The Beginnings of Computer Art in the United States: A Memoir

A. Michael Noll

ABSTRACT

Three decades ago, such terms as computer art, virtual reality and computer animation had not yet entered our vocabulary. This was a time for the experimentation and innovation that produced today's industry of computer art and animation, along with new media for creative experiences with computers. The author has used digital computers in a variety of the visual arts, including still images, stereoscopic images, computer holography, three-dimensional animation, four-dimensional animation, interactive stereoscopic displays and input devices and, ultimately, three-dimensional force-feedback—the latter becoming a major component of today's virtual reality. This research and experimentation in computer art was performed during the 1960s. In this article the author reminisces and describes his early work.

THE BEGINNINGS: HOW IT ALL CAME TOGETHER

In the summer of 1961, I was hired fresh from Newark College of Engineering to work at Bell Laboratories in Murray Hill, New Jersey, on the subjective aspects of telephone service. As part of an employee educational and training program conducted by Bell Labs, I was given an internship at its research division during the summer of 1962. The prime project on which I worked during that summer was the invention and exploration of a new method for determining the fundamental frequency of speech. This project involved the plotting of many graphs of various kinds of speech data. The relatively new Stromberg Carlson SC-4020 microfilm plotter was a major tool in generating these graphs of speech data, and this hardware became the basis for my investigations of computer art.

As a child, I had always had an interest in drawing and created elaborate pictures of the interiors of ships and space vehicles. As I became older, my interest in drawing extended to art in general, and I was a frequent visitor to New York's Museum of Modern Art, although I had no formal or academic artistic training or knowledge. I also had a couple of stereoscopes and was fascinated by their three-dimensional (3D) imagery.

In the 1960s Bell Labs was a great research facility that encouraged considerable freedom to take chances and explore uncharted avenues of discovery. John R. Pierce, the director of the research division where I spent the summer of 1962, was at that time investigating the use of computers in music. William O. Baker, the vice president of research, had created an atmosphere of intellectual freedom that was clearly supported by my immediate supervisors in the research division, namely, Manfred R. Schroeder and Edward E. David, Jr., and also by my colleagues, in particular Peter B. Denes.

So, all the ingredients for my pioneering discoveries in computer art were present: a childhood interest in art and stereoscopy, the freedom to explore new avenues, and the very best technology of the day. I still can remember the day when a fellow summer intern with whom I shared an office, Elwyn Berlekamp, came down the hallway with a computer-generated plot of data that had gone astray because of some programming error. Lines went every which way all over his plots. We joked about the abstract computer art that he had inadvertently generated. It then occurred to me to use the computer, an IBM 7090, and the Stromberg Carlson plotter to create computer art deliberately. Thus my experiments in computer art began in the summer of 1962 at Bell Labs.

The first images that I created used straight lines, combining elements of order with the disorder of randomness. In one series of investigations, randomly placed lines were plotted 90°

to each other, and from these I chose which line density and aspect ratio was most pleasing to me. In other experiments, I used different random distributions to determine their artistic effects. I described the results of these experiments in a Bell Labs technical memorandum entitled "Patterns by 7090," dated 28 August 1962. One pattern, *Gaussian-Quadratic* (Fig. 1), was particularly pleasing to me. Later, I discovered that it reminded me of the Picasso painting *Ma Jolie*. For fun, I would use colored-ink markers to trace over the pattern to produce customized art for my colleagues at work.

At the end of the summer, I returned to my regular department and my work in subjective assessments of telephone transmission quality, but my interests in computer art continued. Much was happening at Bell Labs in the early 1960s involving art, music and animation. Bela Julesz was using the computer and plotter to produce random-dot stereograms for investigations of human visual perception. Kenneth Knowlton was working with the famed animator Stanley Van Der Beek to generate computer-animated movies. Max V. Mathews was using the computer to generate musical sounds. Frank W. Sinden and Edward E. Zajec were creating computer-animated movies to help visualize scientific and technical kinetics.

