there" etc.. A computer can draw thousands of times faster than a professional draughtsman. By using a computer, city planners and architects can have their plans drawn examine the effects of modifications and try out numerous variations which, under normal circumstances, they would never attempt. In short, whatever the artist decides to create, the concepts are immediately translated into visual facts; the moment of artistic idea and the moment of its creation become analogous.

Computer graphic is likely to revolutionize animated movies and the basic concept of the inter-relation of sounds and colour —one of the favourite subjects of artists since the pre-Christian era, both in East and West. In this direction, John Whitney's film: Experiments in Motion Graphics and Permutations, IBM., is an example par excellence. While the potential application of computer graphics would unfold new directions —an ingenious use would reveal panoramic vistas for the inquiring mind—it would equally demand dedicated endeavours from the users, as explained by Bruce Cornwell:

"When I used to make films with ordinary animation, it was so hard to make changes that I froze most of my decisions in advance. Now that I feel free to experiment, I try ten times as many approaches. So, although I can work three times as fast, it takes about three times as much effort"[9]

Is it possible to achieve a personal style by an artist, using a computer as an aid in creation? Artists, such as Grace C. Hertlein, are optimistic, believing that "theoretically at this point, computer painting should become more complex technically and aesthetically."[10] She is also of the view that:

"The limits of the computer artistically are the limits of the artist's imagination, and the degree to which the artist accepts the computer as an aid to creation. If an artist can absorb technology, learn to think in new ways and become liberated within such technical usages, he can transcend the conditions of using a complex machine and express his vision poetically, in a personal way. Thus ultimate freedom for the artist within technology can be achieved through acceptance, discipline, excellence in technology and artistry." [11]

Catalogue No. 28   Fetter, William A.   : Computer Drawing, undated
23½″ x 17¼″
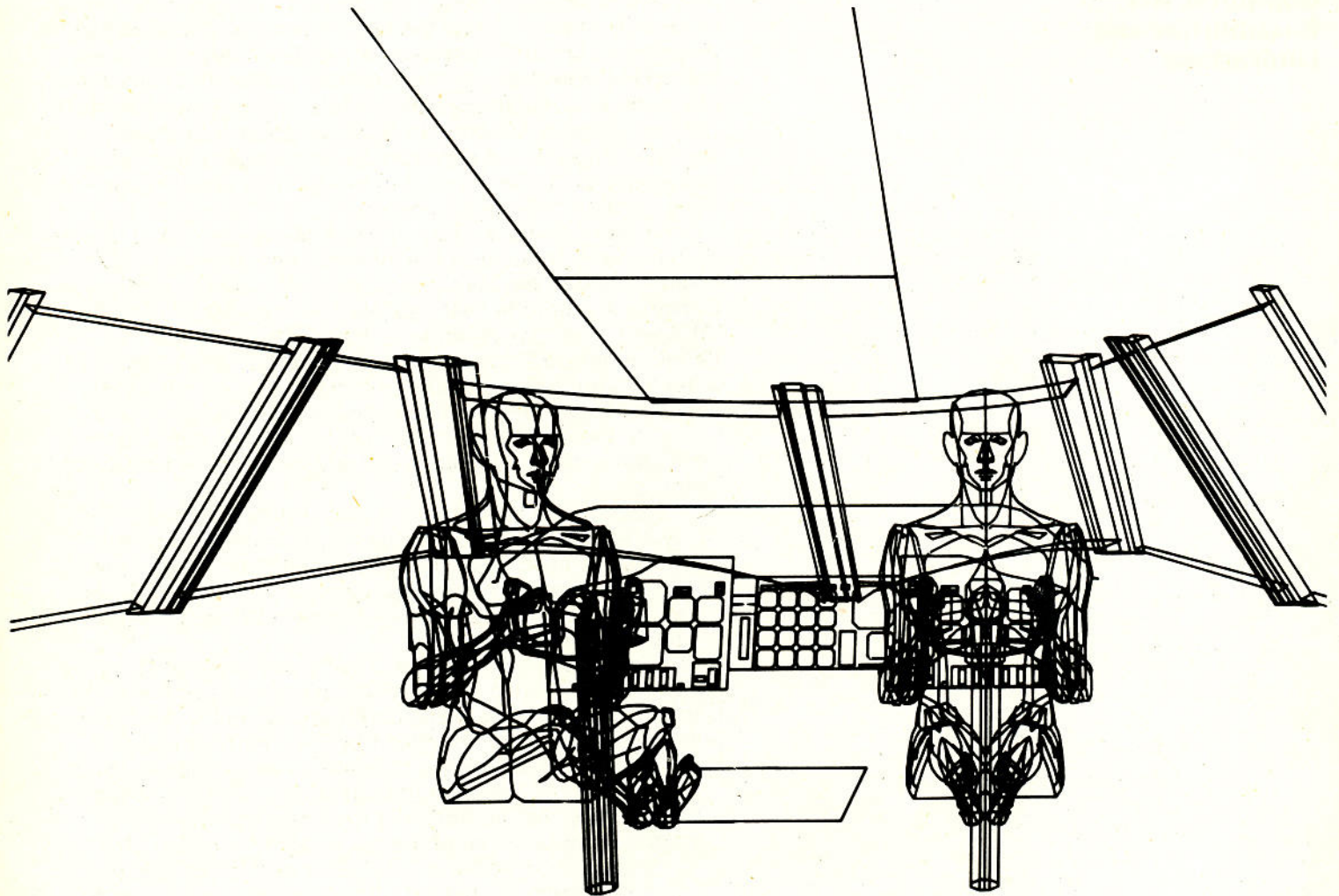
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In this optimistic assessment, the major obstacles are: the limitation of spontaneity, the lack of emotional response and the economic handicaps, especially if the computer is to be made available on a large scale to struggling artists. It is hoped that the business and technological establishments—both in private and public sectors—would find appropriate solutions to ensure a happy union of artists, art, economy and technology.

Notes:

1. Compare these works of computer art with Mondrian, Piet: Composition in Gray, 1919; and Composition with lines, 1917; published in Seuphor, Michael: "Piet Mondrian, Life and Work", New York, Abrams, p. 265 and p. 377 no. 233, respectively.
2. Compare these works of computer art with Gabo, Naum: Linear Construction, 1942-43; and Lippold, Richard; Flight, 1963; published in Kepes, Gyorgy ed.: "Structure in Art and in Science", New York, George Braziller, 1965, p. 19 and p. 152 respectively.
3. Compare these works of computer art with Riley, Bridget: Fall, 1963; published in Rickey, George: "Constructivism, Origin and Evolution", New York, George Braziller, 1967, p. 182 no. 4.
4. Compare the style of these works of computer art with Stanzak, Julian: Tress Passing, 1966, and Wilding, Ludwig; Interference of 2 Structures in 3 Dimensions, 1961; published in Rickey, George Op. cit., p. 188, no. 17 and p. 190 no. 22.
5. See Mondrian, Piet: Plastic Art and Pure Plastic Art, 1934; in Mondrians's "Essays", 1951 edition, New York, Wittenborn, Schultz, p. 57.
6. Cited in Jaffe, H.L.C.: de Stijl, 1917-1931, The Dutch Contribution to Modern Art, Amsterdam, J.M. Meulenholf, 1956, P. 60.
7. Cited in Read, Herbert: Icon and Idea, New York, Schocken Books, 1956, p. 135.
8. Rickey, George, Op. Cit. pp. 180-189.
9. Cited in Boehm, George A.W.: New Graphics for Arts and Science, printed in "Think", March-April, 1969, p. 30.
10. See Hertlein Grace C.: An Artist Views Discovery through & Computer–Aided Graphics, printed in "Computers and
11. Automation", August, 1970, p. 26.
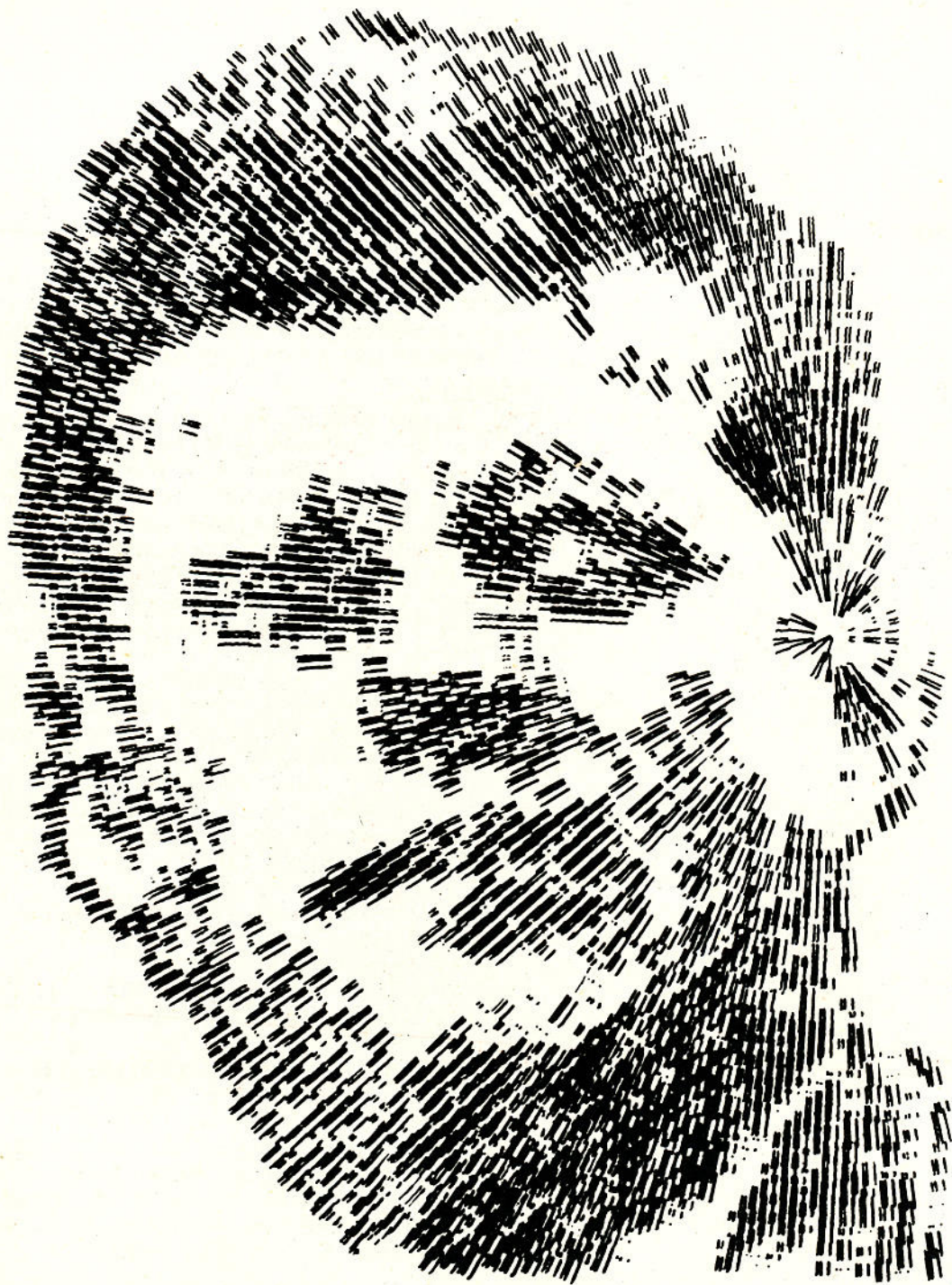
Catalogue No. 124   Franke Dr. Herbert W.   : Analogue Drawing, undated,
23¾″ x 15¾″

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Herbert W. Franke

In contrast with classical machines, which convert energy, the computer processes information. It is a means towards the conception of structural order and at the same time offers itself as an aid to producing aesthetic order. That which evolves from this is known today under the title 'Computer Art'.

Objects of computer art are mostly produced with automatically controlled output devices, plotters, teleprinters and loudspeakers. What is important, however, is not the automisation of the phase of production, but that of the conception, of the 'invention' of the work of art. Whereas, for example, in music the employment of physical machines as output devices—the instruments—is well known, the delegating of the phases of 'design' to the machine is something fundamentally new. The employment of computers always forces towards the clear formulation of the problems, to the exhaustive elaboration of faultless working plans and to the exact description of the processes of realisation. This results in the need, in both the theory and practice of art, for a new vocabulary, disregarding the blunt edges of mere associatively and allegorically comprehensible concepts, whereby the efforts to secure an exact system of aesthetics receive new encouragement. In order to produce computer works of art, a theory of art oriented towards the natural sciences is not necessarily a prerequisite. One can work by the trial-and-error method, i.e. move towards an unknown and unplanned goal through experimentation, or one can use the support of statistically produced laws, the understanding of which has not yet succeeded within the framework of a universal scientific-cybernetic model. On the other hand the best way to work out aesthetic programmes would be to be able to understand the function and the way ot producing an effect of art. Latest results of research, especially in the cybernetic field of work, lead us to suppose that the key to art lies in the realm of perceptual and conceptual phenomena.

