# "Scientists Doing Art, Artists Doing Science"

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Standing on the ridgetop where one can look both into the fields of art and into technical subjects, one is impressed by the scientists, mathematicians and computer scientists who have made contributions in the field of art. I will survey some 20th century art pioneers who began in science-related fields—ones who did not work in the electronic arts, and who are no longer living. Then, I will discuss two who are still alive and currently using electronic means to bring their science-related expertise into the realm of visual arts: **John Whitney** and **Kenneth Knowlton**.

Coming from the other side of the ridge are visual artists who are doing science with an artist's mind. In the course of their work as artists they have been bitten by the bug of some problem that has drawn them over the ridge into the technical realm. They've made contributions in both art and a science-related discipline using electronic tools.

This is a tribute to both scientists and artists whose careers have taken them to both sides of the ridgetop. These are towering figures whom I wish to honor. I have chosen seven to discuss in detail: **Lillian Schwartz, Helaman Ferguson, Kenneth Snelson, Ellen Sandor, Roman Verostko, Harold Cohen, and Myron Krueger**. I will go subject by subject. For instance, I will treat computer science and discuss contributors, taking note of who were the artists and who were the computer scientists.

First, the pioneers: Beginning in the 1930s, **Buckminster Fuller** was exploiting his remarkable geometric insights by designing geodesic domes and truss structures. His engineering was art, in the spirit of Bauhaus design for everyday objects. And, long before anyone else, he was preoccupied with global needs and resources. Will this prolific genius be remembered more for the geodesic domes on the landscape, or his vision for the future? His 1971 World Game, a group activity to teach people an appreciation of world resources in a new way, was an early *Sim World* ecology game. He knew, before most of us, how much people in the industrial countries squander resources. But he was an optimist. Will his vision of ocean-going colonies help care for our expanding population in the next century?

We are particularly indebted to **Frank Malina,** a space scientist and artist who in 1968 gave voice to artists like ourselves by starting the journal, *Leonardo,* from which sprang the organization Leonardo/ISAST. In countless ways, it has provided validating support for art using science and technology that has been so absent in the official art world. ISAST is one of the organizations that makes the ISEA conferences possible.

How did it come about that the co-founder of Jet Propulsion Laboratory in Pasadena in 1944, and later a director of UNESCO's Natural Sciences Department, became so involved in art that he saw the need for this?

He had moved to Paris to work for UNESCO. In 1953, after completing this work, he began doing art there. *Deep Shadows,* 1954, started with the idea of making moirés with mesh, and ended up being his first piece using electric light. He went on to make light boxes with static and moving elements which, in combination, produced moving patterns. A particularly complex one was *Cosmos,* 1965, using over 100 bulbs and 29 rotors. Diffusers were used to give a soft, lyrical quality. He learned by chance that this was not a completely original idea, and wondered why no way existed for artists to search the literature for predecessors and technical information as there is in science. *Three Masks,* in 1965, explored polarized plastic films that moved past each other to produce a color change. He may have been the first to use this technique, which has proved fruitful for several other artists.

His frustration with the lack of literature caused him by 1965 to contact potential publishers regarding an art journal that would allow artists to speak for themselves in clear language, and to have the articles peer reviewed, as in scientific journals. The aim was to promote sharing of information and contacts with colleagues worldwide. In 1967 he reached an agreement with Robert Maxwell to have it published in England at Pergamon Press.

What else was happening at that time? Also in 1967, **Gyorgy Kepes** founded the Center for Advanced Visual Studies at MIT, and Experiments in Art and Technology, an endeavor started by artist **Robert Rauchenberg** and Bell Labs scientist **Billy Klüver,** had just had its Armory Show in New York the year before. So the timing was very good!