There was just too much happening for me to forget my interests in art and computers, and so I continued my investigations on an informal basis. My research into computer art and computer graphics continued to attract the attention of managers in Bell's research department and in 1964, I was transferred into the research division, even though I did not have the usual prerequisite doctoral degree. I had, however, started doctoral study on a part-time basis at the Polytechnic Institute of Brooklyn. This study culminated in my doctoral dissertation, which investigated the use of a three-dimensional force-feedback device to enable the user to feel shapes and objects simulated by software in the computer.
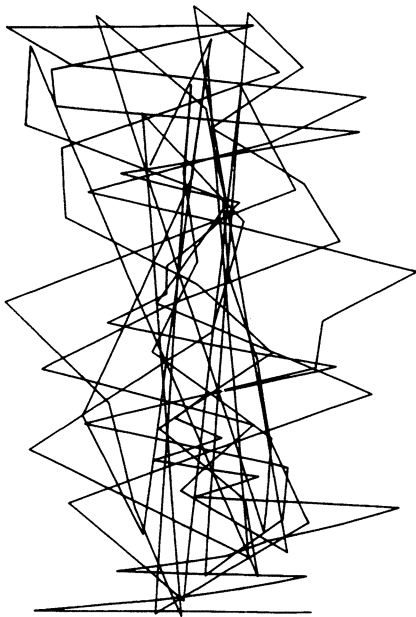
In mid-1971, after receiving my doctorate from Brooklyn Poly, I left Bell Labs to work on the staff of then-President Nixon's Science Advisor, Edward E. David, Jr., who had left Bell Labs to accept this post a year or so before. This change in the

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Fig. 1. *Gaussian Quadratic,* computer graphics, 1962. (©AMN 1965) This was the author's first serious piece of computer art, which he found suggestive of Picasso's cubism. Since there was no physical reality to motivate the work, it can perhaps be considered a combination of abstraction and cubism.

direction of my career took me away forever from computer art and new forms of man-machine communication. Washington opened my vision; I realized that technology alone did not shape the future and that such other factors as policy, finance and consumer needs were perhaps even more important. The study of these nontechnology-related factors thus strongly attracted my attention, and in 1973, when I returned to Bell Labs, my research focused on the social aspects of communication technology. After a few years at Bell Labs, I transferred to AT&T and pursued a career there in the marketing of new telecommunication products and services. About 9 years ago, I left AT&T and initiated an academic career teaching the fundamentals of modern telecommunications technology to tomorrow's managers.

AESTHETICS:
THE MONDRIAN EXPERIMENT

I always had an interest in the human and perceptual aspects of technology. Thus, it was natural that I would want to use my computer-generated patterns as stimuli to investigate aesthetic prefer-

ences. From a book, I was familiar with a Piet Mondrian painting consisting of only short horizontal and vertical bars. Such a pattern lent itself to producing a computer version, and I wrote a program to generate a computer Mondrian (Fig. 2). I then showed copies of the two works to people at Bell Labs to determine which pattern they preferred and also whether they could identify the actual Mondrian work. The results of the study were published in *The Psychological Record* in 1966 [1]. The computer Mondrian was used as the cover art for a textbook by a friend and colleague [2] and also for a textbook on probability [3].

Later, I modified the algorithm so that a series of patterns varying in the range of randomness could be created to even more closely approximate the Mondrian painting. I then designed an experiment using these patterns to determine whether people with formal artistic training had different preferences than those without any such training. I was unable to find any meaningful differences between the two groups of subjects. The details and results of the study were published in *Psychological Record* in 1972 [4].

Op-art was quite popular during the 1960s. In response to this movement, I used the computer to create a mathematical version of Bridget Riley's scintillating painting *Current.* I called my computer version *Ninety Parallel Sinusoids With Linearly Increasing Period* (Fig. 3).
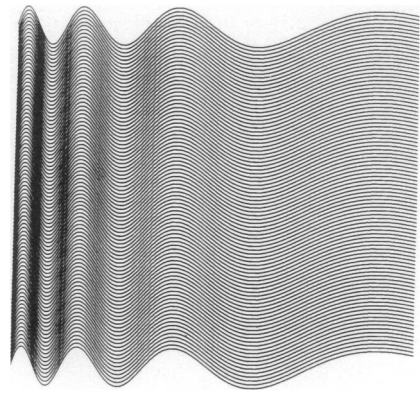
STEREOSCOPIC
PROJECTIONS AND MOVIES

I wrote software for the IBM 7090 so that 3D data could be displayed stereoscopically. The computer generated the stereoscopic projections of the data and then

Fig. 2. *Computer Composition With Lines,* computer graphics, 1964. (©AMN 1965) This work closely mimics a painting by Piet Mondrian.