The explanation of the phenomenon, art, would appear to be found on a very generalised plane of human behaviour. That is proved by the fact that the computer is usable in all realms of art—from music to graphic art and sculpture, film and poetry. In the characteristics of the programmes certain

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analogies become evident which transcend all the differences of the forms of art—for example the co-ordination of redundancy and information, which expresses itself technically in the employment of random-generators. All work in computer art today is a contribution to aesthetic research — even if it is not intended. And it is this aspect which is perhaps most notable in computer art today.

Computer Art in Public

Computer art presents itself to the public not as a scientific working method but as a field of aesthetic creation, sometimes even with the claim to recognition as art. Though this question is secondary in the context, the contact with the outside world, the confrontation with criticism and the resultant competitive situation is, without a doubt, beneficial. It is forced to present itself for discussion and must endeavour to offer objects which do not need to shy from comparison with recognised works of art.

In this context it must be regretted that until now the number of professional artists who have developed some interest in this field is relatively small. The greater part of the work comes from technicians, scientists and mathematicians. The initial purposes were often research work, e.g. the investigation of sight and hearing of the development of technical installations, as for instance with output devices. Thus it is often difficult to say when the first examples of genuine computer art appeared in the individual areas.

The first melody composed by a computer dates back to 1956. It is entitled 'Push-Button-Bertha' and was programmed by M. Klein and D. Bolitho on a Dalatron in the USA. Better known is the 'Illiac Suite' by L.A. Hiller and L. Isaacson, first performed in 1956 at the University of Illinois.

The first exhibition of computer drawing took place in 1953 in the Sandford Museum, Cherokee, Iowa. It was concerned with the 'Electronic Abstractions' by B. F. Laposky, which he had designed with the help of an analogue-calculating system and had presented on the screen of a cathode-ray-oscillograph. It was only in 1965 that computer drawing from large digital computers was shown in public. The first exhibition in Stuttgart in January 1965 was by G. Nees. In the same year other 'authors' presented digital drawing to the public—among them A.M. Noll and F. Nake.

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Computer poems by people like G. Stickel, who later collaborated with O. Beckmann and S.R. Levin are well known; work began in 1963. Even earlier in 1959 T.T. Lutz had experimented with 'stochastic texts'.

It was a long time before works of computer art were noticed by the public. The first world exhibition of computer drawing took place in the Howard Wise Gallery in New York in 1965. The other biggest exhibitions of computer drawing were:

> Cybernetic Serendipity, London 1968
> Tendencija 4, Zagreb 1969
> Computerkunst — On the Eve of Tomorrow, Hannover 1969

Worth mentioning is a series of annual competitions in computer drawing run by the magazine 'Computers and Automation', the first of which took place in 1963.

Directions and Computer Drawing

A decisive question for the practice of computer drawing is whether new visual realms will be discovered with the help of computing machines or whether they will attain better results in the traditional field.

It is understandable that the employment of the computer in artistic graphic creation has begun in the area where the style is closest to the technical laws of order to which automatic drawing devices are primarily suited. From the presentation of mathematical laws to the models of cubist origin is only a step. The geometric structure of such work, the clear drawing of lines and the minimum of complexity greatly relieves the task of programming. Thus it is, that those authors who began on digital drawing at the same time but independent from each other (viz. Nake, Nees and Noll) have produced work of a certain structural similarity. In these first experiments computer drawing did not yet get beyond what would have been equally possible with traditional means. Nevertheless the computer is in a position to open up new territory in the realm of cubism. Whereas with ruler and compasses only the simplest algebraic structures are attainable, the computer can operate with curves of a higher order. It succeeds in particular with the superimposition and co-ordination of curves into larger form complexes with an exactitude that no human artist could achieve. This precision, however, is the pre-condition for satisfactory results, since

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without it the fine adjustment of the microstructure would not be possible. This field of work is moreover better suited to the analogue computer than the digital.

Several authors have turned early on to the depiction of objects, for example C. Csuri and the CTG or Computer Technique Group in Japan. Most famous are the human figures programmed by W.A. Fetter, which served primarily to solve ergonomic problems. Like man, the computer must first receive information about the shape of the object; photographic equipment and television cameras serve this purpose. The great attraction of computer drawings concerned with the reproduction of objects lies in the possibility of building up, reconstructing and demolishing visual arrangements. Thus not only simple superimpositions are possible, as we know them from photography, but one can, for example, interrupt the order systematically (and intentionally) and thus arrive at completely new visual sensations. Furthermore, it is possible to combine several pictures by means of miscalculations — again a method which would be inconceivable without a computer. The possibilities which the large computer offers in the world of objects have only just started to be realised.

Means of Computer Drawing

The equipment which authors/creators employed for the production of computer drawings were initially all intended for technical purposes. Apart from this the development of visual output devices has not yet reached the stage which one would like. Electronic output devices, i.e. television screens and fluorescent screens of cathode-ray-oscillographs, are to be distinguished from mechanical drawing equipment.

The teleprinter machines and rapid printers, which are occasionally used for graphic purposes, can only be regarded as makeshift. Mechanical drawing equipment, the so-called plotters, work quite slowly and are liable to disruptions. They have the added disadvantage that they only provide strokes; shade surfaces have to be reproduced by many thick strokes close to each other. They can reproduce neither grey nor colour sequences and thus restrict the graphic possibilities considerably. On the other hand they do have the advantage of rendering the sketch on to paper, thus supplying an artistic object in the normal sense. Because of the costliness of the

Catalogue No. 77   Nees, Dr. Georg   : Serigraph, undated,
                                             23″ x 33½″
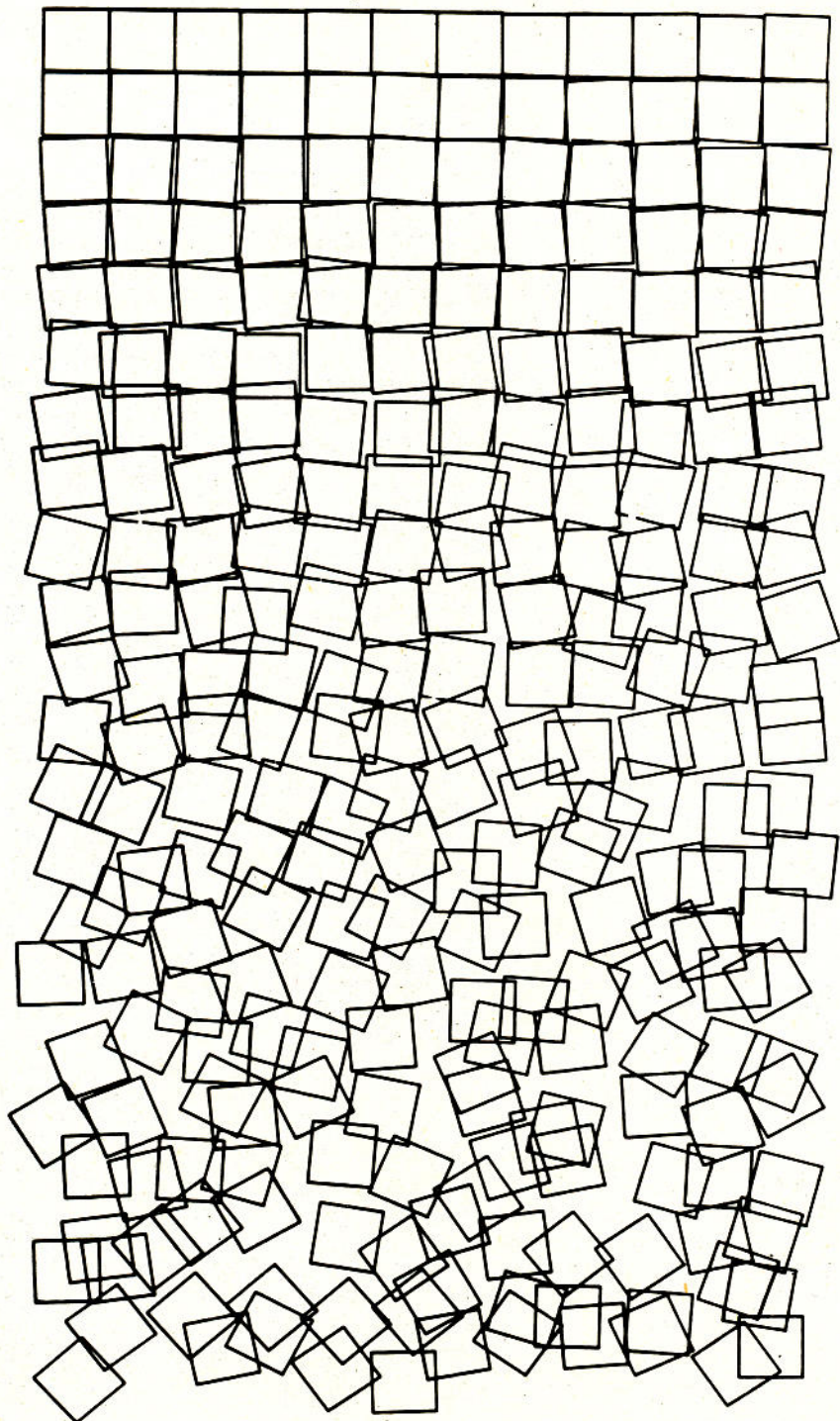
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process one usually has a few prototype sketches made by the plotter and then one uses a duplicating process like screen printing. In contrast with the plotter the screen device offers several advantages. Above all output is quick—in fractions of a second; and it is thus possible, for example, to work by visual control, a procedure whereby the possibilities of the computer are really exploited. It is also possible to depict as many runs as one likes, and colour reproduction presents no great problems. Against this is the necessity to document the formations by a further process; usually photography is used for this. The pictures captured in this fashion are thus burdened by the fault which has always been attached to photography, and makes it difficult to compete with accepted forms of art. While the output devices are bedevilled by an impasse (restricted functions), a digital computer can manage practically everything that an artist can demand of it. The difficulty lies rather in determining an aesthetic idea in a programme. It has proved necessary to draw up individual aesthetic programme languages which are suited to definite artistic purposes.

Through these programmes the computer receives a series of instructions from which it then calculates the configuration of the finished work. This can either be displayed during the process of calculation on a screening device, or the data can be first fed on to a magnetic tape or on to a punched tape, by which the output devices are then controlled.

A characteristic of many programmes for aesthetic structures is the inclusion of chance. In the structural scheme some parts remain empty so that they have to be dealt with during the process of realisation. The programme does not provide a single work of art but a whole variety. For the determination of the independent variable a so-called random-generator is employed. Here one can use a physical device, which provides random impulses—a geiger counter for example, which registers the irregular impact of radio-active particles, or a frenzy generator, by means of which disruptions from the atmosphere or from inside the machine are amplified by electronic conductors. To save the expense of this sort of additional equipment, one can also work with a pseudo-random-generator; here one is dealing with programmes which in fact do not provide purely random numbers but

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numbers which one can use in a completely unregulated series. With the help of stochastic programmes, in which chance is involved, elements which are derived from certain poetic laws can be distributed over the screen surface, or one can determine the frequency of shades or shade combinations (in drawing) without having to determine where the individual elements must lie, or—in music—how the notes are built into the general scheme.

The employment of stochastic processes in graphical, musical and poetic programmes is an example of generally valid artistic experiences which are derived from work with computers: it appears to be characteristic of works of art that they are not determined in a completely regular fashion, but that there is a certain freedom in the choice of variables, co-ordinates, size of constants etc. The human artist possesses this intuitively. In computer art the random-generator serves this purpose: this is the cybernetic model of an intuitive organism.

Programming Art

In the sober descriptive terms of exact aesthetics the production of a work of art is expressed as the distribution of elements over a basic screen of points of distribution. The stylistic laws of art thus appear as rules for the choosing and arranging of the elements. The limited extension of the basic screen or frame-work and the size of the repertoire of the elements qualitatively restrict the multiplicity of possible realisations.

