

The digital computer as a creative medium

In the computer, man has created not just an inanimate tool but an intellectual and active creative partner that, when fully exploited, could be used to produce wholly new art forms and possibly new aesthetic experiences

A. Michael Noll *Bell Telephone Laboratories*

Digital computers are now being used to produce musical sounds and to generate artistic visual images. The artist or composer interacts directly with the computer through a console. This article explores the possibilities of the computer as an artistic medium and makes some predictions about the art of the future.

The notion of creating art works through the medium of machines may seem a little strange. Most people who have heard about the experimental use of digital computers in creative endeavors have probably shrugged them off as being of no consequence. On the one hand, creativity has universally been regarded as the personal and somewhat mysterious domain of man; and, on the one hand, as every engineer knows, the computer can only do what it has been programmed to do—which hardly anyone would be generous enough to call creative.

Nonetheless, artists have usually been responsive to experimenting with and even adopting certain concepts and devices resulting from new scientific and technological developments. Computers are no exception. Composers, film animators, and graphic artists have become interested in the application of computers in their creative endeavors. Moreover, recent artistic experiments with computers have produced results that should make us re-examine our preconceptions about creativity and machines. Some of the experiments, described in this article, suggest, in fact, that a tight interaction between artist and computer constitutes a totally new, active, and exciting artistic medium.

How does an artist work?

There is an anecdote attributed to Henri Matisse about how to approach the creative act of painting. You take a blank white canvas, the French artist said, and after gazing at it for a while, you paint on it a bright red disk. Thereafter, you do nothing further until something occurs to you that will be just as exciting as the original red disk. You proceed in this way, always sustaining, through each new gambit with the paint and brush, the initial high visual excitement of the red disk.

The anecdote is a somewhat simplified version of Matisse's idea, but even if we take it lightly, it can do a number of things for us. For one thing, it dispels some of the sense of mystery that hovers over the procedures of the creative person. It tells us something concrete and easily visualized about the creative process while emphasizing the role of the unexpected ideas for which the artist lies in wait and for which he sets a formal "trap" in his medium.

Even a relatively "passive" medium—paint, brushes, canvas—will suggest new ideas to the artist as he becomes engaged. The resistance of the canvas or its elastic give to the paint-loaded brush, the visual shock of real color and line, the smell of the paint, will all work on the artist's sensibilities. The running of the paint, or seemingly "random" strokes of the brush, may be accepted by him as corporate elements of the finished work. So it is that an artist explores, discovers, and masters the possibilities of the medium. His art work is a form of play, but it is serious play.

Most of all, the Matisse anecdote suggests that the artistic process involves some form of "program," one certainly more complex than the anecdote admits, but a definite program of step-by-step action. Without doing too much violence to our sense of what is appropriate, we might compare it to a computational hill-climbing technique in which the artist is trying to optimize or stabilize at a high level the parameter "excitement."

Once we have swallowed this metaphor, it becomes less improbable to imagine that computers might be used, in varying depths of engagement, as active partners in the artistic process. But computers are a *new* medium. They do not have the characteristics of paints, brushes, and canvas. Nor are the "statements" that grow out of the artist's engagement with them likely to be similar to the statements of, for example, oil paintings. An interesting question to explore, then, is how computers might be used as a creative medium. What kinds of artistic potentials can be evolved through the use of computers, which themselves are continually being evolved to possess more sophisticated and intelligent characteristics?

The character of the computer medium

In the present state of computer usage, artists are certainly having their problems in understanding engineering descriptions and in learning how to program computers in order to explore what might be done with them. However, they *are* learning, and they have already used digital computers and associated equipment to produce musical sounds and artistic visual images.¹⁻⁴

The visual images are generated by an automatic plotter under the control of the digital computer. The plotter consists of a cathode-ray tube and a camera for photographing the images "drawn" on the tube face by deflections of the electron beam. The digital computer produces the instructions for operating the automatic plotter so that the picture-drawing capability is under program control. Musical sounds are produced by the computer by means of a digital sampled version of the sounds that must then be converted to analog form by a conventional digital-to-analog converter.