In the early 1960s, physicist **Robert Wilson** was about to take a sabbatical to do sculpture when he was offered the directorship of the proposed Fermilab in Batavia, IL. He insisted that the contract give him discretion to allocate the money, as long as he got the accelerator built within budget. He proceeded to make a great many aesthetic decisions about the building and layout of the lab. The majesty of the great central building is legendary. He felt it was a visual symbol of the great common endeavor that they were engaged in, contributing greatly to group morale. And, of course, the laboratory was peppered with his sculptures that doubled as cheap solutions to practical problems. One was an outdoor hexagonal sculpture covered with an array of boxlike condensers to boost the energy of the accelerator. Most laboratories would have built a small building for this at somewhat greater cost.[1]

**Two pioneers of the computer age**

Composer **John Whitney** and his brother began in the 1940s to make synthetic music by drawing sine wave variations with a complicated array of pendulums. These appeared on the sound-track edge of movie film, based on how normal sound is coded in this area as a lineal wave-form representing sound harmonics. He combined it with abstract animation, which he had learned to do as early as 1937. Since the advent of personal computers, he has been linking digital sound with digital images, writing software to do this. He believes that a musical experience is one in which harmonic dissonances resolve into consonances through time and resonate deeply in human experience. And, he believes that moving images can be created that correspond to this. But his technical contribution is his realization that music and visual art are all digits now, and can be manipulated in a new way.

Computer scientist **Ken Knowlton** has created many tools for visual art and animation. At Bell Labs he worked with Leon Harmon in 1966 to reproduce scanned photographic images with small symbols for different densities. This was a rough way to obtain grey tones at a time when computer output was very primitive. The curious juxtaposition of overall image and, at close range, unrelated symbols inspired artist **Lillian Schwartz** to collaborate with him. Schwartz' drawings on graph paper became computer graphics. It was with his help that she became a computer artist. Then he wrote BELFLIX (a corruption of Bell Flicks), the first general-purpose program for animation, and a later animation program, EXPLOR, for Lillian Schwartz' use. At SISEA in 1990, he and Katherine Donoghue presented a "Computer Simulation of Calligraphic Pens and Brushes. In his other technical work, he holds 14 patents.

In art, here is how Knowlton has exploited his original idea of symbols to code the density of pixels in a photograph: In one, the dot patterns on 24 sets dominos are arranged to show a man holding a domino. His portrait of Jacques Cousteau uses large and small white shells on a black grid. While working on it, he couldn't see the face up close. He says the lovely expression in the eyes was completely coincidental. Lately, he has been using shells on cultural icons such as Grant Wood's *American Gothic* figures.

**Seven Whose Work Crosses Disciplines**

In the use of computers for archeological and art history research, artist **Lillian Schwartz** is breaking new ground. As new graphic tools are developed, she has a gift for seeing worthwhile ways to use them. Here is her 1984 computer poster for the Museum of Modern Art called *Big MOMA*. It involved texture mapping (fairly new in 1984). This is just one example of her art using the computer.

In archeology, one of her 1981 projects relating to excavations at Carthage was to find an entrance to the harbor at Carthage described in ancient texts. A contour map of the present harbor was scanned in. Lines between the contours forming a mesh of triangles were added, then data about sea level fluctuations and other historical changes was entered. This made an animation that played backward in time and clearly showed the old entrance. A year later they dug it up!

In art history, her famous comparison of Leonardo and the *Mona Lisa* in 1986 happened quite by chance. Gerard Holzman was working on PICO graphics software, and invited her to try scanning in some images that she had on magnetic tape. While she searched for Leonardo's self-portrait, she came upon the *Mona Lisa* and also scanned her. Remembering the debate about Mona's identity, she thought it would be fun to compare her face with Leonardo's. Leonardo had to be flipped from left to right and resized. Then, the tips of the noses were aligned. The match-up of features was so close it was uncanny! The results seemed to show that Leonardo had used himself as the model. Schwartz exhausted other possibilities, comparing *Mona* with other Leonardo studies for the painting. None of them matched as well.

The *Mona Lisa* gambit was used again to follow the trail of another historical mystery: who was Shakespeare? Here, her discovery was that the face of Queen Elizabeth I fit Shakespeare's best! What this proves, she admits, is a mystery.

Her most recent projects concern frescos by the early Renaissance painter, Piero della Francesco. Here are two of them. Analysis of the face in his painting, *Resurrection,* shows an asymmetry in the nose and ear areas. In fact, one ear seems positively deformed. Note how much character the face has. The cauliflower ear and deformed, or perhaps broken, nose suggested to her that della Francesco's model had been a fighter.

