

Full-Body Interactive Exhibits

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Introduction

In the late 1960s, I was a graduate student in Computer Science at the University of Wisconsin. Unlike my peers, with engineering degrees, I had a liberal arts background. Thus, while they were interested in the engineering efficiency of computer design and operation, I thought of the philosophical significance of the encounter between man and machine and in particular the problem of the computer-human interface.

Although my original goals were technical, I quickly realized that the scientific method was not appropriate for discovering the ideal design for this interface. Rather, the design of such an interface had an important aesthetic component. In its purest form, the interface between human and computer suggested a new art form based on composed interaction.

In 1969, I collaborated with a group of artists and technologists on an art and technology exhibit. When the artists resisted making interactivity the focus of the work, I vowed to create environments in which composed interaction was the primary goal. To see my vision of computer art realized, I would have to become the artist.

In 1970, I created an installation called METAPLAY which was an "experiment" in the old-fashioned, romantic sense of the word. Today, scientists always have to know the result that their experiments will yield before they apply for funding let alone run the experiment. In METAPLAY, I did an experiment to see what would happen. I wanted to discover the innate expectations of the technologically naive human. How could a person be induced to interact with a computer without verbal instruction?

I knew that I wanted to respond to a person's behavior using the computer. This desire implied that the computer would be able to perceive the participant's behavior. I had no idea how to achieve that in 1970. Therefore, I decided to fake it. Like the Wizard of Oz, I created my desired interface with smoke and mirrors a bit of interactive theater. I used the only mechanism that I was aware of that could understand human behavior in real time my own eyes.

People walked into the Union Gallery at the University of Wisconsin. They were confronted with a 8 foot by 10 foot rear-projection video screen that contained their own life-sized image. They saw graffiti being drawn on their image. I was sitting a mile away in the computer center drawing with a data tablet. My drawing appeared on an Adage vector graphic display. A video camera was aimed at the Adage screen and its signal was trans-

mitted across campus to the gallery where it was superimposed on the live image and the resulting composite image was projected in front of the participants. In addition, the composite image was transmitted back to the computer center where it was displayed on a monitor that provided the feedback I needed to draw.

People were mildly entertained by the graffiti for a while. Then, they started to make the situation interactive. When they saw the cursor coming toward them, they would run away from it. They would bat it away as if it were alive. Based on that reaction, I changed the cursor from a cross to a circle which I placed at the top of the screen when people entered. Inevitably, someone wondered what would happen if they touched the image of the ball with the image of their hand. They would reach up and hit the ball. I would move it across the screen as if in response to their blow. Typically, a person on the other side of the screen would reach up to hit it back. I had people playing volleyball with a nonexistent ball in 1970.

Then, one day I was drawing something on a person's hand. He was embarrassed by the attention and moved his hand. I followed his hand with the pen. The result was that a line appeared on the screen. It looked as if he had drawn the line with his finger. He moved his finger again and I followed. After a moment of crudely successful drawing, the person next to him reached up and took the line away with his finger. We were able to lead thousands of participants to discover the drawing interaction without saying a word to them. This process was repeated ten hours a day, seven days a week, for six weeks. Many interactions were invented, revealing a set of expectations that were established by juxtaposing a person's image with a graphic object.

One day we were working on a technical problem. We were sending data from a sensory floor in the gallery to the graphics computer in the computer center. There was a problem in data transmission. We talked on the phone trying to identify the nature of the problem and then its source. It occurred to me that we had a better way of discussing our problem. I asked my colleague to display the information he was transmitting on the computer in the gallery, which had a limited graphic capability. Next, I had him aim the video camera at that computer's screen. The result was that the composite video image showed the data transmitted from the gallery computer at the top half of the screen and the data received by the computer center computer at the bottom half of the screen. As we discussed the composite image, it was natural for us to move our hands in front of our respective cameras to point at features we were discussing. It was just as if we were sitting together on the same side of a table talking about information on a piece of paper. The illusion of being together was compelling enough that when the image of my hand briefly overlapped the image of his, he moved his hand. I barely noticed the first time this happened. After several occurrences, I realized that he was unwilling to hold hands with me. Personal distance was being observed in this purely visual world.

Subsequent experimentation confirmed my suspicion. For most people, their image is an extension of themselves. What happens to their image, happens to them. What touches their image, they feel. Thus, I realized that I had stumbled onto a very important set of principles. While we usually think of telecommunication as being between two points, in METAPLAY, we had created a new place which consisted of the information that the two

remote participants shared simultaneously. In the playful part of METAPLAY, one party communicated through computer graphics and the other communicated through physical gesture. In the serendipitous teleconference, we both used our hands and voices to interact. (I should acknowledge that the only reason that I had resorted to telecommunication in the first place was that the university would not let me move the graphics computer to the gallery.)