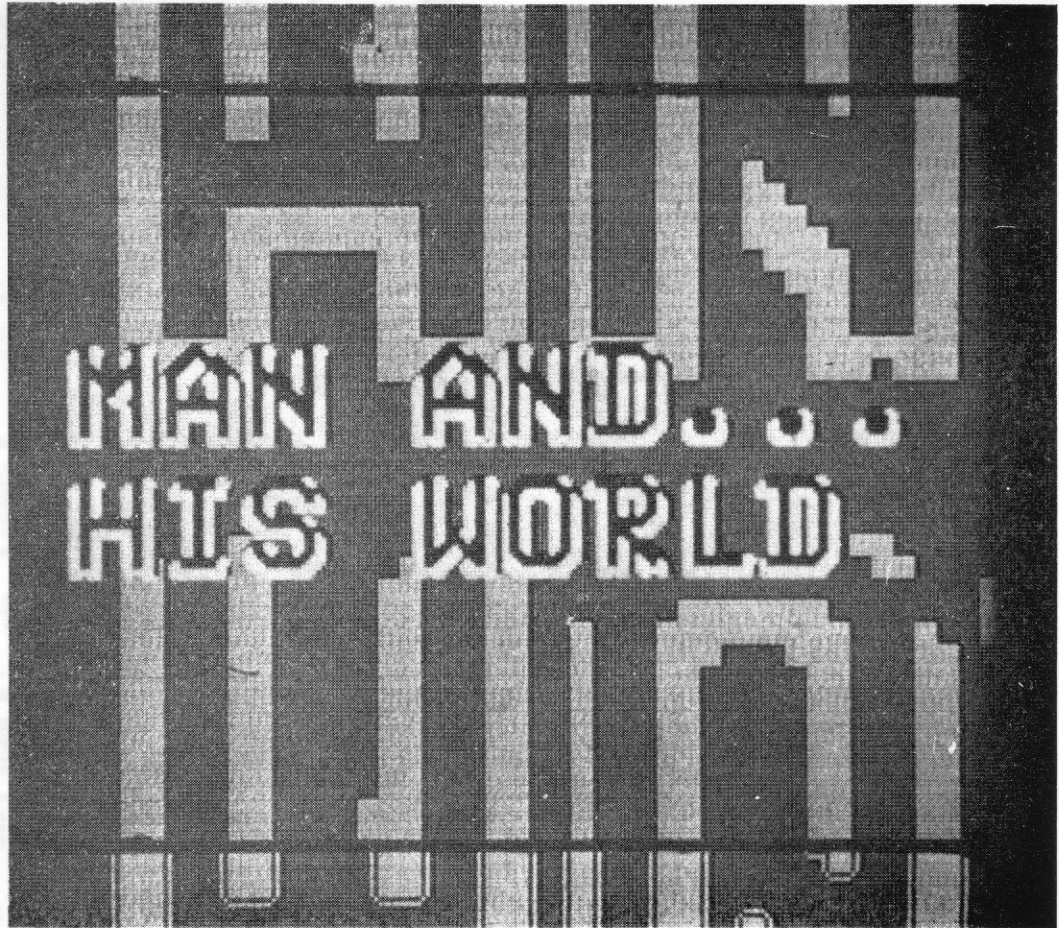
For both of these artistic applications, a challenging problem is the composition of special-purpose programming languages and subroutines so that the artist can communicate with the computer by using terminology reasonably similar to his particular art. For example, a special music compiler has been written so that the composer can specify complex algorithms for producing a single sound and then pyramid these basic sounds into a whole composition. A similar philosophy has been used in a special language developed for computer animation called Beflix.⁵ Both applications share the drawback that the artist must wait a number of hours between the actual running of the computer program and the final generation of pictorial output or musical sounds when he can see or hear the results.