The type of basic screen and the physical nature of the elements (signs in the semiological sense) determine the art form. In graphic art the basic screen stretches two-dimensionally over the drawing surface; in music it is linear and depicted by the distribution of the notation. Since linear problems are easier to deal with, a few details should be given about the task of programming, using the example of music. The programming of drawing and sculpture can be differentiated formally from that of music and poetry only in that in respect of the former two, structural relationships in various directions have to be taken into consideration. This does not allow us to draw the conclusion that the same programme is just as usable as the basic scheme for both graphic art and music, the processes of perception, in parti-

Catalogue No. 84   Noll, A, Michael   : Computer Drawing-
Computer Composition with
Lines, 1964, 23¼″ x 27½″
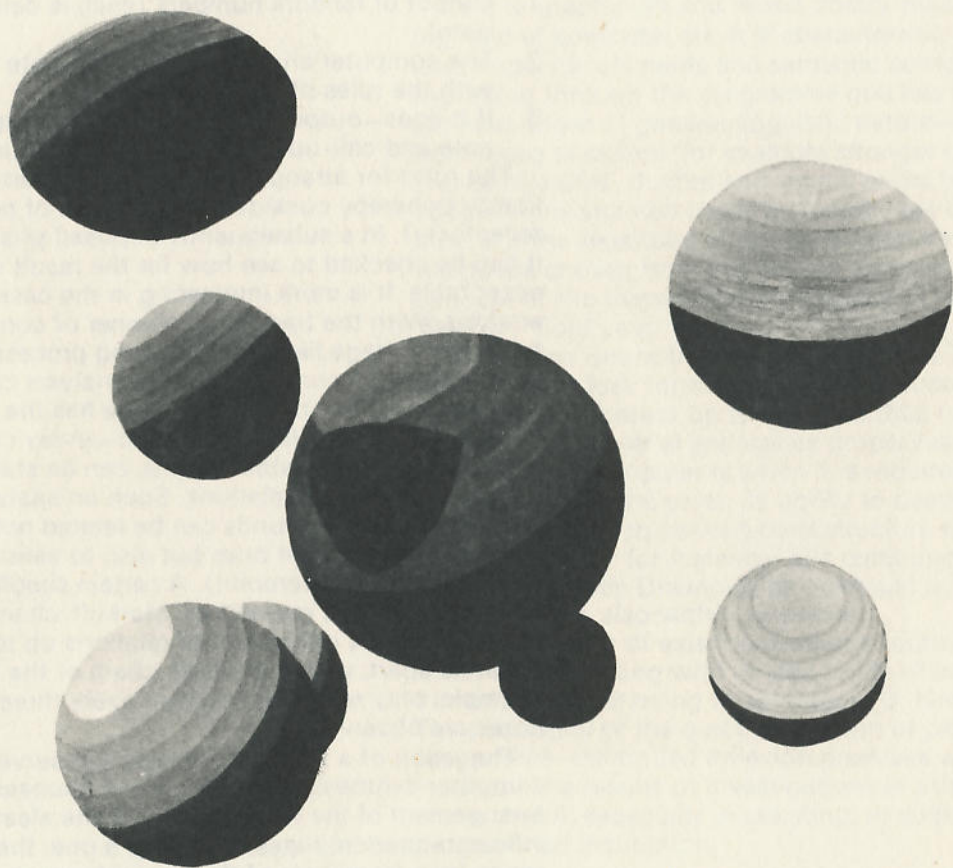
Catalogue No. 95   Raymond, Richard C.   : Nine Spheres in Body -
Centered Cube. Colours
Blue, Green, Gray, Yellow
on White Background, 1970,
16″ x 14″

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cular in respect of the possibility of recognising laws (e.g. shapes), run in wholly different directions according to whether the input goes through visual or auditive channels. The following can serve as a generative principle for computer art:

1. Output of random numbers (each is delegated to one note).
2. The computer checks whether the note given agrees with the rules of the programmes.
3. If it does—output of the note; if not—suppression of that note and call-up of the next random number,

The rules for arrangement can be chosen more or less at liberty (whereby consideration is taken of perceptual receptivity). In a subsequently imposed phase of validation it can be checked to see how far the result is aesthetically acceptable. It is more interesting in the case of a preceding analysis. With the traditional manner of composition this preliminary stage lies in the learning processes of the human artist. In computer art the analysis can take place automatically. For this purpose one has the use of the methods of probability calculation—every conceivable type of law, even aesthetic ones, can be stated by statistically expressible correlations. Such an analysis is admittedly difficult, since the sounds can be related not only to preceding or subsequent ones but also to various others (e.g. harmony and counterpoint). A certain simplification can be achieved with the method of 'Markoff-chains', whereby consideration is only taken of relations up to a certain distance apart; with a Markoff-chain of the third order, for example, only relations between every three successive notes are observed.

The result of a Markoff analysis can serve as a basis for the computer synthesis of music; if one chooses too small an arrangement of the Markoff-chains, the aleatoric (or random) influence predominates; if too big a one, the result is a series from fragments of the original composition (of the input). In this way we can discover the number of notes over which aesthetic rules can be effectively extended. The most interesting type of application would be if one were to express general rules of human perception in the pro-

grammes in the same sort of sense as in a cybernetic theory of art, which sees in the aesthetic process an optimal adaptation of the model of information to the ability and readiness to perceive.

The Computer and other Art Forms

Next to graphic art and music, poetry must stand as the third big field of computer art. It is characteristic of poetry that it uses linguistic elements and semantic content. In the rules expressed through the programme one has to distinguish between those of general linguistic nature—grammar etc.— from those of poetry; for example, stronger rules for the choice of words, rhythm and rhyme could be made. Generally, coherence is attained today by a definitely unsatisfactory trick. For the repertoire of nouns, adjectives and verbs, words are chosen from the field of association of a certain concept of the theme; thus for example 'Christmas', 'Spring', 'Cold', etc.

There is no doubt that the production of language is the most difficult task for the computer—not only in art. The examples we possess up to now can thus only be seen as experimental material and not as proper results. A notable aspect of the computer is, when it is required to operate with simplified linguistic units, its ability to destroy linguistic arrangements or to convert their structure etc.—as in concrete poetry, for instance. The combination of Graphic Poetry (or Poetic Drawing), as practised by M. Adrian and A. Sutcliffe, is also within its power.

The extension of existing aesthetic routines is also simple when one is dealing with related fields of art—in the transition from drawing to sculpture (G. Nees) or to filming. The possibility of the quick realisation of pictures and their programme–controlled inflexion promises well for this medium. The results of investigations in this direction will prove useful, especially in teaching, in audio-visual and programmed instruction.

Future Aspects

As cybernetic aesthetics show, both aesthetic and didactic objects obey the same rules. Thus, through scientific theory and computer technology, two previously separate fields draw closer together. The distinction between conditioned and unconditioned organisation is no longer meaningful,

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as it has been proved that art also serves biological and sociological purposes, if one wishes it do so: as training for our perception—our visual and auditive apparatus, our thought—and as an encouragement to creative activity. It becomes evident that the onlooker, listener or reader is by no means as passive as we have assumed up to now. At the 'consummation' of art his contribution is strong and independent.

Computer art has the power to bridge the gap between artist and public. Aesthetic programmes do not have to be arranged for a statistical realisation and can be disposed towards an arbitrary variability. The viewer can thus involve himself creatively; he can carry on a dialogue with the aesthetic programme and discover, in the process of communication, completed forms which correspond to his ideas. There is already an indication of such possibilities today in such work as the programme KNOBS by J. Cage and L. Hiller or a graphic demonstration programme from IBM by K. Thomas. These examples show that technology does not have to be antagonistic towards art. On the contrary, if one understands art not as a historical phenomenon but as a living evolutionary process, then this evolution can be channelled into completely new areas through technology. Computer art— even though (or better, because) it has only just been born— is definitely more than a passing vogue—it may even play a decisive role in the art of the next thousand years.

Catalogue No. 86   Noll, A. Michael   : Waveform, undated,
                                              23" x 27½"
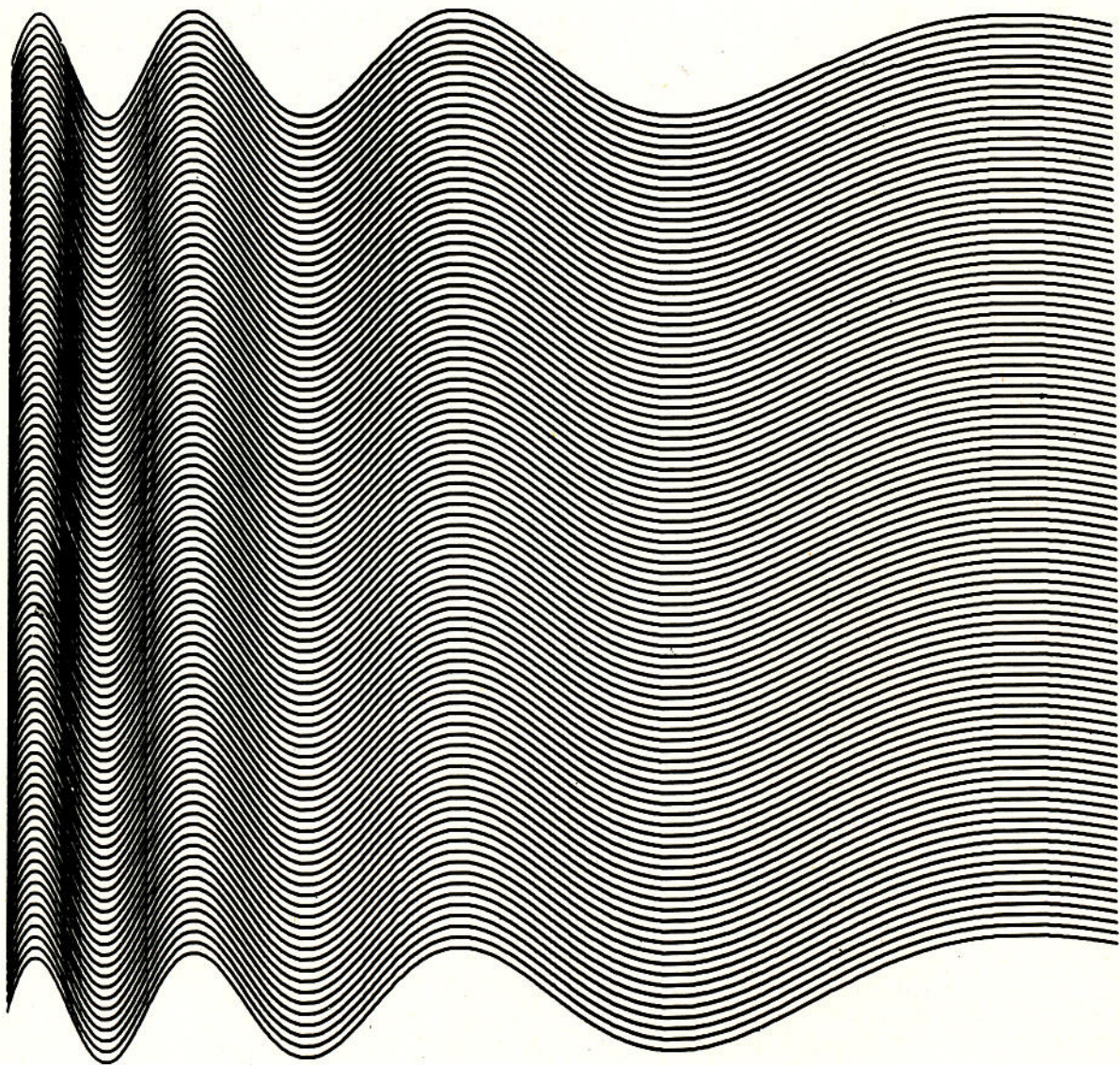
The Computer in the service of Art

S.L. Kapoor
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Within two decades of its birth, the computer has helped revolutionise thought and action in every sphere of human activity. And the spectrum of its applications is growing wider and richer every day.

Today, man is not only using the computer in scientific and industrial fields, but also in the field of humanities. The computer is being used by artists, scholars, musicians and creative researchers as a tool for innovation and creativity.

But it is in graphics that the computer and the arts have collaborated closely. These graphics grew out of pragmatic considerations. Engineers and designers used the computer to see the same design in different perspectives. Soon it was realised that the computer could be used to create desired sequences of drawings in a variety of ways. Today, the process of adjusting a design at any stage of its development is commonplace.

From these beginnings, the computer's role in the graphic arts grew steadily. Today the computer is itself becoming an exciting medium of creativity. In the words of Professor Leslie Mezei of the University of Toronto, "with the computer an artist can go from realism to impressionism to expressionism; and still be working with the same picture. It will not usurp the creativity of the artist, but give him another tool to work with, one with more versatility and challenge than the brush."

The computer helps the artist transcend his physical and technical limitations, enhance exercise of his imagination and attempt experiments in flexibility and variations, otherwise impossible.

Display Unit

The field of computer art has grown so wide that it is difficult to list all the techniques employed. But these broadly fall into three categories. The first is through the use of the IBM 2250 Cathode Ray Tube (CRT), which has a TV-like screen. The computer-programmed graphics and alphameric information can be displayed on this screen at high speed to provide a visual communication between the computer and the user. In addition, keyboards and a lightpen (actually a photocell) provide the user with a versatile means of entering and modifying information.