For frescos, Renaissance painters made big "cartoons" (drawings) to transfer to the wall. Holes were made along the lines, and charcoal dust pounded through them onto the wall. To save labor, parts of cartoons were often re-used. As in computer graphics, these could be flipped over or moved. As she logged examples of this rule-based behavior, Schwartz found a way to do a virtual restoration of a damaged patch in the background behind the portrait of St. Julien. The texture in it had been created, she found, by moving the same stencil around at random. She was able to make a facsimile of the basic stencil and move it on the computer image to create a piece that fit. She expects that sleuths like herself can construct restored images in computer memory which may be useful to historians whether or not the funds are found to restore the actual work.

From her study of previous artists and from making art herself with a new-fangled art medium, she concludes: "If the artist captures something essential prior to death, then we remain moved because of the spirit preserved in the artwork. That movement continues to exist because moved because of the spirit preserved in the artwork. That movement continues to exist because the expression is inconclusive, speaking to us as a spark unbound by time and space. The computer also represents a process. But it is a polymorph of mathematical and logical design. What it can do is subject to what we believe it can do for us....the qualitative sensations of the creative act remain the elusive domain of the artist."[2]

Turning now to mathematics, **Helaman Ferguson** marries the Stone and Bronze Ages with mathematics and the Computer Age. His interest in stone began when he was apprenticed in his youth to a stonecutter. He studied painting in college and took graduate-level sculpture courses. His doctorate, however, was in mathematics, which he taught at Brigham Young University for 17 years. Now, he designs new computer-based algorithms for operating machinery and for visualizing data. Scientists, he finds, are buried in an avalanche of data, and need his help in "sculpting" it into something they can grasp.

Concurrently, he does sculpture. And what sculpture! Mathematical relations take shapes never before seen. He molds abstract formulas into something ordinary passers-by can enjoy. The tactile qualities of stone or bronze lend a special warmth to his ideas. He enjoys the adventure of carving the unpredictable stone, concentrating to the same degree as when doing a difficult calculation. His technique is always subtractive, carving away, a more risky process than building up. Finding the right embodiment for the idea must come first, which sometimes takes years of turning the problem over in his mind. Then, he begins to carve, using hand and power tools.

Earlier, he created stone sculpture measuring by hand and eye, but now uses a computer-guided system developed by the National Institute of Standards and Technology. The actual transfer of the pattern to stone is by means of a measuring device not unlike a retractable tape measure that goes from a fixed point at his computer apparatus to the points he measures on the stone. Its measurement of a given point will show up on the computer screen where it can be compared with the desired measurement for that spot. He carves until these match. This is not easier, just different. The computer method has problems of its own!

His *Umbilic Torus NC* was cast in bronze using the ancient lost-wax process. The original was carved in high density foam. Similar to a Moebius band, the shape of *Umbilic* has a peculiar quality: It only has one edge. It is covered with a surface-filling fractal curve. The surface design was inscribed by a computer-driven milling machine. Ferguson enjoys this pattern's resemblance to those on ancient Chinese bronzes and Mayan carvings. He likes to think his marbles and bronzes will last as long.

"I celebrate mathematics," he says. "Among the greatest myths of our age are mathematical equations, their equal signs heros. Today's Atlas holds up a world of aircraft; he is the equal sign in the Navier-Stokes equation; airplane designs are simulated by equations before they are considered safe to bear humans aloft. I regard mathematics as a design language for vital images."[3]

In physics and chemistry, we have sculptor **Kenneth Snelson** who is making models of electron orbits around the nucleus of the atom. Snelson has made his mark in the world with his enormous tensegity sculptures. He invented compression-tension structures while a student of Buckminster Fuller's in 1948. When Fuller saw the idea, he named the concept Tensegrity, refined it, claimed it as his own and patented it—not one of Bucky's finer moments.

We need to know a little more about the atom to know what Snelson is doing. Allow me to oversimplify! The atom has a hard, dense core, made of protons and neutrons. The nucleus is more in the realm of nuclear physics, which does not concern us here. Around the nucleus circulate

Electrons have too many puzzling properties to enumerate here: for example, are they particles or waves?. Therefore, the famous logo of the atom that shows electrons whizzing around the nucleus like beady little planets is misleading. Physicists prefer to describe properties of electrons mathematically and not to think of them visually at all, or to portray them as a swarming "electron cloud."