Since the scientific community currently is the biggest user of computers, most descriptions and ideas about the artistic possibilities for computers have been understandably written by scientists and engineers. This situation will undoubtedly change as computers become more accessible to artists who obviously are more qualified to explore and evolve the artistic potentials of the computer medium. Unfortunately, scientists and engineers are usually all too familiar with the inner working of computers, and this knowledge has a tendency to produce very conservative ideas about the possibilities for computers in the arts. Most certainly the computer is an electronic device capable of performing only those operations that it has been explicitly instructed to perform. And this usually leads to the portrayal of the computer as a powerful tool but one incapable of any true creativity. However, if creativity is restricted to mean the production of the unconventional or the unpredicted, then the computer should instead be portrayed as a creative medium—an active and creative collaborator with the artist.

Computers and creativity

Digital computers are constructed from a myriad of electronic components whose purpose is to switch minute electric currents nearly instantaneously. The innermost workings of the computer are controlled by a set of instructions called a program. Although computers must be explicitly instructed to perform each operation, higher-level programming languages enable pyramiding of programming statements that are later expanded into the basic computer instructions by special compiler pro-

This frame is selected from a movie produced by Stan Vanderbeek using a special animation programming language devised by Ken Knowlton. Each frame consists of a fine mosaic of dots that are combined to make desired shapes and forms. Intriguing and unusual "dissolves" and "stretches" that are easily done using the computer would be tedious if not impossible to execute by conventional hand animation techniques.



grams. These programming languages are usually designed so that the human user can write his computer program using words and symbols similar to those of his own particular field. All of this leads to the portrayal of the computer as a tool capable of performing tasks exactly as programmed.