The ultimate extension of these concepts was the creation of a new telecommunication place that I dubbed VIDEOPLACE. One would enter VIDEOPLACE through an installation similar to that used in METAPLAY. Instead of being alone on the screen, your image would be joined by the images of other people who were in distant locations. The experience would be similar to METAPLAY, except that what had been accomplished with human intervention would instead be accomplished automatically by computer. To make the remote participants look like they were in a new place, the video image would include graphic scenery which would provide a context for their interaction. Since we had already discovered that people who see their images together, act like they are together, and that they expect something to happen when their images touch graphic objects, we decided to make that sense of touch effective. In VIDEOPLACE, when a person touches the image of another person or the image of a graphic object, the computer can detect that contact and respond to it in any imaginable way, including moving the object, making it disappear, changing its color, or causing it to emit a tone.

In addition, the participant's image can be subjected to forces that are not operating on his body. The computer can move, scale, and rotate the participant's live video image exactly as if it were a graphic object.[Figure 1] This movement can be in response to the participant's action, in response to the action of another participant or graphic creature, or at a scripted moment in the interaction. The result is that VIDEOPLACE is an artificial reality in which the laws of cause and effect are composed from moment to moment.

VIDEOPLACE was proposed as the theme of the US Bicentennial. There were to be VIDEOPLACE installations at several locations in the US, Europe, and Japan. While VIDEOPLACE was obviously not implemented on such a global scale, it was an official Bicentennial project. It did receive some funding from the National Endowment for the Arts, and a preliminary version of VIDEOPLACE was exhibited in the Milwaukee Art Museum in 1975.

In 1974, I began the construction of the VIDEOPLACE system. While no components from that era still exist, the system has been in constant operation since that period. It slowly metamorphoses from one technology to the next. The organic development of the system is unlike any technology project I am aware of. By the mid-1970's, VIDEOPLACE was capable of rudimentary operation. In the following decade, the system grew by accretion with the gradual improvement of its ability to understand what the participant standing in front of the camera was doing with respect to the graphic world. In the early 1980s, VIDEOPLACE had evolved to the point where it was capable of a wide range of interactions based on real-time understanding of the participant's behavior.

At the end of 1982, my 1974 dissertation appeared in book form as *Artificial Reality* (Addison-Wesley). It considered the technology and aesthetics of interactive media like VIDEOPLACE. It also forecasted the current goggle-and-glove technology as another way of accomplishing similar results.

In 1985, I went public with a paper describing working technology at the SIGCHI Conference (Computer-Human Interaction). Later that year, VIDEOPLACE was shown in the SIGGRAPH Art Show, also in San Francisco. The VIDEOPLACE exhibited at that time was a single-ended installation in which one or more people interacted with the computer. They stood before a neutral background of translucent plastic, backlit by fluorescent lights to provide a very high contrast image which enables the computer to distinguish the participant from the background.[Figure 2] This video image was thresholded and subjected to a two-dimensional filter to eliminate noise pixels. The resulting binary image is passed on to a series of specialized computers that operate in parallel to analyze the participant's silhouette in order to locate head, hands, torso, and fingers. These processors are thousands of times faster than a PC. Since they operate in parallel with the host computer, the elaborate perception algorithms exact no penalty from the performance of the system.

The resulting exhibit is not a single piece in the traditional artistic sense, but a new medium in which many interactive vignettes have been composed. Partly, this strategy is a matter of engineering efficiency. By having a single installation present 50 different experiences, VIDEOPLACE is intended as a celebration of the rich opportunity that interactivity offers us. From an artist's point of view, the variety of interactions can hold people's attention longer than any single painting or sculpture. From an exhibitors vantage, a single installation can be continually renewed with new compositions.

As an interactive artistic medium, artificial realities differ from earlier art in that the artist leaves the work unfinished. Its completion is provided by the unique behavior of each individual who interacts with it. This possibility confuses the identity of the artist. In the past, humanity could afford very little creative effort. Therefore, a few individuals were assigned the role of aesthetic specialists to do art for the rest of humanity who were too busy plowing the fields. However, today, it is appropriate to invite all individuals to quicken their aesthetic sensibilities, not to consume art as passive spectators, but to actively participate in its creation.