However, chemists do try to visualize groups of electrons. The underlying basis for the Periodic Table of Elements, they believe, is that electrons are arranged in "shells" around the nucleus (figuratively speaking). If the outermost shell is full, the atom is like an inert neon atom, not reactive with other elements. An atom naturally possessing one more electron would represent a different element with an additional shell, a new element on the Periodic Table. Atoms with incomplete outer shells react with other atoms. Some atoms, like chlorine, are very reactive for this reason.

Snelson, yearning for a balance of forces to account for the apparent solidity of the atom, hit upon a concept of halo-like domains on a shell, not running around its equator, but rather like circles drawn on the surface of a balloon. He sees the halos as pressing like stones in a spherical arch, attracted toward the nucleus by its electric charge, but restraining each other in place. He has read much on the subject and has made models with many materials. One type, made out of circular magnets, turned up an odd relationship. Circular magnets can make shapes, but only certain numbers of them will make spheres. With one exception, these numbers match the number of electrons that can occupy shells, according to the Periodic Table. Using his idea, he can represent the atoms of all elements.

He always felt that his physical models didn't capture the beauty of his idea. On his SGI computer he has done a prodigious amount of work to render his models of the atom. His work has been shown at places where scientists could see and discuss it. Scientists don't feel the models meet their concerns, and quarrel with them somewhat. To date, no one has made a discovery using them. Their "uselessness" keeps them in the realm of art, which suits Snelson just fine. His computer graphics are deep and rich computer art.

But, tensegrity, which he thought of in 1948, is being used more than forty years later to show the "close cooperation of proteins" inside and outside of cells![4]

Now we turn to scientific visualization. **Ellen Sandor,** who also started as a sculptor, has recruited and led a team that created a new way to display scientific computer graphics. These displays, called PHSColograms (for PHotography, Sculpture and Computers, pronounced SKOL-o-grams) represent a new medium for artists as well.

In 1981 she made a big 3-D triptych for the wall of an office on Wall Street. Two years later, she recruited a team that called itself $(Art)^n$. It created a huge camera studio to make barrier-strip autostereograms. Autostereograms, so-called because a 3-D illusion can be seen with the unaided eye, were invented around the turn of the 20th century. A big still-life or diorama was photographed several times (usually nine), each time from a different angle. The film being exposed was covered with a "barrier screen," a black film with thin, transparent vertical lines—so that each image reached it only from a particular angle.

When one views an autostereogram, one moves past it. Another screen on this strange photograph allows each eye to see only one of the nine images at a time as you move by. The two eyes each see slightly different images, which the brain translates into three dimensions. Autostereograms are very difficult to make. Exposures are long. Moving the subject and the barrier film must be done precisely. One mistake ruins a day's work.

The resulting project combined these images with other media for a colorful 20' high installation in the lobby of a Chicago office building. They called it *PHSCologram 1983*. The ones that followed were often of sculptures and scenes with exaggerated perspective made especially to be photographed by the process. After seeing *PHSCologram 1983,* Dan Sandin, of The University of Chicago's Electronic Visualization Lab, understood the implications of it for scientific work. After he joined $(Art)^n$ in 1985, computers were used, greatly simplifying the mechanics and making possible PHSCologams of synthetic, computer-generated, completely imaginary objects. **Donna Cox**, at the National Center for Supercomputing Applications in Urbana, IL, has used the PHSCologram technology to model three-dimensional projections of four-dimensional objects. (She is another artist who is making a contribution to science by helping scientists to be more effective in visualizing their data). The $(Art)^n$ team includes, besides Dan Sandin and Donna Cox, **Stephan Meyers, Jim Zanzi, Randy Johnson** and **Ron Nielsen.**

A breakthrough, the Stealth Negative technique, was introduced by American Printers and Lithographers in 1988. This allowed $(Art)^n$ to by-pass the labor of physically making a photographic negative. The computer generates the barrier screen design and 13 different views of the subject. It creates a file which can be read by the computer of a prepress scanner, the same used in the printing industry to make four-color separations for printing plates. The output is transparent, in black-and white. Each of the four transparencies is exposed to the appropriate color of photographic film, and all are sandwiched together to make the four-color image, which is then contact printed onto Cibachrome film. The Cibachrome is mounted on the backside of a sheet of clear plastic. The computer also prints the black-and-white barrier screen, which is mounted on the front side of the plastic. Lit from behind by a lightbox, it produces the colorful 3-D illusion.