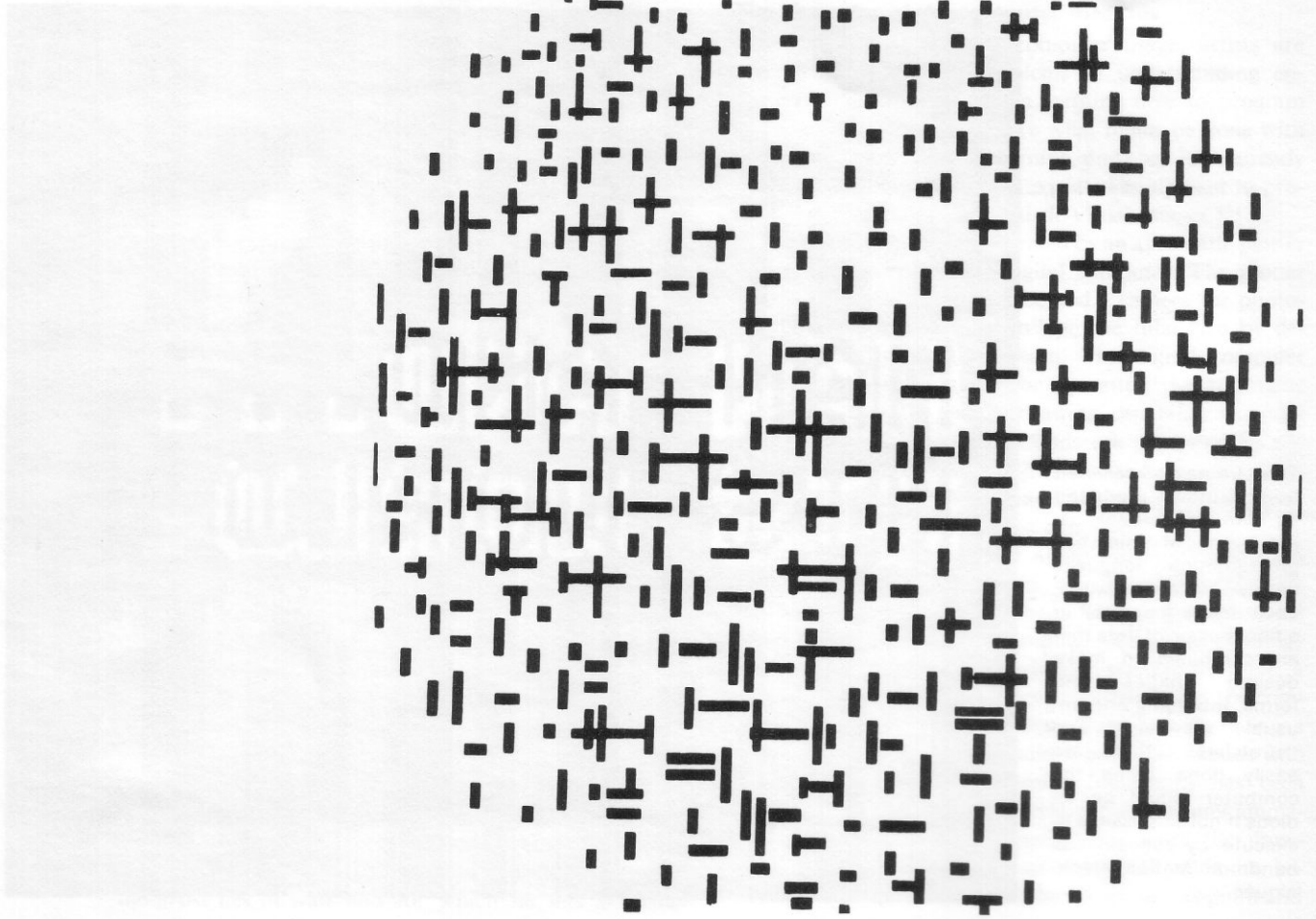
However, the computer is such an extremely powerful tool that artistic effects can sometimes be easily accomplished that would be virtually impossible by conventional artistic techniques. For example, by calculating and drawing on the automatic plotter the perspective projections from two slightly different directions of some three-dimensional object, the computer can generate three-dimensional movies of novel shapes and forms. Such three-dimensional animation, or kinetic sculpture, is far too tedious to perform by any other method. The computer's ability to handle small details has made possible intriguing dissolves and stretches, such as those executed by Stan Vanderbeek, without the tedium of conventional hand animation. Mathematical equations with certain specified variables under the control of the artist have also been used by John Whitney to achieve completely new animation effects. Much of "op art" uses repetitive patterns that usually can be expressed very simply in mathematical terms. The waveforms reproduced on page 89, which are like Bridget Riley's painting "Currents," were generated as parallel sinusoids with linearly increasing period. Thus, computer and automatic plotter can eliminate the tedious part of producing "op" effects.

Computers most certainly are only machines, but they are capable of performing millions of operations in a fraction of a second and with incredible accuracy. They can be programmed to weigh carefully, according to specified criteria, the results of different alternatives and act accordingly; thus, in a rudimentary sense, computers can appear to show intelligence.⁶ They might assess the results of past actions and modify their programmed algorithms to improve previous results; computers potentially could be programmed to learn. And series of numbers can be calculated by the computer that are so complicatedly related that they appear to us as random.

Of course, everything the machine does must be programmed, but because of the computer's great speed, freedom from error, and vast abilities for assessment and subsequent modification of programs, it appears to us to act unpredictably and to produce the unexpected. In this sense, the computer actively takes over some of the artist's creative search. It suggests to him syntheses that he may or may not accept. It possesses at least some of the external attributes of creativity.

The Mondrian experiment

How reasonable is it to attribute even these rudimentary qualities of creativity to an inanimate machine? Is creativity something that should only be associated with the products of humans? Not long ago, in 1950, A. M. Turing expressed the belief that at the end of the century "one will be able to speak of machines thinking



without expecting to be contradicted.”⁷ Turing proposed the now well-known experiment consisting of an interrogator, a man, and a machine, in which the interrogator had to identify the man by asking the man and the machine to answer questions or to perform simple tasks.