There can be a number of ways of drawing images on the screen of the IBM 2250 display unit. For example, the artist

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can sit near the display screen and by pressing certain keys on the Program Function Keyboard and entering information by means of the lightpen, he can develop a pattern. This interaction of the artist with the computer to develop a pattern is, however, under a Program Control. Each key on the Program Function Keyboard can be associated with a particular function. The function may be drawing a straight line, a circle, an ellipse, a parabola, a sine curve, a smooth line connecting several points, enlarging the pattern, etc.. By judiciously using these functions, a highly creative pattern can be developed. The artist may even write his own programme to develop some unique curves on the screen.

To explain the mechanics, let us assume that a programme already exists. The artist takes the lightpen and touches it on the screen while pressing a switch by means of his foot. Then he touches the screen at some other point while pressing the foot switch. He can then press an appropriate key on the keyboard to draw a straight line between the two points he has entered on the screen. He may then point to a third point and draw lines connecting both points to the third point. Or he may choose a different function to draw a circle passing through these three points. He may draw a series of circles with drifting origin. This way he can form a pattern on the screen from his imagination. He may then enlarge or contract certain portions or the whole of the pattern. He may even draw three-dimensional patterns and make the computer move the pattern around in space to show different perspectives. The pattern shown on the screen can be filmed to provide a permanent visual display. This process is interactive, man and machine working together, reacting to each other, in a living moving way. The artist can explore a whole new world of forms which offers totally new possibilities like using things like 100-dimensional geometry. The effect is described as drawing with light in three dimensions.

Computer Plotter—

Another method of creating computer graphics is through a plotter. This device can plot on paper in the x-y on the instructions given to the computer. It uses a ballpoint pen which can be chosen in different colours. By using a suitable programming technique the limitation of 30″ wide paper, which the plotter uses, can be overcome, and designs
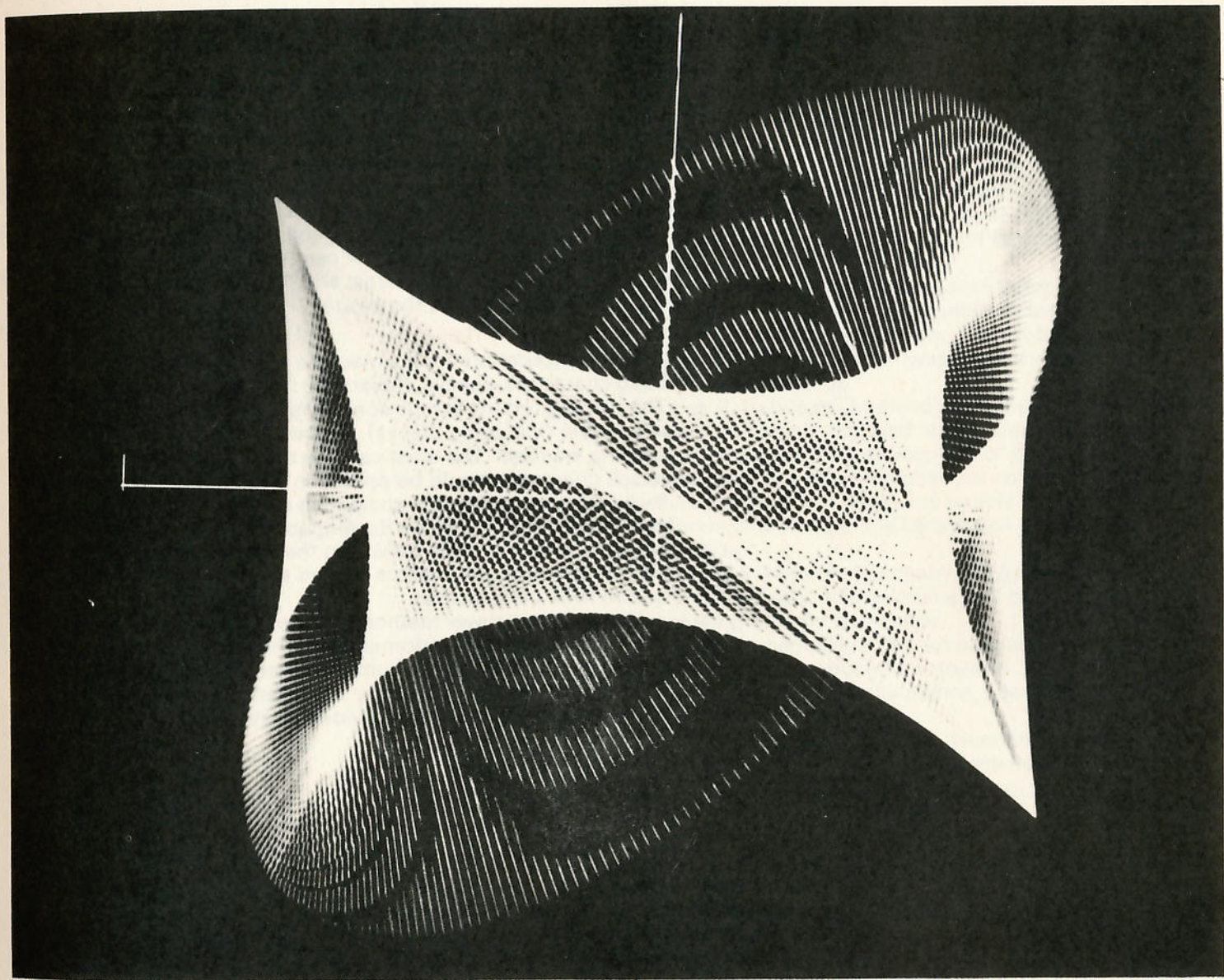
Catalogue No. 101   Sacon, Len   : Computer Drawing in
Colour, Undated,
$13\frac{1}{2}''$ x $10\frac{3}{4}''$ (The work is
the reproduction of an
original photograph.)

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of virtually any size can be developed.

The process is quite simple. The programme resident in the memory of the computer gives instructions to the mechanical arm of the plotter to move the arm between the two points. The programme continuously traces the plotter arm to produce drawings. The results are not only sophisticated in form but also surprisingly sensuous. The key to the drawings lies in the programme. The programme written in FORTRAN may use standard plotter routines which can draw some familiar mathematical shapes. The artist will normally take the help of a programmer to use the plotter.

Computer Printer—

The computer printer is a machine which can print any alphabetic characters, special characters, like : ⅄ @ and numerals. The printing is done at high speed with 132 characters printing in one line (including blanks). Character spacing and line spacing are fixed. The artist can use the spacing chart to indicate which character should be printed in which printable space. By suitably arranging the characters on the printable spaces, many artistic forms can be developed. Cards are punched from the artist's design shown on the spacing chart and a simple computer programme is used to generate the output on the IBM 1403 printer.

However, whatever method of drawing computer graphics is used, the performance of the computer depends solely on the instructions from the artist. The computer by itself is incapable of doing any intelligent work. It is the man behind the computer who provides creativity.

Important dates in the development of Programme-Controlled Calculating Machines (Computers)

1623 Wilhelm Schickard (Germany) designed the first calculating machine that could add, subtract, multiply and divide. It was destroyed in a fire and never rebuilt.

1642 Blaise Pascal, a 19-year old Frenchman, invented the first true calculating machine to survive and be used.

1672 Leibnitz (Germany, France) developed multiplication device; a mathematical conception of the binary numerical system (dyadic). Idea of logical calculation.

1801 Joseph Jacquard, a French weaver, exhibited an automatic loom which used punched cards to control the pattern woven by the loom. For probably the first time in history, information was represented by holes punched in the cards.

1833 Charles P. Babbage (England) developed an 'Analytical Engine' that had all the elements of the digital computer. First conception of programme-controlled automation—mechanical construction, decimal system. Babbage was unable to complete his forward-looking plans because of technical difficulties.

1890 Dr. Herman Hollerith (Germany, USA) developed the Electric Tabulating Machine and cut the data processing time by two-thirds.

1901 The basic numerical punch keyboard and other system improvements introduced by Hollerith.

1908 The Hollerith automatic tabulator, operating at a speed of 150 cards, introduced.

1911 Statistics Reichsamt, in Berlin, Germany, used Hollerith machines to handle commerical statistics.

1913 Burroughs Accounting Machines introduced its difference engine in England.

1914 The Monroe Calculator introduced.

1919 Fredrik Rosing Bull designed his tabulator and sorter in Norway; tabulators with alphabetic printing invented; electric synchronized time clock system introduced.

1920 Printing tabulator introduced.

1923 Electric key punch introduced.

1924 IBM established as successor to C.T.R.

1928 Punched cards increased from 45 columns to 80 columns.

Important dates in the development of Programme-Controlled Calculating Machines (Computers)

1931   Introduction of the first of the IBM 600 electronic calculators series, which handled multiplication and division.

1933   Dehomag produced and introduced B.K. machines which could roll totals and three programme cycles.

1935   Zuse: beginning of development work.

1936   Fingerprint selecting sorter released.

1937   Dehomag signed contract for German census of 1938, requiring 70 sorters, 50 tabulators and 90 million cards.

1938   Schreyer: development of logical structural elements for programme-controlled calculating devices. Construction of an experimental model.

1941   Dehomag developed and constructed a punched card controlled linotype machine—Z3—first workable programme–controlled calculating device; electro-mechanical construction (Relais), binary numerical system, circuit theory, notion of mathematically logical calculating machine.

1942   Special device for wing–measurement (Relais-technology)

1944   IBM's first large scale computer, the Automatic Sequence–Controlled Calculator, presented to Harvard University—special device of wing-measurement with measuring dials attached (first operation control).
Dirks: electronic calculating devices with magnetic storage ; Aiken : Mark I — electro–mechanical technology.

1945   Z4 — electro-mechanical technology, mechanical storage mechanism, binary numerical system, floating point—the only device saved from German developments; Stibitz; Special calculator, Relais—technology, binary numerical system, floating point, calculating with complex figures; Dr. John Mauchly and J. Presper Eckert built ENIAC (Electronic Numerical Integrator and Calculator). It contained two moving parts other than input-output gear. The ENIAC weighed 30 tonnes, taking 15,000 sq. ft. of space. Its speed was 5000 additions per second (compare it to today's computers working in nano-seconds—a nano-second is one billionth of a second).
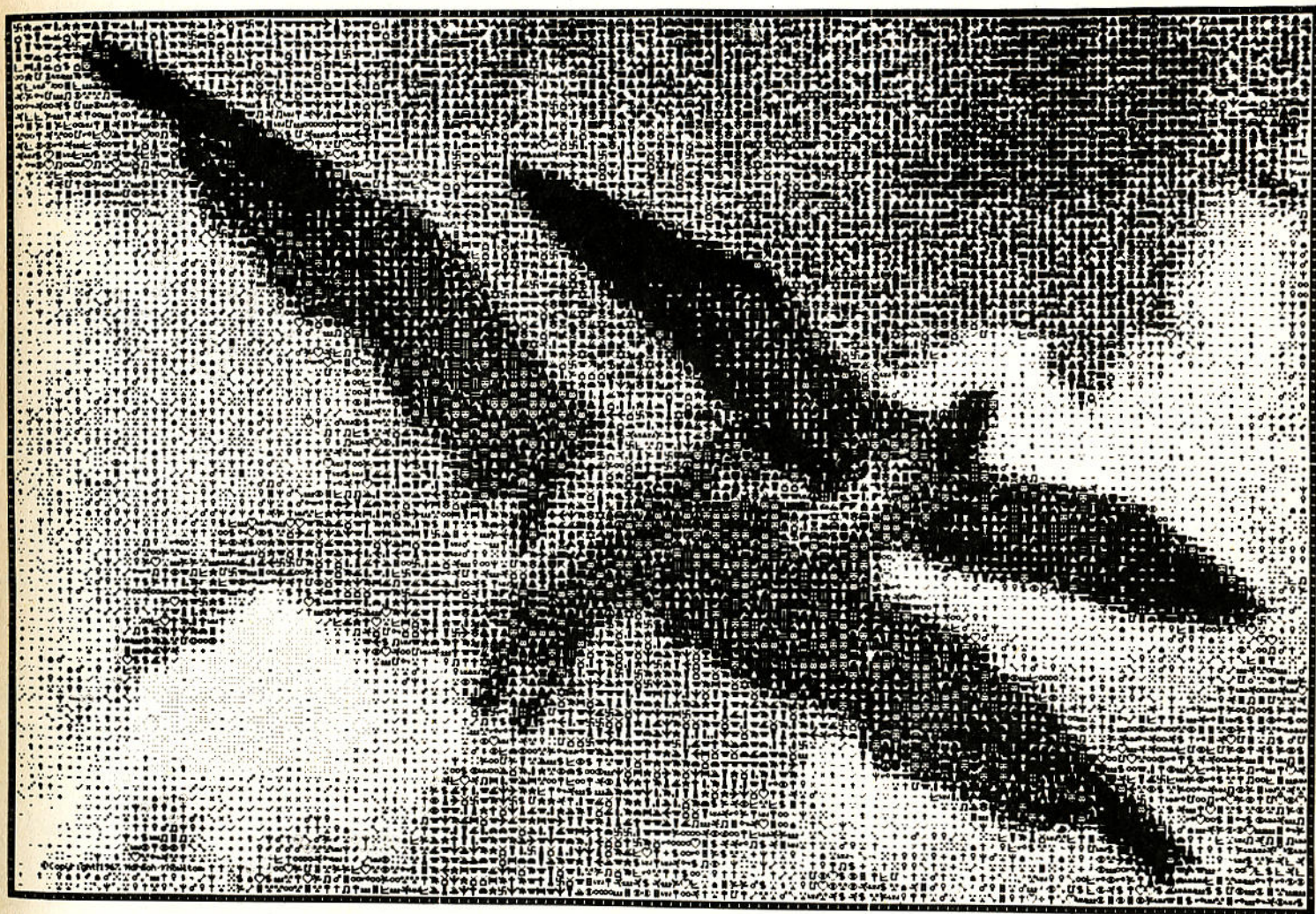
Catalogue No. 44   Knowlton, Kenneth C.   : Gulls, undated, 15¾″ x 23¼″

Important dates in the development of Programme-Controlled Calculating Machines (Computers)

1948   Elglisg Electric Company started work on an automatic computing engine aided by the National Physical Laboratory.

1950   German universities began building computers: G1 G2 and G3 at Goettingen, Dera at Darmstadt, Perm at Munich and D1 and D2 at Dresden.