At the moment, these displays make wonderful science exhibit pieces, but are too expensive to be used routinely to help scientists visualize data. However, $(Art)^n$ anticipates that PHSCologram capability will be used in laboratories when small computers become more powerful.

Ellen Sandor is eager for artists to avail themselves of the technology. The artist in her also responds to the science images as art. She says: "For someone who is not a technical person, I have fallen in love with visualizing the invisible."[5]

In the realm of artificial intelligence (AI), **Roman Verostko, Harold Cohen,** and **Myron Krueger** have made contributions that are very intriguing for what they tell us about the emerging human-machine symbiosis. Symbiosis is when two species live intertwined, each supplying what the other lacks.

A personal art concept has led **Roman Verostko,** director of this conference, to explore computers for art. The tension between control and uncontrol are his subject, pursued for many years in drawing and painting using the Surrealist technique of "automatic" painting (i.e. making marks with no attempt to edit in order to access other realms of the psyche).

In 1970, Verostko learned to program, and in 1982 began writing a program to create art. A concept that fascinated him was epigenesis, that is, how a seed (genotype) unfolds into a mature being (phenotype). The computer program is a genotype that he creates. By its output (phenotype) he learns more about the logical structure he has created. It reveals something about computer logic that interests him. Sometimes, a bug creates an aberration. If it is lovable, he retains it. Taking cues from feedback like this, he modifies the program. As this process has developed over the years, he has created a program, Hodos, rich enough for other artists to use for their own art concepts.

His original fascination with control and uncontrol, the tension of opposites, is still observable in his present work. Hodos randomly repeats a line theme in many locations and rotations. Verostko has enabled the computer plotter to draw the line motif large with a Chinese brush. He inks and hands the brush to it when prompted by the computer program. That's symbiosis! Verostko's teaching a computer to make expressive lines, says Roger Malina, is "like teaching dolphins to talk to us."[6] Verostko says: "Software, in an uncanny way, appears to have a life of its own. The artist's role is to humanize it."[7]

Artist **Harold Cohen** has given great attention to the marks humans make and why. In his curious quest, he has not only extended what we understand artificial intelligence (AI) to be, but has ventured into cognitive science, the psychology of knowing, as well: What does it mean to draw, to look at a drawing and understand it, and what is it possible to tell a computer about generating one?

In 1966 Cohen was a visible success: at the Venice Biennale he had been one of five painters to represent Britain; but his career soon made a right-angle turn. An abstract painter, he was wrestling with the Abstract Expressionist dogma that really pure and good paintings had no meaning beyond the beauty of the painted surface. So, he experimented with making marks that looked like they *ought* to mean something more. From whence came the glimmer of meaning? From the viewer. This dialog was the basic issue in his work for many years.

Discontented with the big-time art world, he accepted a one-year invitation to the University of California at San Diego in 1967. He ended up staying, because he stumbled upon something new. Jef Raskin, then a graduate student in music and later one of the developers of the Macintosh computer, persuaded some of his non-technical acquaintances to learn programming—in spite of the fact that early manuals and rudimentary computers made this difficult.

Six months later, it struck Cohen that programming decision structures and the decision-making process in painting bore some similarity. (If...then...else...) routines were a branching structure that created unpredictable outcomes. This is called a *contingent* system, in which rules and feedback, plus randomness, (deterministic plus non-deterministic factors), create a result that is unanticipated—but usually comprehensible.

Could a drawing create itself, using a computer? What rules would it need? The computer's rules would instruct its pen plotter to draw. It would become a tool for describing and testing Cohen's hypotheses about the image-making activity of the brain. His work converged with artificial intelligence (AI) research because he assumed that the symbol-manipulating computer could be treated as functionally equivalent to the brain.