A crude approximation to Turing’s experiment was performed using Piet Mondrian’s “Composition With Lines” (1917) and a computer-generated picture composed of pseudorandom elements but similar in overall composition to the Mondrian painting.⁸ Although Mondrian apparently placed the vertical and horizontal bars in his painting in a careful and orderly manner, the bars in the computer-generated picture were placed according to a pseudorandom number generator with statistics chosen to approximate the bar density, lengths, and widths in the Mondrian painting. Xerographic copies of the two pictures were presented, side by side, to 100 subjects with educations ranging from high school to post-doctoral; the subjects represented a reasonably good sampling of the population at a large scientific research laboratory. They were asked which picture they preferred and also which picture of the pair they thought was produced by Mondrian. Fifty-nine percent of the subjects preferred the computer-generated picture; only 28 percent were able to identify correctly the picture produced by Mondrian.

In general, these people seemed to associate the ran-

The picture on the left, “Composition With Lines” (© Rykmuseum-Kröller-Müller), is a reproduction of a work by the Dutch painter Piet Mondrian. The picture on the right was generated by a digital computer using pseudorandom numbers with statistics approximating the Mondrian painting (© A. Michael Noll 1965). When xerographic reproductions of both pictures were shown to 100 subjects, the computer-generated picture was preferred by 59 of them. Only 28 subjects identified the Mondrian painting. Apparently, many of the observers associated randomness with human creativity and were therefore led astray in making the picture identifications.

domness of the computer-generated picture with human creativity whereas the orderly bar placement of the Mondrian painting seemed to them machinelike. This finding does not, of course, detract from Mondrian’s artistic abilities. His painting was, after all, the inspiration for the algorithms used to produce the computer-generated picture, and since computers were nonexistent 50 years ago, Mondrian could not have had a computer at his disposal. Furthermore, we must admit that the reduction in size of the original painting and its xerographic reproduction degrades its unique aesthetic qualities. Nevertheless, the results of the experiment in light of Turing’s proposed experiment do raise questions on the meaning of creativity and the role of randomness in artistic creation. In a sense, the computer with its program could be considered creative, although it can be argued that human creativity was involved in the original



program with the computer performing only as an obedient tool.

These questions should perhaps be examined more deeply by more ambitious psychological experiments using computer-generated pictures as stimuli.

Toward real-time interaction

Although the experiments described show that the computer has creative potentialities beyond those of just a simple tool, the computer medium is still restrictive in that there is a rather long time delay between the running of the computer program and the production of the final graphical or acoustic output. However, recent technological developments have greatly reduced this time delay through special interactive hardware facilities and programming languages. This tightening of the man-machine feedback loop is particularly important for the artist who needs a nearly instantaneous response.

For example, in the field of music an electronic graphic console has been used to specify pictorially sequences of sounds that were then synthesized by the computer.⁹ Functions for amplitude, frequency, and duration of a sequence of notes were drawn on the face of a cathode-ray tube with a light pen. If desired, the computer combined specified functions according to transparently simple algorithms. Thus, the fine details of the composition were calculated by the computer and the overall structure was precisely specified by the graphical score. The feedback loop was completed by the computer-generated sounds heard almost immediately by the com-

poser, who could then make any desired changes in the score.

A similar man-machine interactive system has been proposed for choreography.¹⁰ In this system, the choreographer would be shown a computer-generated three-dimensional display of complicated stick figures moving about on a stage, as shown on page 94. The choreographer interacts with the computer by indicating the spatial trajectories and movements of the figures. Random and mathematical algorithms might be introduced by the computer to fill in certain fine details, or even to give the choreographer new ideas to evaluate and explore.

A new active medium

The beginnings of a new creative partnership and collaboration between the artist and the computer clearly emerge from these most recent efforts and proposals. Their common denominator is the close man-machine interaction using the computer to generate either musical sounds or visual displays. The computer acquires a creative role by introducing randomness or by using mathematical algorithms to control certain aspects of the artistic creation. The overall control and direction of the creative process is very definitely the artist's task. Thus, the computer is used as a medium by the artist, but the great technical powers and creative potentialities of the computer result in a totally new kind of creative medium. This is an *active* medium with which the artist can interact on a new level, freed from many of the physical limitations of all other previous media. The artistic po-

tentialities of such a creative medium as a collaborator with an artist are truly exciting and challenging.