1951   Statistical machines used to complete Swiss census. IBM set up its customer service workshop in Bombay. Indian Statistical Institute installed a computing machine.

1952   IBM announced IBM 701, its first large-scale electronic data processing system, designed primarily for scientific calculations. It was 25 times faster than the Selective Sequence Electronic Calculator.
Zuse developed and built the relay-calculator units for the programme-controlled card punch powers M9 of Remington Rand.
First German electronic computer G1 began work at Goettingen.

1953   IBM 702 computer for commercial use and IBM 650 and intermediate size electronic computer for accounting and scientific computations announced.

1954   IBM developed the punched card transmitter that 'talks' over regular telephone circuits. The IBM transceiver operated at the rate of approximately 10,000 alphabetical or numeric characters a minute.

1955   Magnetic core storage cells developed.

1956   ERMETH, a computer designed and built at Swiss Federal Institute of Technology, placed under operation.
Programmers Reference Manual FORTRAN was issued.

1957   IBM introduced the 610 auto-point computer capable of 214 additions or subtractions and 52 divisions or multiplications a minute.

1958   Siemens announced its first computer 2002. IBM introduced 709 Electronic Data Processing System. It could make up to 2.4 million decisions per minute in terms of true and false answers and could memorize over 1 million bits of information.

Important dates in the development of Programme-Controlled Calculating Machines (Computers)

1959 New Products: IBM 1401 Data Processing System for commercial applications, and IBM 1620 computer for scientific applications.

1960 Practice of renting computer on hourly basis introduced at the first data centre.
Electric typewriters without type bars or moveable bars introduced. It was called Selectric.

1961 Two computers installed in India.

1962 Introduction of 7710 Communication Unit. It permitted computers installed at different places to inter-communicate through high-speed facilities. Using the Telstar satellite, computer information was exchanged between New York and Paris.

1963 First Data Processing Machine manufactured at the IBM plant in Bombay.

1964 A breakthrough in computer technology made with the introduction of System/360—the first commercially available Data Processing System designed on use of micro-electronic.
Number of computers in India rose to 15.

1965 CDC introduced 6800 computer with an executing speed of 12 million instructions per second.
Seventeen more computers installed in India.

1966 India's first computer manufactured at the IBM plant in Bombay.
Six System/360 computers installed at NASA's Manned Spacecraft Centre at Houston.

1967 Twenty-two computers installed in India.

1968 An experimental image distribution system developed by the Advanced System Development Division allows the use of standard TV monitors as computer terminals in a new information network. Under the control of IBM 1800 computer, the system makes it possible to display computer-generated text, graphics or numerical information on the TV screen.

1969 NASA used computers to land men on the moon.
Computers used by Indian agriculture scientists to trigger off the Green Revolution.
The number of computers crossed the 100 mark in India.

Important dates in the development of Programme-Controlled Calculating Machines (Computers)

1970 IBM introduced a new series of computers called System/370, a highly advanced computer system— several times faster than the previous computers. It prints words and numbers at the incredible rate of 2000 lines a minute.

1971 Indian Railways using 14 computers affected a saving of Rs. 16 crores through computerized inventory control in a single year.
The number of computers in India reached about 140.

1972 The Computer Art Exhibition held in India.

N.B.

The data regarding the development of computer technology in the U.S.S.R. and the East European countries could not be obtained; so not included in this chronology.

Biographies of Artists and details of other Participants

Alsleben, Kurd
Professor at the School of Sculpture, Hamburg;
Chairman of the Committee of Aesthetic Information
in the Society for Programmed Instruction, Berlin.
Born 1928, Koenigsberg (Neumarkt) and lives in Hamburg;
studied at the School of Sculpture,Karlsruhe, 1949;
professional adviser and founder of an organisation team,
Quickborn, 1956; first realisation of his Office-Landscape
"Buerolandschaft" (Bertelsmann), 1960; development of
the Principle of Subjective Space for Designing Offices,
1964; Lecturer at the school of Designing in Ulm, 1965.
Publications: Aesthetic Redundance, 1962; Language and
Writing in the Age of Cybernetics (together with Helmar
Frank, Abraham A. Holes among others), 1963; Teaching
Machines—with Cybernetics & Paedagogy in View, 1964.
Editor: Cybernetics and Organisation, 1963; and
Praxeology, 1966.

Beckmann, Otto
Member of the Art Intermedia, Experimental Group. Born
1908, and lives as an artist in Vienna; experimented for the
production of Sound Sequences and Cinematic Films since
1966; worked for the creation of Electronic Computer
Graphics since 1968; together with Gerhard Stickel,
German Computer Centre, experimented with "Typographi-
cal Montage", 1966.

Citron, Jack P.
Studied musical compositions at the Hamilton School of
Music, Philadelphia; B.A. (Physics)-University of
Pennsylvania; M.A. (Physics)-UCLA; Ph. D. (Physics)-
UCLA; Prior to IBM, (1945-64); a musician and music
teacher; teacher of the Schillinger System of Musical
Composition and the Mathematical Basis of the Arts;
U.S. Air Force; Research Assistant (Physics)—UCLA; Lecturer
(Physics)—UCLA; Staff Member—Los Angeles Scientific
Centre; at present employee of IBM, Los Angeles,
California, U.S.A.
Special Field: Application of computers in music and arts,
and application of computer in Education.
Professional Memberships: Association of Computing
Machinery (ACM), Users of Automatic Information Display
Equipment (UAIDE).

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Cohen, Dan

Professor, Harvard University, Mass., U.S.A.

Compro, New Jersey

Annual Computer Art Contest; A Selection of Winning Entries, 1968, by Strand, Kerry; Craigmilee, Gray; France, A.M.; Walker, Dr. Evan Harris and Jenkins, Larry.

Computer Technique Group (CTG), Japan

The creative team consists of the following: Haruki Tsuchiya–System Engineer; Masao Komura–Product Designer; Kunio Yamanaka–Flight Technician; Junichiro Kakizaki–Electronic Engineer; Makoto Ohtake–Architect; Koji Fujino–System Engineer, and Fujio Niwa–System Engineer. Worked on Computer Graphics and Computer Poetry at the IBM Scientific Data Centre, Tokyo, with the help of IBM Japan since 1967. The programme was written in FORTRAN IV. Computer Graphics were made on IBM 7090; and the Computer poems were created on HITAC 5020. The drawings of the Computer Graphics were made on a Cal-Comp 563-Plotter.

Fetter, William A.

Supervisor, Computer Graphics Task Force, The Boeing Company, Renton, Washington.

Franke, Dr. Herbert W.

Studied Physics, Chemistry, Psychology, Philosophy, at University of Vienna; research project at the Institute of Technology, Vienna, 1951; worked in Industry, 1951-56; free lance correspondent, 1956; Creative Radiography, 1954; Rational Aesthetics since 1955; worked on the application of an Analog-Calculation System and a Cathode-Ray-Oscillograph for the production of Computer Graphics, 1956; and on the Principle of Optimization of Aesthetics, 1966; and also became Chairman at the International College, European Forum, Alpbach; President of the Seminar: "Cybernetics and the Theory of Information", University of Frankfurt, 1968-69; worked on the "Research on Future" (together with Prof. Dr. E.H. Graul) University of Marburg, 1969; and also worked on development of Digital Graphics. Publications: Kunst und Konstruktion, Munich, F. Brukmann, 1957; Phaenomen Technick, Wiesbaden, F.A. Brockhaus, 1962; Phaenomen Kunst, Munich, H. Moos, 1967; Sinnbild

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der Chemie, Munich, H. Moos, 1968; Methoden der Geochronologie, Berlin, Heidelberg, New York, J. Springer 1969. At present working on Computergraphik—Computerkunst, to be published at Muenchen, F. Bruckmann.
Exhibitions: "Experimentelle Aesthetik" and "Elektronische Graphik", Vienna, London, Zurich, Munich, Stuttgart, Kaiserslautern, Berlin etc..Group Exhibitions: "On the Path to Computer Art", Berlin, Karlsruhe, Davos,and participated in Venice Biennale, 1970.

Fuchshuber, Dr. Roland

Born 1932,Wuerzburg; studied at the Institute of Technology, Aachen, 1951-55; obtained his doctorate degree under Prof. Dr. H. Cremer, 1956; research for the Ministry of Economics of Nordrhein, Westfalen, 1957; Research Attaché at the French National Scientific Research Centre (head of a Research Laboratory at the University of Nancy), 1958; Euratom—Member of the Founders Committee of the Group "Cetis", Bruxelles and Ispra (here began the experiments on Computer Graphics); Lecturer for Electronic Data-Processing and Cybernetics at the State College of Mechanical Engineering, Cologne since 1961; and organised an Exhibition of Computer Graphics in Rheine, 1966.

Grassl, Alfred

Born 1941 and lives in Vienna; Diploma in Engineering and works as an assistant at the Institute of Low Frequency Technique at the Institute of Technology, Vienna.
Exhibitions: Secession, Vienna; Data Centre of the "Zentralsparkasse",Vienna; Gallery "Werkstatt",Breitenbrunn at the Neusiedler Lake.

Knowlton, Kenneth C.

Bell Telephone Laboratory, Inc. Murray Hill, N.J., U.S.A. Development of varying methods of "Picture Processing" at the Research Department of the Bell Telephone Company. Picture Processing includes: (1) the Transformation of Graphics, (2) the Transformation of Non-Visual Data into Pictures, (3) the Manufacture of Pictures under given Rules, and (4) the Combination of these Methods.
Devised a system out of Programming language BEFLIX for the construction of a picture, on a square roster. Production of Computer Films for science and teaching with aid of an

Catalogue No. 60   Mezei Leslie   Computer Drawing, Trans-
formation of Girl's Face,
undated, 22¾″ x 17¾″

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electronic micro-film recorder (Stromberg–Carlson 400). The programme is written in Beflix and an Expanded FORTRAN Language for film production using an IBM 7094. Researched with B. Julesz and C. Bosche on the Systems of Human Perception.

Kreis, Peter
Director of the Institute for Automatic Data Processing, Consulting and Development, Darmstadt.
Studied Physics Mathematics, Chemistry, Philosophy and Paedagogy at the Technical College, Darmstadt, and obtained a Diploma in Mathematics, 1949; scientific work in various Academies, Institutes and Companies in Denmark, Italy, Canada and West Germany, 1957-62; founded the Institute for Automatic Data Processing, Consulting and Development—known as aiv—in Darmstadt, 1962; and an author of standard books on the programming of Computer Languages.

Land, Dick
Professor, Engineering Science Laboratory, Cambridge, Mass., U.S.A.

Laposky, Ben F.
Lives in Cherokee, Iowa, U.S.A.; developed Oscillons or Electronic Abstractions, since 1950; and coloured Oscillons, since 1956—colour results from connecting rotating colour filters: about 170 exhibitions in 37 states of the U.S.A. and six foreign countries, since 1953.

Marc, Adrian
Born 1930; passed high school, Vienna, 1950; studied at the Academy of Fine Arts, Vienna 1951-52, and after that for three years with Prof. Wotruba; studied at the "Académie de la Grande Chaumière", Paris and at the "Academia Brera Milan 1952-54; organised several exhibitions of paintings, graphics, sculptures and mobile objects and the first "inventionistische' texts, Vienna. 1954; scholarship for kinetic sculpture and painting, Oslo, 1955; worked as a graphic artist and photographer, Vienna, 1956; visited Holland and France, 1957-58, and was a guest student at the "ITHEO"; since then he has continuously worked on and experimented with films and movement, light and colour; various exhibitions in Europe and abroad—demonstrations of kinetic objects, mobile sculptures, fotomontage and experimental films, 1958-61:

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various assignments with Austrian and German TV and film, and also worked as "Animator", 1961-64; began with the study of the Psychology of Perception at the University of Vienna, 1965; began with the experiment on Optical and Lingual Dispersion at the Institute of Higher Studies and Scientific Research, Vienna, and was awarded the "Theodor-Koerner" award for sculpture, 1967.