Fig. 3. *Ninety Parallel Sinusoids With Linearly Increasing Period,* computer graphics, early 1960s. This work was strongly influenced by Bridget Riley's *Current* and is an example of the application of computers to op-art.

instructed the microfilm plotter to create two plots: one for each eye. I used one of my stereoscopes from childhood to view the images. The technique is described in a Bell Labs technical memorandum I wrote entitled "Stereographic Projections by Digital Computer," dated 27 March 1964. In the early 1960s digital computers were still somewhat new, and the adjective "digital" was usually used to distinguish them from their analog parents.

Again, the imagery was mostly artistic, although I also plotted some 3D speech spectrograms as part of my research in speech analysis and synthesis. I produced a series of stereoscopic images, used them as stimuli for some exploratory investigations of perceptions of aesthetic value and found that stereoscopic versions of the patterns were preferred over flat two-dimensional (2D) versions.

THE HOWARD WISE
GALLERY EXHIBIT

The Howard Wise Gallery on New York's West 57th Street had acquired a reputation for innovation and for introducing new artists and new artistic forms to the public. In 1964, Wise approached one of my colleagues at Bell Labs, Bela Julesz, who was using the computer and plotter to produce random-dot stereograms for investigations of human visual perception. Bela introduced me to Wise, who wanted to exhibit Bela's and my computer-generated images at his gallery.

Bela was always very careful not to call his images "art," since the images were stimuli for psychological investigations of visual perception. I, however, had generated many of my images solely for

their aesthetic or artistic effects and was much more willing to call them art. In the end, we compromised and called the exhibit "Computer-Generated Pictures." The announcement for the exhibit was a small deck of IBM punched cards. The exhibit ran from 6–24 April 1965 and was the first major exhibit of computer art in the United States. I later found out that Frieder Nake and George Nees had a public exhibit in Germany of their digital computer art only a few months earlier in 1965.

The Howard Wise Gallery exhibit included photographic enlargements of a number of our computer-generated images. The stereoscopic images were reproduced using polarized technology and then mounted between clear plastic sheets. Special polarized spectacles were used by those attending the exhibit. The response by the public and media was disappointing. I remember spirited discussions with Wise about how we would split the revenues from sales, but in the end not a single work was sold! The short review of the opening in the *New York Times* by Stuart Preston [5] was positive and opened with "The wave of the future crashes significantly at the Howard Wise Gallery. . . ."

Although the research management staff at Bell Labs was very supportive of the Howard Wise Gallery exhibit, the legal and public relations folks at AT&T became worried that the Bell Telephone companies that supported Bell Labs would not view computer art as serious scientific research. Hence an effort was made by AT&T to halt the exhibit, but it was too late, since financial commitments had already been made by Wise. Accordingly, Bela and I were told to restrict publicity, and, in an attempt to foster such restriction, Bell Labs gave Bela and me permission to copyright all the pictures in our own names.

I decided to register the copyright for *Gaussian-Quadratic* with the Copyright Office at the Library of Congress. At first they refused since a machine had generated the work. I explained that a human being had written the program that incorporated randomness and order. They again refused to register the work, stating that randomness was not acceptable. I finally explained that although the numbers generated by the program appeared "random" to humans, the algorithm generating them was perfectly mathematical and not random at all. The copyright was finally accepted, thereby giving *Gaussian-Quadratic* the distinction of being perhaps the first

registered piece of copyrighted art produced with a digital computer.

The Howard Wise Gallery exhibit was a first for me and was followed by exhibits of my computer art in a number of countries: England, Yugoslavia, Czechoslovakia, Brazil, Germany, India and Spain.