Interactive aesthetic experiences

In the previous examples the artist sat at the console of the computer and indicated his desires to the computer by manually using push buttons or by drawing patterns on an electronic visual display. These are probably efficient ways of communicating certain types of instructions to the computer; however, the communication of the actual subconscious emotional state of the artist could lead to a new aesthetic experience. Although this might seem somewhat exotic and conjectural, the artist's emotional state might conceivably be determined by computer processing of physical and electrical signals from the artist (for example, pulse rate and electrical activity of the brain). Then, by changing the artist's environment through such external stimuli as sound, color, and visual patterns, the computer would seek to optimize the aesthetic effect of all these stimuli upon the artist according to some specified criterion.

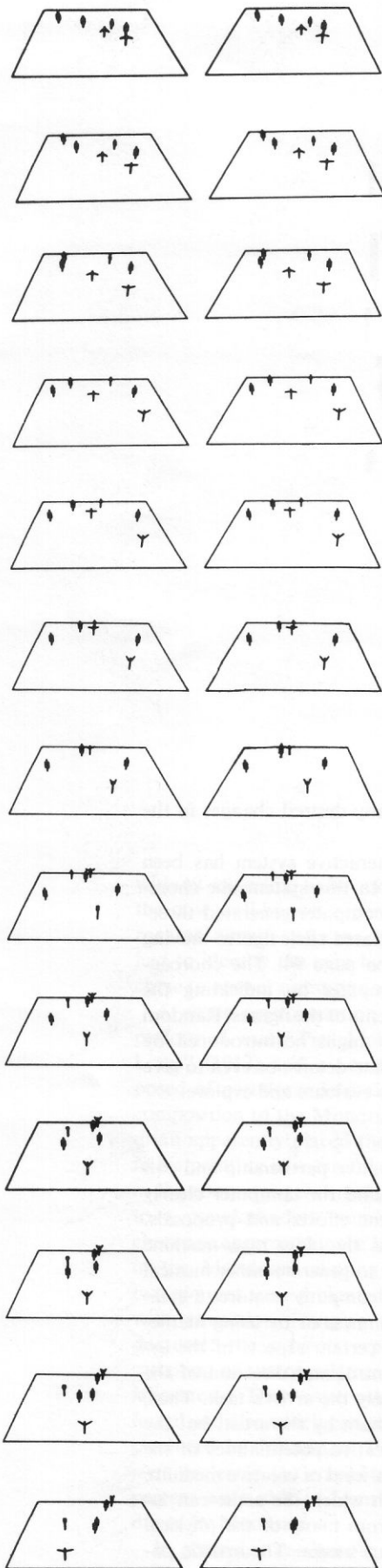
This interactive feedback situation with controlled environment would be completely dynamic. The emotional reaction of the artist would continually change, and the computer would react accordingly either to stabilize the artist's emotional state or to steer it through some pre-programmed course. Here then is a completely new aesthetic experience utilizing man-machine communication on the highest (or lowest, if you will) subconscious levels and computer processing and optimization of emotional responses. Only a digital computer could perform all the information processing and generate the sights and sounds of the controlled environment required for such a scheme. One is strongly tempted to describe these ideas as a consciousness-expanding experience in association with a psychedelic computer!

Although such an artistic feedback scheme is still far in the future, current technological and psychological investigations would seem to aim in such a direction. For example, three-dimensional computer-generated color displays that seem to surround the individual are certainly already within the state of the art. Electroencephalograms are being scrutinized and studied in great detail, using advanced signal analysis techniques; it is not inconceivable that some day their relation to emotional state might be determined.

Artistic consequences

Predictions of the future are risky in that they may be really nothing more than what the person predicting would like to see occur. Although the particulars should be viewed skeptically, they actually might be unimportant; if the art of the future follows the directions outlined here, then some general conclusions and statements can be made that should be independent of the actual particulars.