Professional Experience: Construction of optical phenomena, rhythmic inference and visual structures, also experimented with "word material", 1954; construction of Semantic Infra— and Metastructures since 1960; construction of Optical Semantics, 1964; the results were made visible through pictures, and kinetic objects, tests and films.

Exhibitions: Exhibited in Rome, Paris, Vienna, Graz, Buenos Aires, Stuttgart, Klagenfurt, Milan etc.

Mezei, Leslie

Professor of Computer Science, Toronto University, Canada. Department of Computer Science, McLennan Laboratories. Field of Interests: Use of computers in Documentation and Art.

Publications: On the Future Development of Computer Art in Graphics, Film, Typography and Design,(together with Arnold Rockman)in the magazine "Arts", Canada; The Computer as an Artist, 1964; and The Electronic Computer: A New Tool for the Artist, 1967.

Mott-Smith, John C.

Image Processing Branch of the Data Science Laboratory, Bedford, Mass., U.S.A.

Nake, Dr. Frieder

Born 1938, Stuttgart; studied at the University of Stuttgart and obtained Diploma in Mathematics (and also studied Physics, Electronics, Philosophy, Literature, Politics), 1958-64; training for two months at the programming department of IBM Germany, 1959; Research Assistant at the Calculating Centre and sometime at the Institute for Mathematics of Stuttgart University, 1961-64; Scientific Assistan at Calculating Centre of Stuttgart University (occupied with Probability Theory, Statistics, Programming, Computer Graphics, Aesthetics), since January 1964; Editor of Student Magazine "THS"; appointed Professor (on the subject of

Biographies of Artists and details of other Participants

Probability Theory), 1967; Post-Doctoral Fellow of National Research Council of Canada, University of Toronto, Canada (studied formal languages, Theorem Proving, Graphic Data Processing, Artificial Intelligence), 1968-69.
Selected Projects: "Computer Art ER 56", "Matrices Multiplication", and "Generative Aesthetics I". Worked in collaboration with designers on various problems: Discussion & Programming Concrete Problem (Pattern on Pattern, interpolation between various Patterns, visualizing Texts, Chance Texts, Sound Poems), Toronto, 1969. Exhibitions in Stuttgart, Darmstadt, Recklinghausen, Frankfurt/M., Dortmund, Zurich, Munich, Ulm, Montreal, Marseilles, Berlin, Den Haag, Zagreb, Davos etc.

Nash, Williams, Howard — Working Group: The group consists of:

(a) Nash, Katherine: Professor, Department of Studio Arts, University of Minnesota, Minneapolis.
(b) Williams, Richard: Professor at the University of New Mexico.
(c) Howard, Milton: Professor at the University of New Mexico.

Nees, Dr. Georg

Director, Computer Centre, Siemens AG. Erlangen. Born 1925, Nuernberg; worked on problems of Computer Graphics, since 1964; began work on dissertation about Computer Graphics, Department of Philosophy and Scientific Theory, Stuttgart University, 1965; began work on Computer Sculptures, 1968; obtained Doctorate, and published "Generative Computer Graphics" Siemens AG., and made the Computer film "Traces of Meaning", 1969; with engineer Rase, used computers for architecture; worked out plan with ALGOL Programme, Siemens System 4004 (data processing), and automatic sketching GRAPHOMAT Z 90 to create a Space-Perspective Image, 1970.
Exhibitions: In Studio Gallery of Technological Institute, Stuttgart, (first exhibition of Digital Computer Graphics), 1965; Cybernetic Serendipity, London, 1968; Computer Art: On the Eve of Tomorrow, Kubus, Hannover, 1969; On the Way to Computer Art, New Congress Building, Davos, and participated in the Venice Biennale, 1970.

Biographies of Artists and details of other Participants

Noll, A. Michael
Bell Telephone Laboratories, Inc., Murray Hill, N. J.

Palyka, Duane M.
Research Associate, College of Engineering, Computer Science, University of Utah, Salt Lake City, U.S.A.

Peterson, H. Philip
Control Data Corporation Digigraphics Laboratories, Burlington, Mass., U.S.A.

Raymond, Professor Richard C.
Born 1917, Spokane, Washington, USA; B.S. (Physics) Washington State Univeristy, 1938; Ph.D. (Physics) University of California, 1941; began painting, 1962 and began designing paintings by computer, 1964. Member: Phi Beta Kappa, Sigma Xi, American Physical Society. Fellow: Institute of Electrical and Electronic Engineers.
One-man Show: Computed Paintings and Sculptures, Zurich, 1968.
Professional Experience: Research Associate, Massachusetts Institute of Technology, Cambridge, Mass., U.S.A., 1941-42; Research Associate, Harvard University, Cambridge, Mass., U.S.A., 1942-45; Associate Professor of Physics, The Pennsylvania State University, University Park, Penn., U.S.A., 1945-52; Head, Electronics Department, The RAND Corporation, Santa Monica, California, 1953-56; Manager TEMPO, General Electric Co., Santa Barbara, California, 1956-62; Consultant—Information Science, 1963; and at present working for the General Electric Company, 570 Lexington Avenue, New York, N.Y. 10022.

Sacon, Len
Boston, Mass., U.S.A.

Schroeder, Dr. Manfred R.
Acoustics and Speech Research Laboratory; Bell Telephone Laboratories, Murray Hill; and Physics Institute, Goettingen University.
Born 1926, Ahlen, Westfalen; studied at the University of Goettingen and obtained Diploma in Physics, 1951; admitted to Ph. D. in Physics, 1954; Research work at the Bell Telephone Laboratories in Murray Hill, New Jersey.
Field of Interests: Acoustics, especially Architectural Acoustics, Electro-Acoustics, underwater Acoustics, Speech

Catalogue No. 13   Fetter, William A.   : Computer Drawing, undated,
                                                                  $23\frac{1}{2}'' \times 17\frac{1}{4}''$
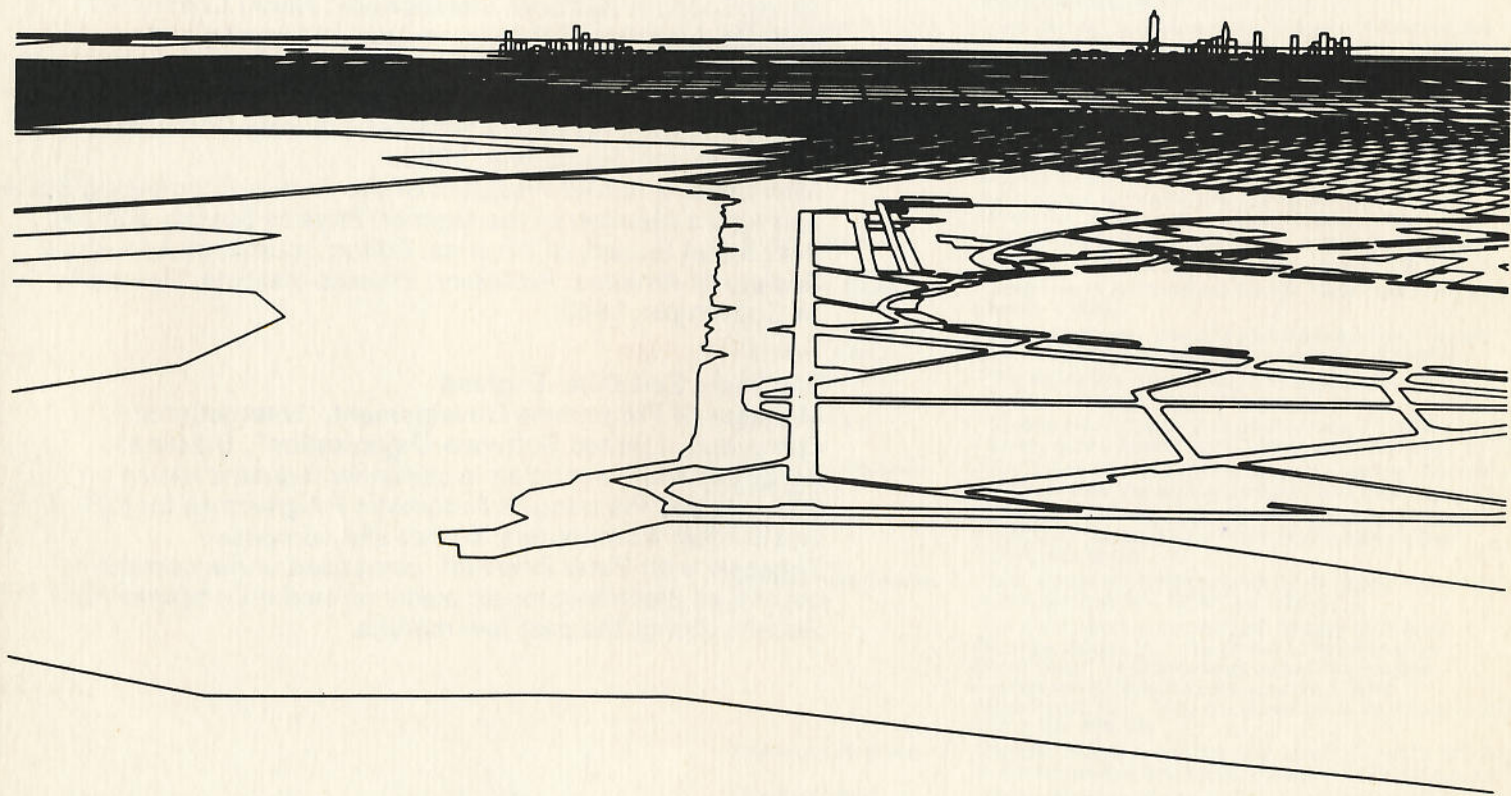
Biographies of Artists and details of other Participants

and Hearing, and Communication Sciences. Worked out a Statistical Theory of Chance Current Fields, new methods of measuring Acoustics, and countless patents in other fields. Director of Acoustic Research Department of Bell Laboratories, 1958; Director of Acoustics and Speech Research Laboratory, 1963; Director of Acoustics, Speech and Mechanics Research Laboratory; responsible for U.S. Government in National Stereophonic Radio Committee; and also Member of the Committee on Hearing and Bioacoustics of the Armed Forces and the National Research Council, 1964; joined the Committee for New Technologies, formed by the President's National Advisory Commission on Health and Manpower, 1966.

Member and former President of the Audio–Engineering Society and also a Member of the German Physics Society and the Acoustical Society of America. Editor: Journal of Acoustical Society of America; Professor, Physics Institute, University of Goettingen, 1969.

Sutcliffe, Alan

Bracknell, Berkshire, England
Manager of Programme Development, "International Computers, Limited, Software Organisation", Bracknell, Berkshire. Mathematician in container industry; works on Systems and Planning of Automatic Programmes for KDF 9 and System 4 computers, author and composer;
Together with Peter Zinovieff composed, under computer control, an electronic music piece; formed a Computer Arts Society during the past few months.

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Armstrong, Russel M.   "A Low Pressure Manifesto for Computer Art." Computer Studies in the Humanities and Verbal Behavior 1 (1968), pp. 217-20.

Barnett, Jonathan   "Will the Computer Change the Practice of Architecture?" Architectural Record 137 (1965), pp. 143-50.

Berkeley, Edmund C.   "Computer Art: Turning Point." Computers and Automation 16 (1967), p.7

Berry, William B.N.   "An Automated System for Retrieval of Paleontologic Data in a Museum." Instruction for Computer Research in the Humanities Newsletter 4 (1969), pp. 3-4.

Bird, Junius   "The Use of Computers in the Analysis of Textile Data." In Conference on Computers and Their Potential Applications in Museums. New York, The Museum of Modern Art (1968).

Boehm, George A.W.   "New Graphics for Art and Science." Think (March-April 1969); pp. 27-30.

Bosche, Carol   "Computer-Generated Random Dot Images." In Design and Planning Two: Computers in Design and Communications, edited by Martin Krampen and Peter Seitz, New York, Hastings House (1967), pp. 87-92.

Burton, Virginia   "Computers Confront the Curator." The Metropolitan Museum of Art Bulletin 26 (1967), pp. 20-23.

Campaion, David   Computers in Architectural Design. New York, American Elsevier (1968).

Citron, Jack, and Whitney, John H.   "Camp-Computer-Assisted Movie Production." AFIPS Conference Proceedings 33 (1966); pp. 1269-305.

Chaldecott, John   "The Automatic Typewriter for Computer Input." Museums Journal 67 (1967), pp. 97-104.