An important conference on the use of computers in design and art was held at the University of Waterloo in Ontario in June 1966. The conference, named the Third International Design Seminar, was organized by Maurice Constant and Martin Krampen and was unique in bringing together artists, designers and technologists. Much computer-generated imagery and animation was shown at the conference. It was an opportunity for me to learn about the work of such other pioneering institutions as Lawrence Livermore Laboratory, where George Michael was responsible for stimulating the early exploration of computer animation and graphics using the Stromberg Carlson microfilm plotter.

THREE-DIMENSIONAL ANIMATION: 3D MOVIES

A number of my colleagues at Bell Labs were exploring computer animation. This led me to produce a series of stereoscopic projections that could be viewed as a 3D movie. I wrote the software and described it in a Bell Labs technical memorandum [6]. The 3D animation included a random object that changed its shape in a random fashion and a rotating four-dimensional (4D) hypercube (Fig. 4) projected perspectively into three dimensions.

The idea for investigating the four-dimensional hypercube was suggested to me by Doug Eastwood, a colleague at Bell Labs. The stereoscopic pairs were plotted head-to-head in a single frame and then projected through a special prism adapter (called Prism-Stereo) that required the use of polarized glasses to obtain a 3D effect. I also produced versions of the 3D movies with the stereo pairs plotted adjacent to each other, but this required the viewer to look cross-eyed at the screen to fuse the stereo pairs.

COMPUTER HOLOGRAPHY

The stereoscopic animation program could generate a series of perspective views of a 3D object seen from positions rotating around the object. A colleague at Bell Labs, Michael C. King, got the
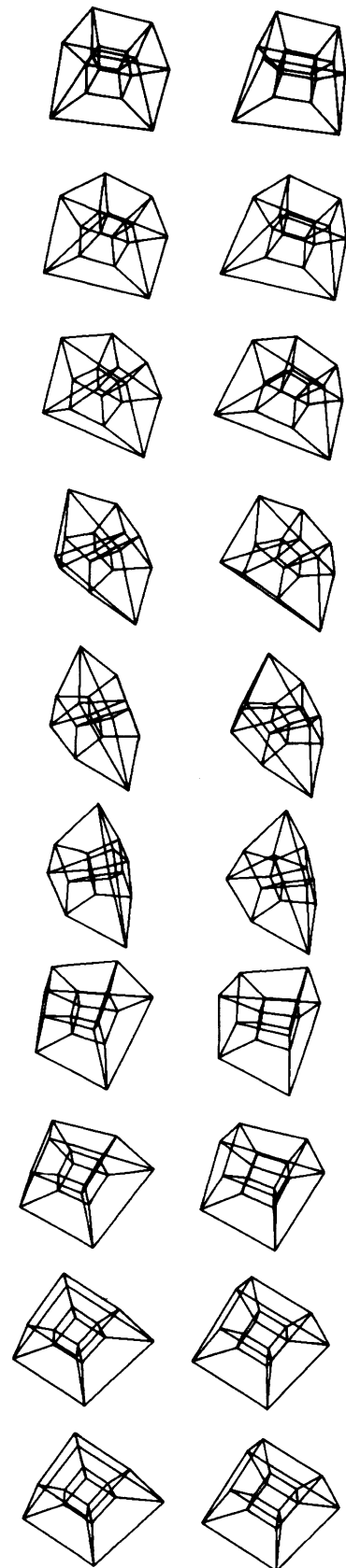