The aesthetic experience will be highly individualistic, involving only the individual artist and his interactions with the computer. This type of participation in the creative and aesthetic experience can be experienced by artist and nonartist alike. Because of the great technical and creative power of the computer, both the artist and nonartist are freed from the necessity of strong technical competence in the use of different media. The artist's "ideas" and not his technical ability in manipulating



The choreographer of the future might sit at the console of a computer and see a display of human figures stylized by simple stick figures as shown in these frames from a computer-generated movie. By interacting with the computer, the choreographer might create his dance composition, perhaps leaving certain movements to be suggested by pseudo-random and mathematical algorithms within the computer.

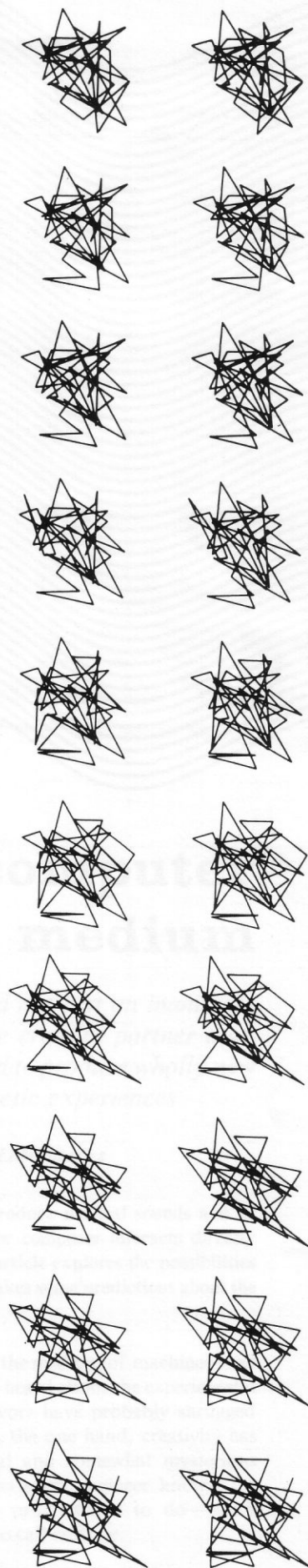
media could be the important factor in determining artistic merit. Conceivably, a form of "citizen-artist" could emerge, as envisioned by Allon Schoener.¹¹ The interactive aesthetic experience with computers might fill a substantial portion of that great leisure time predicted for the man of the future.

The artist's role as master creator will remain, however, because even though the physical limitations of the medium will be different from traditional media, his training, devotion, and visualization will give him a higher degree of control of the artistic experience. As an example, the artist's particular interactions with the computer might be recorded and played back by the public on their own computers. Specified amounts of interaction and modification might be introduced by the individual, but the overall course of the interactive experience would still follow the artist's model. In this way, and for the first time, the artist would be able to specify and control with certainty the emotional state of each individual participant. Only those aspects deliberately specified by the artist might be left to chance or to the whims of the participant. All this would be possible because the computer could monitor the participant's emotional state and change it according to the artist's specifications. The artist's interaction with the computer would be of a new order because the physical restrictions of the older media would be eliminated.

This is not to say that the traditional artistic media will be swept away; but they will undoubtedly be influenced by this new active medium. The introduction of photography the new medium of the last century—helped to drive painting away from representation, but it did not drive out painting. What the new creative computer medium will do to all of the art forms—painting, writing, dance, music, movies—should be exciting to observe. We might even be tempted to say that the current developments and devices in the field of man-machine communication, which were primarily intended to give insight into scientific problems, might in the end prove to be far more fruitful, or at least equally fruitful, in the arts.

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These frames are the left and right images of a 3D pair from a computer-generated three-dimensional movie. The object randomly changes its shape in what might be called a form of kinetic sculpture. To view the 3D effect, place a sheet of paper on edge between a stereo pair. Position your head so that each eye sees only one image. With a bit of adjustment, the images should seem to converge and appear three-dimensional.