Clarke, John J.   "Computers and Art." Computer Usage 3 (1968), pp. 1-4. "Cracking the Sevres Code." Think 34 (1968), pp. 32-33.

Csuri, Charles, and Shaffer, T.   "Art, Computers and Mathematics." American Federation of Information Processing Societies 33 (1968), pp.1293-98.

Ellin, Everett   "Museums and the Computer: An Appraisal of New Potentials." Computers and the Humanities 4 (Sept. 1969), pp. 25-30.

Gardin, Jean-Claude   "Four Codes for the Description of Artifacts." American Anthropologist 60 (1956), pp. 335-57.

"On the Coding of Geometrical Shapes and Other Representations, with Reference to Archeological Documents." In proceedings of the International Conference on Scientific Information (1958) Washington, D.C., National Academy of Sciences, (1969), Vol. 2, pp. 889-901.

Genovese, Carmelo   "Graphic Activity and Computer Use." Computer Studies in the Humanities and Verbal Behavior 1 (1968), pp. 31-35.

Gundlach, Rolf   "Documentation of Ancient Egyptian Objects in Germany." Institute for Computer Research in the Humanities Newsletter 4 (1969), pp. 1-3.

Harmon, L.D., and Knowlton, K.G.   "Picture Processing by Computer." Science 164 (1969), pp. 19-29.

Heller, Jack   "Permuted Indexes and Catalog Cards Constructed from the Museum Computer Newwork's Data Bank." ICRH Newsletter 4 (1969); pp. 3-6.

Hertlein, Grace C.   "An Artist Views Discovery through Computer-Aided Graphics." Computers and Automation 19 (1970), pp. 25-26

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Hislop, Richard   "Information Retrieval and Computer—Printed Indices." Museums Journal 67 (1967), pp. 91-97.

Huff, William S.   "The Computer and Programmed Design: A Potential Tool for Teaching." Design and Planning Two: Computers in Design and Communication, edited by Martin Krampen and Peter Seitz, New York, Hastings House (1967) pp. 103-16.

Huggins, W.G., and Entwistle, Doris R.   "Computer Animation for the Academic Community." AFIPS Conference Proceedings 34 (1969), pp. 623-27.

Ives, Roger   "Computer-Aided Sculpture." Computers and Automation 18 (Aug. 1969), p. 33.

Kallis, Stephen A.   "Motion Picture Animation by Computer." Computers and Automation 18 (1969), pp. 30-34.

Knowlton, Kenneth C.   "Computer-Generated Movies, Designs and Diagrams." In Design and Planning Two: Computers in Design and Communication, Edited by Martin Krampen and Peter Seitz, New York, Hastings House (1967).

Lawson, Carol   "The Computer: New Tool for Artists." Scientific Research 4 (1969), pp. 35-38.

Lindsay, Kenneth C.   "Art History and the Computer." Computers and the Humanties 1 (1966), pp. 27-30.

Mallary, Robert   "Computer Sculpture: Six Levels of Cybernetics." Art Forum (May 1969), pp. 29-35.

Mezei, Leslie   "Artistic Design by Computer." Computers and Automation 13 (1964), pp. 12-15.
"Computer Art." Arts Canada 25 (1968), pp. 13-18.
"Computer Art: A Bibliography." Computer Studies in the Humanities and Verbal Behavior 1 (1968), pp. 48-50.

Rockman, A., and   "The Electronic Computer as an Artist." Canadian Art 21 (1964), pp. 365-67.

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Malojevic, Petar   "Some Thoughts on the Art/Computer Relationship." The Magazine of the Institute of Contemporary Arts 6 (Sept. 1968), pp. 16-19.

Noll, Michael A.   "Human or Machine: A Subjective Comparison of Piet Mondrian's 'Composition with Lines' and a Computer-Generated picture." The Psychological Record 16 (1966), pp. 1-10.
"Choreography and Computers." Dance Magazine (Jan. 1967), pp. 43-45.
"Computer Animation and the Fourth Dimension" AFIPS Conference Proceedings 33 (1968), pp. 1279-83.
"Oil Paintings Produced with the Aid of a Computer." Computers and Automation 17 (1968), p. 156.
"Computers and the Visual Arts." In Design and Planning Two: Computers in Design and Communication, edited by Martin Krampen and Peter Seitz, New York, Hastings House (1967), pp. 64-79.

Ogden, Steward, and Wadsworth, Nelson   "On-Line Graphics at the University of Utah" Datamation 15 (Nov. 1969), pp. 159-65.

Paisley, William J.   "Identifying the Unknown Communicator in Painting, Literature, and Music." Journal of Communication 14 (1964), pp. 219-37.

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Paquette, Russell   "Cybernetic Art: The Computer as Renaissance Man." SDC Magazine 12 (Apr. 1969), pp. 1-25.

Phillips, Richard L., and Geister, Donald E.   "Production of Computer-Animated Films from a Remote Storage Tube Terminal." Proceedings of Conference on Computers in the Under-graduate Curricula (June 16, 17, 18, 1970). The University of Iowa, Iowa. Iowa City Centre for Conferences and Institutes.

Prown, Jules D.   "The Art Historian and the Computer: An Analysis of Copley's Patronage, 1753-1774." The Smithsonian Journal of History 1 (1966), pp. 17-30.

John Singleton Copley. 2 Vols. Cambridge, Mass., Harvard University Press (1968).

Reed Danial J.   "The Catalog of American Portraits." The American Archivist 30 (1967), pp. 453-58.

Rensberger, J.M. and Berry, W.B.N.   "An Automated System for Retrieval of Museum Data." Curator 10 (1967), pp. 297-317.

Scheid, Kenneth G.   "Computers, Printing and Graphic Design." In Design and Planning Two: Computers in Design and Communications edited by Martin Krampen and Peter Seitz, New York, Hastings House (1967): pp. 53-58.

Smith, Ray W.   "The Akhenaten Temple Project." Expedition (1967), pp. 24-32.

Vanderbeek, Stan   "New Talent—the Computer." Art in America (Jan.—Feb. 1970), pp. 86-91.

Wylie, Chris ; Romney, Gordon; Evans, David; and Erdahl, Alan.   "Half-tone Perspective Drawings by Computer". AFIPS Fall Joint Computer Conference Proceedings 31 (1967), pp. 49-58.

List of Exhibits

Alsleben, Kurd and Passow, Cord

1. Computer Drawing 2, 1960, $5\frac{3}{4}'' \times 3\frac{1}{4}''$
2. Computer Drawing 4, 1960, $11\frac{1}{2}'' \times 7\frac{3}{4}''$
   (Nos.2 and 4 were created in 1960 in Hamburg on an analogue computer with an attached graph-plotter. The parameters of a differential equation were altered, or static interference was fed in.)

Beckmann, Otto and Grassl, Alfred

3. Computer Drawing, 1968, $11\frac{1}{4}'' \times 7\frac{1}{2}''$
4. Computer Drawing, 1969, $12'' \times 7''$
   (These drawings, produced with a hybrid system constructed by Grassl, displayed on a storage – oscillograph.)

Citron, Jack P.

5. Drawing, Undated, $15\frac{1}{4}'' \times 11\frac{3}{4}''$
6. Drawing, Undated, $15\frac{1}{4}'' \times 11\frac{3}{4}''$
7. Drawing, Undated, $15\frac{1}{4}'' \times 11\frac{3}{4}''$
8. Drawing, Undated, $15\frac{1}{2}'' \times 11\frac{3}{4}''$
9. Drawing, Undated, $15\frac{1}{4}'' \times 11\frac{3}{4}''$
10. Drawing, Undated, $15\frac{1}{4}'' \times 11\frac{3}{4}''$
    (Honor Societies: Phi Beta Kappa and Sigma Xi, programmed on an IBM 2250 using a curve-generation-programme and algorithms, directly from the front of the IBM 2250.)

Craigmile, Gray

11. Hummingbird Kerry Strand, Undated, $11\frac{1}{2}'' \times 15\frac{1}{4}''$
    (Colour co-ordination and plotting techniques. Compro, New Jersey. A selection of winning entries from the 1968 Annual Computer Contest.)

Csuri, C. and Shaffter, J.

12. Random War 1967, Undated, $25\frac{1}{2}'' \times 19\frac{1}{4}''$
    Motif Edition, London (Computer Graphic from ICA Exhibition — Cybernetic Serendipity)

Fetter, William A.

13. Computer Drawing, Undated, $23\frac{1}{2}'' \times 17\frac{1}{4}''$
14. Computer Drawing, Undated, $23\frac{3}{4}'' \times 17\frac{1}{2}''$
15. Computer Drawing, Undated, $23\frac{3}{4}'' \times 17\frac{1}{2}''$
16. Computer Drawing, Undated, $23\frac{3}{4}'' \times 17\frac{1}{2}''$
17. Computer Drawing, Undated, $23\frac{3}{4}'' \times 17\frac{1}{2}''$
18. Computer Drawing, Undated, $23\frac{3}{4}'' \times 17\frac{1}{4}''$
19. Computer Drawing, Undated, $23\frac{1}{2}'' \times 17\frac{3}{4}''$
20. Computer Drawing, Undated, $23\frac{1}{2}'' \times 17\frac{1}{2}''$
21. Computer Drawing, Undated, $23\frac{3}{4}'' \times 17\frac{1}{2}''$
22. Computer Drawing, Undated, $23\frac{1}{2}'' \times 17\frac{1}{4}''$
    (The main processors which were used were IBM 7094 or CDC 6600. Superscription of data occasionally required the use of a tele-reading device. Entries were done on a Gerber or on a Calcomp apparatus.)

List of Exhibits

Frank, Dr. Helmar

23. Two-dimensional Random Drawing, Undated, $28\frac{1}{2}'' \times 17\frac{1}{2}''$
24. Two-dimensional Random Drawing, Undated, $28\frac{1}{4}'' \times 11\frac{1}{4}''$
    (Written with a ballpoint with varying redundancy. These drawing series are part of an investigation which has set itself the task of finding a beginning of a theory of aesthetic information in computer-created instructional programmes. Computer S303 P with N820 as a satellite computer.)

Franke, Dr. Herbert W.

25. Analogue Drawing, Undated, $23\frac{3}{4}'' \times 15\frac{3}{4}''$
26. Analogue Drawing, Undated, $23\frac{3}{4}'' \times 15\frac{3}{4}''$
27. Analogue Drawing, Undated, $23\frac{3}{4}'' \times 15\frac{3}{4}''$
28. Analogue Drawing, Undated, $23\frac{3}{4}'' \times 15\frac{3}{4}''$
29. Analogue Drawing, Undated, $23\frac{3}{4}'' \times 15\frac{3}{4}''$
    (Photographic reproduction from the screen of a cathode-ray-oscillograph)
30. Analogue Drawing, Undated, $19'' \times 15\frac{1}{4}''$
31. Analogue Drawing, Undated, $22\frac{1}{2}'' \times 14\frac{3}{4}''$
32. Analogue Drawing, Undated, $19'' \times 16''$
33. Analogue Drawing, Undated, $24'' \times 15\frac{1}{2}''$
34. Analogue Drawing, Undated, $24'' \times 14\frac{1}{4}''$
    (Serigraphs from photos taken from the screen of a cathode-ray-oscillograph)

Franke, Dr. Herbert W. in collaboration with Farber, G., Maier, H. and Vordermaier, J.

35. Digital Drawing, Three coloured, Undated, $19'' \times 19$
    (Serigraph. The programmes for the digital drawings come from a DVA of the Siemens System 4004)

Franke, Dr. Herbert W. in collaboration with Henne, P. and Maier, H.

36. Digital Drawing, Black and White, Undated, $26\frac{3}{4}'' \times 19''$
37. Digital Drawing, Black and White, Undated, $26\frac{3}{4}'' \times 19''$
    (Serigraphs. The programme for the digital drawings come from a DVA of the Siemens System 4004)

France, A.M.

38. Inspiralation, Undated, $10'' \times 10''$,
    (Compro, New Jersey. A selection of winning entries from the 1968 Annual Computer Contest)

Fuchshuber, Dr. Roland

39. Analogue Drawing, Undated, $18\frac{3}{4}'' \times 15\frac{1}{4}''$,
40. Analogue Drawing, Undated, $19\frac{1}{2}'' \times 16\frac{1}{2}''$.
    (Representations of cybernetic model-variations)

Jenkins, Larry

41. Plexus, Kerry Strand, Undated, $11'' \times 15''$,
    (Compro, New Jersey. A selection of winning entries from the 1968 Annual Computer Contest)

List of Exhibits

Knowlton, Kenneth C.
42. Telephone, Undated, 21" x 14"
43. Mural, Undated, 39½" x 16¼"
44. Gulls, Undated, 15¾" x 23¼"
45. Gargoyle, Undated, 20½" x 14"

Kreis, Peter
46. Series 'The Surface in Space', Undated, 14¾" x 14"
47. Series 'The Surface in Space', Undated, 14¾" x 14"
48. Series 'The Surface in Space', Undated, 14¾" x 14"
49. Series 'The Surface in Space', Undated, 14¾" x 14"
50. Series 'The Surface in Space', Undated, 14¾" x 14"
51. Series 'The Surface in Space', Undated, 14¾" x 14"
   (Series 'The Surface in Space' is written with the programme 'COMPART' from
   the aiv-Institute in FORTRAN IV. The programme serves to depict solid
   surface, taking penetrative perspective into consideration. Output was
   produced partly on an oscillograph–Stromberg-Carlson, and partly on a
   mechanical sketching device from the firm Kontron – a product of Houston-
   Instructions.)