He gave his program, called Aaron, rules and feedback. With feedback, Aaron could avoid messing up the drawing it had already done. And, it would know when to stop. *Three Behaviors for partitioning Space,* 1972, was an early result. Beyond a few rules about where to place lines, what else would Aaron have to know to give the impression that these are marks that convey *intention,* a drawing, not simply some process like erosion leaving its trace?

The next year in a remote spot in California, he saw petroglyphs. Once they had meant something to someone. They looked to him as if they *ought* to mean something, just as his old paintings had. Cohen concluded that all humans recognize and can use outlines, or closed figures, to represent objects. Could a computer draw such a closed figure, a blob? What other elements in the petroglyphs suggested what Aaron should know? Repetition, division, a sense of the overall use of the space. By 1977, his drawings had reached "preschool," with a groping, wavering line (deliberately avoiding splines, the computer's slick look), and a space populated with significant-

*looking* forms.

He was immensely pleased. These appeared to have a meaning that was really absent. They elicited from the viewers the meaning-generating response that he felt refuted the reductionist dogma of abstract expressionism. Also, Cohen had made a tool for further exploration.

Also by 1977, he was beginning to do installations with Aaron churning out drawings. (Particularly difficult with computer-shy curators and technical troubles). Before Cohen's name was on the wall at the San Francisco Museum in 1979, a European critic walked into his installation and remarked that the work looked like paintings he had seen before by...Harold Cohen! Like Verostko, he had made the computer the tool for his own vision, a vision based on a concept that produced a distinctive-looking result.

However, Cohen had reached a plateau. He couldn't think of any more "primitives" like blobs to teach it. The next step was to teach it something about the real world—knowledge representation, as it is known in AI. First, pictorial space: Our mind's strategy to judge spatial relations is to detect when one object hides another. Programming Aaron to imply hidden objects was an extension of Aaron's knowing where the others were already drawn: suitable lines between existing objects could work wonders.

Secondly, recognizable things: Aaron learned to make stick figures. Cohen conceived a clever idea: The computer scribbled or made stick figures, but held them in memory, did *not* output them to the plotter. These were outlined, the way children sometimes do. The program only plotted the outline. He also gave Aaron some simple rules about four-legged animals.

He really crossed over to figuration in 1985. Someone challenged him to do the Statue of Liberty. Aaron needed simple anatomical rules: what limbs connect to what. Outlined scribbles evolved into plant life, and the statues evolved into figures in his *Eden* series by 1987.

Recently, Cohen has tackled facial features, solving the problem of putting details inside of objects. Arms and hands are in complicated spatial arrangements. When a figure has crossed arms, which is "forward," hiding the other? Consider what he had to tell Aaron about *that*. The figures must now exist in 3-space with x,y,z coordinates. He has had to invent rules for hidden-line removal entirely different from CAD system ones. It illuminates what *we* know to in order to draw.[8]

Cohen began doing computer art nearly 25 years ago. It took several years to get any results. For years, art professionals couldn't imagine computers in the same compartment as art. However, when computer graphics came on the scene, most programmers were busy creating a synthetic reality of a different sort, based on light and perspective, as in the last 500 years of Western European art and photography. Most computer artists were busy using the equipment as paint-boxes, image enhancers or controllers. Few realize what Cohen has accomplished.

Cohen believes the business of the highest-level art in every period is to rethink what art is. I believe many of us here are engaged in this, in our own way. As we begin to think globally, the Western art-historical tradition will recede into proper perspective. Cohen's investigations can be seen as part of a general movement to identify what is universal in art-making. They also suggest another way artists and machines can build upon each others' work, symbiosis.

Finally, we have **Myron Krueger,** a computer scientist who became an artist. By so doing, he has learned much about virtual reality, artificial intelligence *and* about human behavior.

We are acquainted with virtual reality (VR), the head-mounted display and DataGlove, which grew out of flight simulation. Myron Krueger's vision of VR is much more comfortable: it is a space that surrounds you, not a suit of gear.