Fig. 4. This series of stereographic images is from a computer-generated movie showing the perspective projections of a rotating four-dimensional hypercube (1965). The stereo pairs will fuse if they are observed cross-eyed. The author later used the technique to generate main title sequences for a movie (see Fig. 5) and a television special.
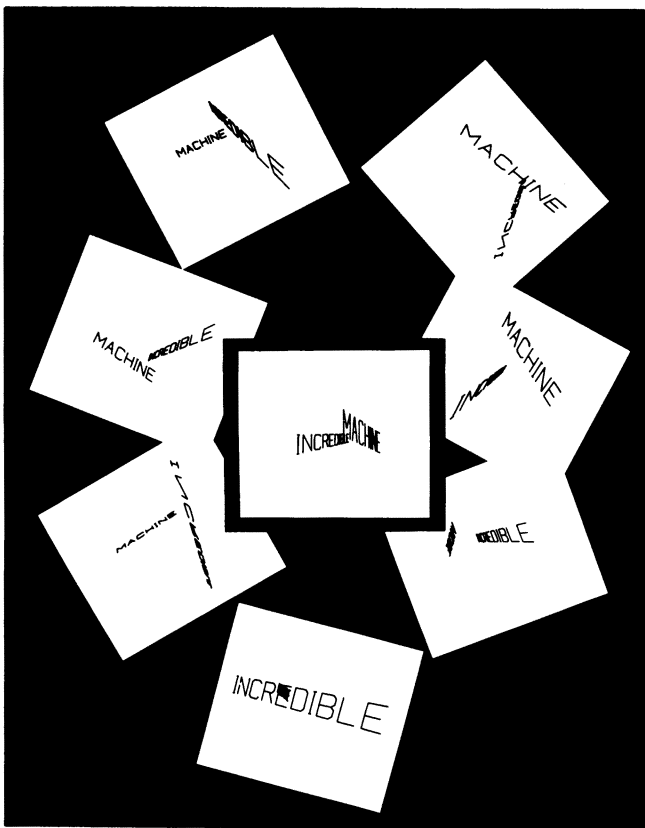
idea to combine all these views in a strip hologram that could be viewed with a simple point source of white light, such as a flashlight. I used one of my random 3D objects to generate the perspective views, then King combined them in a hologram created with the help of his assistant, Daniel H. Berry. This approach to computer-generated holography resulted in a new form of computer sculpture.

FOUR-DIMENSIONAL ANIMATION

The stereoscopic projections of the rotating 4D hypercube had a smooth animation that was pleasing and fascinating to look at. This gave me the idea of using the technique to animate letters and words. I placed letters and words in 4D space and then had the computer rotate the configuration in four dimensions and create a movie of the two-dimensional perspective projections of the projections from four-space. The resulting animation looked great. The technique was used to create the main title sequence for an award-winning movie short on computer research at Bell Labs entitled *Incredible Machine,* produced by Owen-Murphy Productions in 1968 (Fig. 5).

The 4D animation was seen by Walter De Faria of Lee Mendelson Productions on a background visit to Bell Labs for an *Encyclopedia Britannica* television special that he was producing for NBC (National Broadcasting Company). He asked me to create the main title sequence using the 4D animation technique, and I agreed to do so. The special, written by Arthur C. Clarke, was called "The Unexplained" and was about various unexplained phenomena; it was colorcast on 3 April 1970. I remember the wonder that De Faria had at the speed with which different animations could be done on the computer. These two title sequences are examples of perhaps some of the earliest use of computer animation to do title sequences.