Land, Dick and Cohen, Dan
52. Coloured Computer Drawing, 1969, 13½" x 10½"
53. Coloured Computer Drawing, 1969, 10½" x 13½"

Laposky, Ben F.
54. Oscillon 16, Undated, 7½" x 9½"
   (Electronic Abstraction)
55. Oscillon 11, Undated, 4½" x 6¼"
   (Electronic Abstraction)
56. Oscillon 18, Undated, 4½" x 6¼"
   (Electronic Abstraction)
57. Oscillon 501, Undated, 4¾" x 6¾"
   (Electronic Abstraction)

Marc, Adrian
58. Computer Text, Undated, 35" x 9"
   (Semantic infra – and metastructures, optical semantics)

Mezei, Lesli
59. Computer Drawing, Transformation of Babel, Undated, 33" x 29"
60. Computer Drawing, Transformation of Girl's Face, Undated, 22¾" x 17¾"

Mott-Smith, John C.
61. Computer Drawing in Colour, Undated, 9½" x 7"
62. Computer Drawing in Colour, Undated, 9½" x 7"
63. Computer Drawing in Colour, Undated, 9½" x 7"
64. Computer Drawing in Colour, Undated, 9½" x 7"
65. Computer Drawing in Colour, Undated, 9¼" x 7"
66. Typed Text, containing a part of artist's statement, Undated, 7" x 9½"
   (The programme used served to develop particle tracks in complicatedly
   disposed fields of force. Out of this, J.C. Mott-Smith developed a system of

List of Exhibits

producing visually attractive curve combinations and superimpositions. The patterns are produced on the screen of an electronic visual output device and photographed one after the other through coloured filters.)

Nake, Dr. Frieder

67. Serigraph, Undated, $18\frac{3}{4}'' \times 25''$
68. Multiplications of Matrices—Plotter Drawing, Undated, $19'' \times 19''$
69. Serigraph, Undated, $18\frac{3}{4}'' \times 19''$

Nash, Catherine

70. Graphic Structures from the Line-printer, Undated, $13\frac{1}{2}'' \times 10\frac{3}{4}''$
71. Graphic Structures from the Line-printer, Spheroids, Undated, $13\frac{1}{2}'' \times 10\frac{3}{4}''$
72. Graphic Structures from the Line-printer, Soft as Night, Undated, $13\frac{1}{2}'' \times 10\frac{3}{4}''$
73. Graphic Structures from the Line-printer, Triangle M, Undated, $13\frac{1}{2}'' \times 10\frac{3}{4}''$
74. Graphic Structures from the Line-printer, Triangle 9, Undated, $13\frac{1}{2}'' \times 10\frac{3}{4}''$

Nees, Dr. Georg

75. Computer Drawings—Plotter Sketches, Undated, $23\frac{1}{2}'' \times 24''$
76. Serigraph, Undated, $23'' \times 33\frac{1}{2}''$
77. Serigraph, Undated, $23'' \times 33\frac{1}{2}''$
78. Serigraph, Undated, $23'' \times 33\frac{1}{4}''$
79. Serigraph, Undated, $23'' \times 33''$
80. Serigraph, Undated, $23'' \times 26\frac{1}{2}''$
81. Serigraph, Undated, $23'' \times 26\frac{3}{4}''$
82. Plotter Sketch of an Architectonic Structure, Undated, $18\frac{1}{4}'' \times 25\frac{3}{4}''$
   (In collaboration with Dipl. Ing. Rase)

Noll, A. Michael

83. Computer Drawing—Gaussian-quadratic, 1965, $23'' \times 27\frac{3}{4}''$
84. Computer Drawing—Computer Composition with lines, 1964, $23\frac{1}{2}'' \times 27\frac{1}{2}''$
85. Computer Drawing—Vertical-horizontal number three, 1965, $23'' \times 27\frac{1}{2}''$
86. Computer Drawing—Waveform, Undated, $23'' \times 27\frac{1}{2}''$

Palyka, Duane M.

87. Computer Drawing, Undated, $29'' \times 11''$
88. Typed Text : statement by the artist, Undated, $29\frac{1}{2}'' \times 11\frac{3}{4}''$
   (Phase pictures from the fil-like sequence 'Random Movement'. This was a six-minute-series of graphic configurations, which can be varied at will by the alteration of the parameters of a random-generator. The production is carried out with two combined Bendix-20-computers and three Philco television tubes.)

Peterson, H. Philip

89. Computer Drawing: 'Digital Norbert Wiener, Undated, $18\frac{1}{2}'' \times 24\frac{3}{4}''$
   (The picture is constructed exclusively of character-symbols. Numbers with two digits represent the density of shade of the surface elements which they cover, forming as a basis a scale of grey of 100 gradations. Numbers were so allotted that higher ones produced the darker shading. A control-data-digigraphic scanner-model 280 combined with a computer Model 160 scanned a small black and white transparency of Norbert Wiener and distributed the different shades of density over the 100,000 screen spaces. A Cal-Comp-564 Plotter, connected to a Control-Data Computer 3200, wrote the characters.

The scanning and computing time on the DCC 160 was 4 minutes; the drawing time for the Cal-Comp-564-Plotter was 16 hours.)

90. 'Mona Lisa', Undated, 29½" x 44¾"

(This picture was produced in a similar fashion to the previous one, after a copy of Leonardo da Vinci's portrait.)

Raymond, Richard, C.

91. Nine Spheres on Black Background, 1970, 16" x 18"
92. Three Small Blue Spheres and one Large Yellow-Red Sphere on White Background, 1970, 18" x 16"
93. Four Small Blue Spheres. Part of one Large Yellow-Red Sphere on White Background, 1970, 16" x 18"
94. Nine Spheres in Spiral Formation. Colours Yellow, Blue, Grey on White Background, 1970, 16" x 14"
95. Nine Spheres in Body-centred Cube. Colours Blue, Green, Grey, Yellow on White Background, 1970, 20" x 18"
96. Eleven Plastic "I" Beams held in place by Fine Steel Wires, 1970, 14½" x 11" x 10"
97. Five Brass Wires rise randomly from a base of Black Wood, 1966, 11" x 8¼" x 7"

Robbins, D.W.

98. 3-D Checkerboard Pattern, Undated, 19¼" x 22¾"

Motif Edition, London (Computer Graphic from ICA Exhibition — Cybernetic Serendipity).

Sacon, Len

99. Computer Drawing in Colour, Undated, 13¼" x 10¾"
100. Computer Drawing in Colour, Undated, 10¾" x 13¼"
101. Computer Drawing in Colour, Undated, 13½" x 10¾"

(The works are reproductions of original photographs. The programme on which they are based allows the deforming and re-orientation of three-dimensional surfaces, under the supervision of the photographer, T. Child, and the output operator. When an aesthetically pleasing pattern appeared it was photographed and transformed into a colour picture; the application of colour was at the will of the photographer for a general heightening of the aesthetic effect.)

N.B. The conversion of the programme was done by an Adage Graphics Terminal Model 30.

Samson, M.S.

102. Asymetrie (red), Undated, 25" x 19¼"

Motif Edition, London (Computer Graphic from ICA Exhibition—Cybernetic Serendipity)

Schroeder, Dr. Manfred R.

103. Relative Primes, Undated, 20¾" x 20¾"
104. Computer 'Brushstroke' Technique, Undated, 37¾" x 30"
105. Prime Spectrum, Undated, 20¾" x 20¾"
106. Modulated Rings, Undated, 20¾" x 20¾"
107. Wortreiches Auge, (Verbose Eye), Undated, 20¾" x 20¾"
108. Brownian Motion, Undated, 20¾" x 20¾"
109. Contour Portrait, Undated, 20¾" x 19¼"

Sutcliffe, Alan

110. Poems for Spasmo, Computer prints, Undated, $10\frac{3}{4}''$ x $7\frac{1}{4}''$
    (These works form part of SPASMO, a multi-media-composition for tape-recorder, solo piano, colour slides and audience. Every run of the programme produces 256 poems. By the input of a different vocabulary and other data one can produce the output of another series of poems. The programme is written in FORTRAN and was run on an ICL 194 in the ICL office in Reading. The first performance was given in the Queen Elizabeth Hall, London on 10th February 1969.)

Walker, Dr. Evan Harris

111. Idealized Brush Strokes, Undated, 11'' x 15''
    (Compro, New Jersey. A selection of winning entries from the 1968 Annual Computer Contest.)

Williams, Richard

112. Graphic Structures from the Line-printer, N and Z No. 5, Undated, $13\frac{1}{4}''$ x $10\frac{3}{4}''$
113. Graphic Structures from the Line-printer, N and Z No. 6, Undated, $13\frac{1}{4}''$ x $10\frac{3}{4}''$
114. Graphic Structures from the Line-printer, N and Z No. 4, Undated, $13\frac{1}{4}''$ x $10\frac{3}{4}''$
115. Graphic Structures from the Line-printer, N and Z No. 3, Undated, $13\frac{1}{4}''$ x $10\frac{3}{4}''$

Computer Graphics from ICA Exhibition—Cybernetic Serendipity

Artists Not Known

116. Running Cola is Africa, 1967/68, 25'' x 19''
117. Return to Square, 1967/68, 19'' x 19''
118. Human Figure, Boeing Computer-Graphic, Undated, 25'' x $19\frac{1}{4}''$
    (Motif Edition, London)

Computer Technique Group (CTG), Japan, Computer Drawings

Artists Not Known

119. Return to Square (B), Undated, $31\frac{1}{4}''$ x $35\frac{1}{4}''$
120. Perspective Pillar Collection, Undated, $31\frac{3}{4}''$ x $35\frac{1}{4}''$
121. Kennedy in the Rectangular, Undated, 31'' x $33\frac{3}{4}''$
122. Kennedy in a Dog, Undated, $31\frac{1}{4}''$ x $35\frac{1}{4}''$
123. Monroe in the Net, Undated, 24'' x $26\frac{1}{2}''$
124. Three Shot Kennedy, Undated, $27\frac{3}{4}''$ x $36\frac{1}{2}''$
125. Kennedy in the Net, Undated, $28\frac{1}{2}''$ x 36''
126. Optical Wave, Undated, 28'' x $36\frac{3}{4}''$
127. Twisted Circles, Undated, $31\frac{1}{2}''$ x $36\frac{1}{4}''$
128. Miracle Stones, Undated, 38'' x $23\frac{1}{4}''$
129. Random Flower, Undated, $31\frac{1}{4}''$ x 33''
130. Cubic Kennedy No. 1, Undated, $27\frac{1}{2}''$ x $35\frac{1}{2}''$
131. Cubic Kennedy No. 2, Undated, 30'' x 35''
132. Turning Sine Curve, Undated, 27'' x 37''

133. Collection of Random Window, Undated, 30″ x 30″
134. Individualisation Age, Undated, 39¼″ x 25″
135. Shot Kennedy, Undated, 28″ x 36½″
   (Deformations, Metamorphoses, Improvisations, Alternations of a square screen)

Univac Computer Graphics Group (Minnesota, USA.)

Artists Not Known
136. Computer Drawing in Colour, Undated, 19¾″ x 23½″
137. Computer Drawing in Colour, Undated, 19¾″ x 23½″

Computer Films
138. Whitney, John J.   : Experiments in Motion Graphics and Permutations, IBM
139. Nees, Georg   : Spuren von Bedeutung (Traces of Meaning), Siemens AG.
140. Beckmann, Otto   : Computer Film

Computer Music
141. Barbaud, Pierre   : Franzcesisches Gagaku
142. Bruen, Herbert   : Infraudibles
143. Grossi, Pietro   : Mixed Paganini
144. _____   : Permutations of Five Sounds
145. _____   : Continuouse
146. Hiller, Lejaren A. : Illiac Suite for String Quartet
147. _____   : Computer Contata
148. _____   : Hpschd
149. Mathews, Max V.   : Rhythm Developments
150. _____   : The British Grenadiers
151. _____   : Johnny comes Marching Home
152. _____   : International Lullaby
153. _____   : Eight-Tone Canon
154. Meertens, Lambert   : Quartet No. 1, C minor
155. Randall, J.K.   : Variations 6-10
156. Roberts, Arthur   : Sonatina for CDS 3600
157. Strand, Gerald   : 6 Compositions

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