In 1969, as a graduate student in computer science, Krueger was invited to join a collaborative art project called *GLOWFLOW*. It was a computer-controlled immersive environment. Phosphorescent liquids pulsed through horizontal tubes around a darkened room, the flow interactively controlled by people stepping on pressure sensors in the floor. The artists in charge didn't want the meditative mood disturbed by people playing with the cause-and-effect of the interaction, so a delay was deliberately built in. Krueger strongly disagreed with this, feeling that real-time interaction was the fundamental gift the computer offers the arts. He became an artist to create what he called *responsive environments*.

In the first, *METAPLAY,* a video camera displayed a person's image on a big screen. A computer tracked body movements and offered a computer graphic response. Computer graphics drawn by a live artist were superimposed on the participant's live image. Krueger still remembers when a participant drew a picture in the air with his finger, causing a computer graphic outline to flow from his "finger" across the screen—unplanned, but a logical extension of the setup. Krueger has become a student of behavior in order to factor it into the programming for his pieces.

His next piece, *PSYCHIC SPACE,* was based on the assumption that people are problem-solvers. It presented a maze on a big screen to the participant, with a clue about where he or she stood in it—but not just any maze. If one tried to leap the boundaries, the lines stretched! After each maze was solved, the person was "trapped" in yet another. Provoking! Krueger programmed 40 different responses. Often, these countered people's normal expectations, poking fun at those taking it too seriously.

In the mid-1970s, Krueger conceived *VIDEOPLACE,* which was "nowhere," in what we now call cyberspace. The silhouettes of people at different locations were juxtaposed on the same image. A person, finding his or her image on the screen with the moving image of another person, found it irresistible to interact. People seeing their images touch reacted as if being physically touched.

*CRITTER* took this a step further: The silhouette of a person could interact with a cartoon bug that had a big repertoire of responses. Chase it, it fled. Stand still, it climbed up. When it reached the top of the head (victory!) several things could happen, the final one being that as it jumped up and down, the image of the person disappeared. People were so identified with their image on the screen that many looked down and checked their body as this happened!

A recent piece, *VIDEODESK,* has practical applications. Hands of people from several locations can be projected onto the same virtual desktop and point to text or graphics without a mouse while working together.

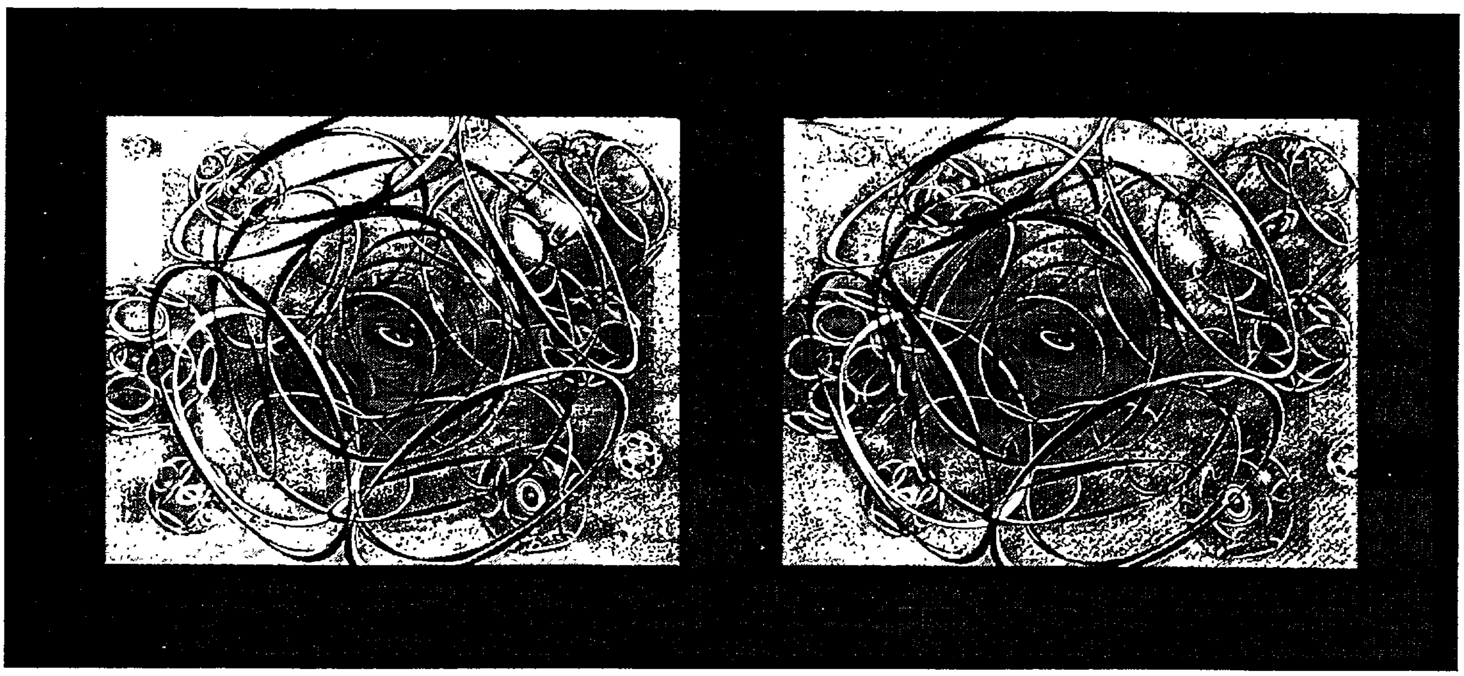
Like Verostko and Cohen, Krueger uses the branching structure of his computer programs to activate a variety of scripts. Krueger changes these, not only in response to what he notices about them, but about the behavior of people playing in his environments. The object of the artist always is to toy with expectations and hold a viewer's interest. With so many variations, people cannot exhaust the possibilities in one session. Moreover, the program can accumulate experience. Ultimately, it will be able to create new interactions. This is symbiosis!