COMPUTER CHOREOGRAPHY

Because I lived at my parents' home in Newark, New Jersey, and attended Brooklyn Poly at nights, I was able to attend many concerts, operas and ballets in New York City. The idea of using computers in ballet occurred to me while attending a performance of Ballanchine's *Apollo* at the New York City Ballet with a friend who was a dance student. The interrelationships between the dancers in the work fascinated me, and I envisioned a computer version of the work using computer-animated stick figures. My dance-student friend quickly edu-
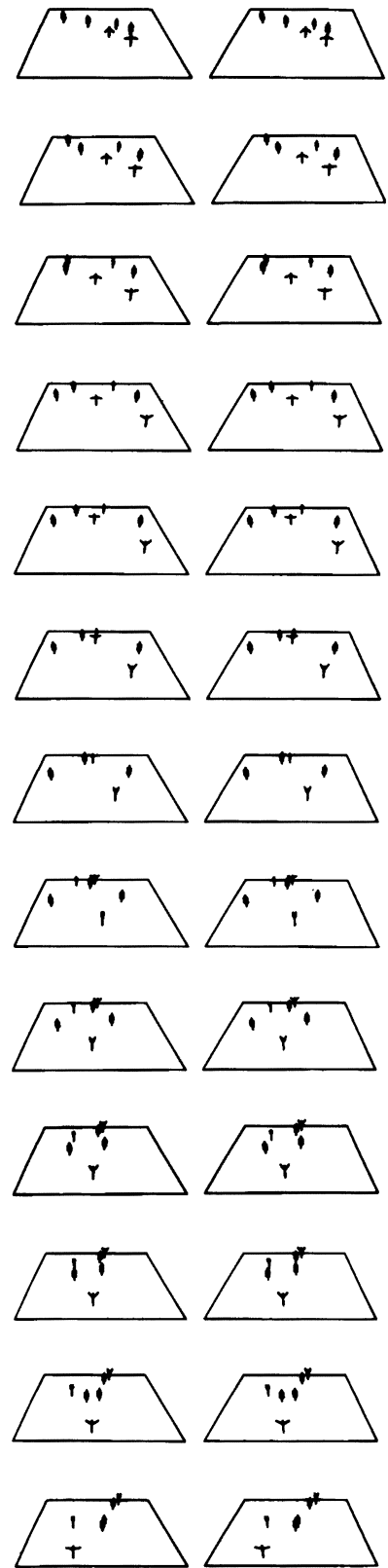
Fig. 6. The author used the computer to generate a simulated ballet, showing simple stick figures moving about on a stage (1965).

cated me about the various forms of dance notation that were available, and I went to work developing programs to create and animate simple stick figures. I incorporated random motion around a stage employing six stick figures: three large "male" figures and three small "female" figures.

The original computer-generated ballet, which I completed in 1965 (Fig. 6), was a computer-generated stereoscopic movie. I later produced a 2D perspective version that was easier to show since special polarized glasses were not needed. At the time, I envisioned a creative choreographic situation in which the choreographer would interact in real time with a computer to compose a ballet while manipulating and seeing computer-generated stick figures. The final work could then be transposed through the computer to dance notation to give to the human dancers. The computer-generated ballet became a concrete example of what potentially could be done with computers in dance, and I showed the movie to various dance notation organizations in New York and also to a number of choreographers, including Rebekah Harkness and Merce Cunningham. Although there was much interest, the technology was not then available. The required "friendly" interfaces are still topics for research.

INTERACTIVE STEREOSCOPY

In the mid-1960s at Bell Labs, Peter B. Denes installed one of the earliest computer systems dedicated solely to the use of researchers in an interactive real-time laboratory environment. I designed 3D input devices and displays for use with his Honeywell DDP-224 computer system and described them in a Bell Labs technical memorandum entitled "Software Package for Real-Time Interactive Computer Graphics on the Honeywell DDP-224 Computer," dated 6 June 1968. Users could draw in three dimensions while looking at a true stereoscopic display of the results.
A few years later, Denes and I implemented a scanned display for use with the DDP-224 computer. The scan-conversion from rectangular coordinates to the scanned image was done by software. A patent for the idea was filed 5 February 1970, but great controversy ensued with the Patent Office since part of it involved software that in general could not be patented at the time. The case ultimately made its way to the Supreme Court, but AT&T ordered Bell

Labs to abandon the case. AT&T was concerned that the Court might become overburdened since the Court was expected to hear cases involving competition in telecommunications that might determine the fate of the Bell System.

"FEELIES"

During a visit to Bell Labs in the 1960s, Canadian animator Maurice Constant described his ideas about some form of human-machine environment in which designers could use their hands to mold shapes that were stored in a computer. It occurred to me that such a "feelie" device could be constructed by motorizing one of my 3D input devices for the DDP-224 computer. I proposed this project to management at Bell Labs and also to my dissertation committee at Brooklyn Poly, and they both approved. During the last few years of the 1960s and extending into the first few years of the 1970s, I designed and constructed this tactile device and connected it to the DDP-224 computer. With it, a user could feel around some computer-simulated object or shape within the space of a cubic foot. At the same time, the user could look at a stereoscopic display. The tactile device was a motorized joy-stick. The user grasped a ball at its top, and as it was moved, position data was generated and sent to the computer. The computer then created signals to control the motors, thereby producing a force response (Fig. 7).