Being ahead of one's time can be fascinating, but not very remunerative. Especially at the beginning, obtaining funding was hard. Using the low-budget equipment of that era, the problem was for the computer to keep up with people. Krueger overcame this by teaching himself electrical engineering and chip design to add special-purpose processors. According to Howard Rheingold, author of *Virtual Reality,* "Krueger has logged more hours building artificial spaces and putting them through their paces than anybody else in the VR world."

Beyond this, to his delight, he has exposed unexpected behavior in people. In 1977 he prophesied: "We are incredibly attuned to the idea that the sole purpose of our technology is to solve problems. It also creates concepts and philosophy. We must more fully explore these aspects of our inventions, because the next generation of technology will speak to us, understand us, and perceive our behavior. It will enter every home and office and intercede between us and much of the information and experience we receive. The design of such intimate technology is an aesthetic issue as much as an engineering one. We must recognize this if we are to understand and choose what we become as a result of what we have made."[9]

**Footnotes**

1. Robert Wilson: Private correspondence with the author in which Wilson discussed his hexagonal sculpture.
2. Lillian F. and Laurens R. Schwartz, *Computer Artist's Handbook* (New York: W.W. Norton, 1992).
3. Helaman Ferguson, announcement for show at New York Academy of Sciences, 1991
4. Steven R. Heideman, "A New Twist on Integrins and the Cytoskeleton," *Science*, Vol. 260, pages 1045-1208, May 21, 1993, p. 1080-81. (In it, tensegrity is mistakenly attributed to Fuller).
5. Harold Henderson, "Art or Science?" *Reader*, Vol. 20, No. 45, Aug. 16, 1991, p. 18.
6. George Boole, *Derivation of the Laws of the Symbols of Logic from the Laws of the Operations of the Human Mind*, with computer illustrations by Roman Verostko and preface by Roger Malina (Minneapolis: St. Sebastian Press, 1991).
7. Roman Verostko, "Epigenetic Painting: Software as Genotype," *Leonardo*, Vol.. 23, No. 1, 1990, p. 23.
8. Harold Cohen: Unpublished article describing recent work.
9. Howard Rheingold, *Virtual Reality* (New York: Simon & Schuster, 1991), p. 113.



*Stereoscopic Atom Landscape III*, computer art by Kenneth Snelson, 1987

## Suggested Reading

HAROLD COHEN
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