I filed a patent for the tactile man-machine communication on 26 May 1971, and it was issued on 1 November 1975 (U.S. Patent Number 3,919,691). The

patent, which expired last year, was quite broad and covered the overall concept of a force-feedback device and a display coupled to a digital computer. This tactile man-machine communication system, designed and implemented in the late 1960s and early 1970s, was the genesis of much of today's virtual reality. I envisioned the use of a head-mounted display (invented years before by Hugh Upton of Bell Helicopter) with half-silvered mirrors so that a computer-simulated image could be superimposed over the real world while a user simultaneously grasped and felt a computer-simulated object.

PUBLICATIONS

There was much emphasis at Bell Labs during the 1960s on educating artists and musicians about the potential for using computers, and many artists and musicians visited the Labs to observe first-hand what was being accomplished. Korean-American television artist Nam June Paik visited with me during that time to learn about the potential for using computers to create the type of visual imagery that he was then obtaining by manipulating television images. This emphasis on education led me to publish much of my work as a means of educating and affecting others.

The bibliography at the end of this article lists 17 published papers describing my research in the use of digital computers in the visual arts and in new forms of interaction with computers. The intent of these papers was to document my research and to open the doors to new areas of future work and discovery.

Fig. 7. This drawing is from the front page of the author's patent (No. 3,919,691), issued 11 November 1975, of a tactile human-machine communication system. Position data is generated as a user moves a stick-like mechanism within the space of a cubic foot. The computer, in response to a stored description of some shape or object, generates signals to energize the tactile device so that it appears as if the user has bumped into the shape or object. A stereoscopic display simultaneously depicts the object and the movement of the tactile terminal. The breadth of this patent encompasses much of today's "virtual reality."
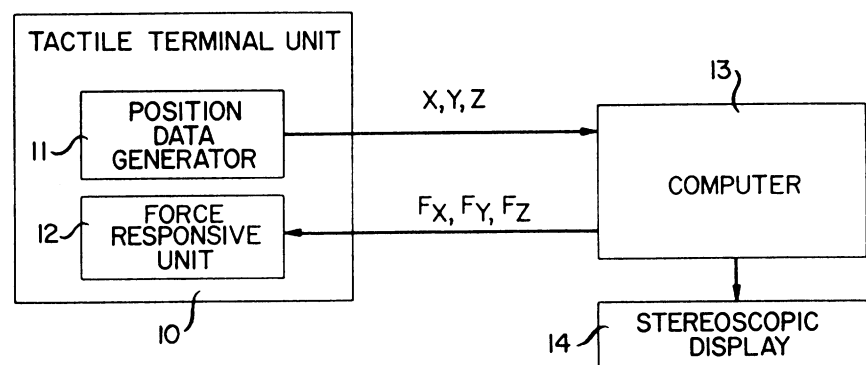
Some of the papers expressed my views about the future of computer art. In "The Digital Computer as a Creative Medium," I explored the idea that artists had a new creative partner or medium in computers as assistants in the creative process. In "Art Ex Machina," I foresaw the day when a new breed of computer artist would emerge, trained in both art and computers.

SOME LAST THOUGHTS

At the time of my research into computer art at Bell Labs, I was simply having much fun and enjoying the challenge of exploring new territory. I had little idea then that the use of computers in the visual arts would progress as rapidly as it has. This rapid progress is the result of technological innovation that has lowered the cost and increased the capabilities of the technology, thereby making it much more available. The commercial use of computer graphics still leads the artistic applications, and I have not noticed any major museum of modern art giving much attention to computer art. However, the computer is only a medium, and the medium should not be emphasized over the artistic result. If there is any failing in computer art it is that the medium is still an excuse for poor art. I hope that this will soon change as computers become much more prevalent in our art schools. Computers might actually be the single common tool that will lead to an integration of various arts, such as music, animation, sculpture, drama, architecture, design and dance. The fu-

ture of computers in the arts continues to excite me, and I look forward to seeing the maturing of this still new artistic tool and medium.

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