One class of VIDEOPLACE interactions pursues this goal. The participant enters the environment and finds that his movements create aesthetically pleasing patterns. He has been given a new art medium to play with. Since he does not recognize this medium as corresponding to any existing art form, he is not inhibited about exploring it. Therefore, he will often move his body motivated solely by aesthetic goals, even though aesthetics ordinarily would never guide his behavior. What is important is that the aesthetic experience is created by the person who will appreciate it. It is not created by one specialist to be critiqued by another specialist who will then instruct the public as to what they should like and why.

The most basic of this class of interactions was based on the METAPLAY drawing interaction. In DIGITAL DRAWING, you hold up your finger and the image of your finger draws on the screen.[Figure 3] It is liberating to be able to draw without touching anything. It is especially charming if you try to erase what you have drawn by rubbing your hand over it. The computer recognizes the gesture and erases the screen as if by magic. In a variation on this interaction, you can draw an invisible path that is continually traversed by flowing particles. By synchronizing your drawing movements with the flow of the particles, you can create a complex choreography of light. In related interactions, you can paint with your whole body or just your fingertips. You can create abstract geometric shapes or become an animated Mondrian painting. In a more sophisticated interaction, eight copies of your shrunken image are arranged on the screen in a circular pattern.[Figure 4] The dynamics of the resulting kaleidoscopic medium are so rich that it will often captivate an individual for an hour. The CRITTER interaction was the result of a tremendous effort. CRITTER is a simple computer-generated creature who perceives the participant's behavior and interacts with him in a playful way.[Figure 5] If the participant moves, CRITTER will chase him. If the participant holds out his hand, CRITTER will land on it. If the participant holds still, CRITTER will climb to the top of his head and do a little jig in celebration upon reaching the summit. It is also possible to get CRITTER to dangle from your finger. If you shake your finger, CRITTER will fall off and plunge to the bottom of the screen where it flattens as it strikes. After observing thousands of people attempting to capture CRITTER, we have made it possible. The first step is to surround it with your image. CRITTER will try to escape frantically. If the surrounding area is slowly constricted, it will explode only to be resurrected a moment later. CRITTER is a stand-in for artificial intelligence or, at least, artificial personality. It is a playful artificial entity that is so engaging that you forget that the creature you are playing with is not really there.

Another theme of the work has resulted from the manner in which it was originally developed. I thought of METAPLAY as a way of simulating a computer-human interface that I could not yet implement. Success would occur when I could replace myself by a computer. What really happened was that I had stumbled onto a superior concept computer mediated human-to-human interaction. The computer was allowing me to interact with another person in a new way. I could establish a simple world in which two people in different locations could interact with each other. This was the first time that telecommunication was identified as a fundamental part of the artificial reality concept. The artistic opportunity was that the artist could define the circumstance in which two people would interact and could thus be a third party to their interaction.

Towards this goal, I connected the VIDEOPLACE environment with the VIDEODESK, which has an overhead camera aimed down at a seated person's hands as they rest upon a light table.[Figure 6] The image of the VIDEODESK participant's hands can then appear in a composite image that includes the VIDEOPLACE participant's full body. Either image can be moved, scaled, or rotated as a consequence of actions in the graphic world. The VIDEODESK participant controls the selection of response rules with her left hand. Since she has more knowledge and power than the VIDEOPLACE participant, her role is to facilitate a playful experience for the other participant. She is a benign Big Mother, as opposed to her tyrannical sibling.

She can join the other participant in any of the single-ended interactions, making them into cooperative aesthetic teleconferences. She can also take advantage of the juxtaposition of her image with the other participant's. There is a tension created when the two images touch. In one case, we take advantage of this by making a sound when the VIDEODESK participant's finger touches the image of the VIDEOPLACE participant. A different sound is made when the VIDEOPLACE participant touches her hands with his finger. Thus, while there is an embarrassment about touching, nothing happens unless one participant touches the other.

In another variation, the VIDEODESK hand reaches in and pushes the VIDEOPLACE participant's image across the screen. Seeing their image abused in this way usually leads the latter to push back. Often, a full scale fight ensues. Then, the VIDEODESK hand strikes the VIDEOPLACE participant's image in the head. The image is knocked down and pops back up again like the inflatable children's toy with sand in the bottom.

In another case, the VIDEODESK hand extends a finger and a graphic string dangles from its tip. [Figure 7] At the end of the string hangs the shrunken image of the VIDEOPLACE participant. Finding himself suspended in this way, this participant wonders if there is any way he can make his image swing on the string. He tries a few exploratory moves. He discovers that by moving from side to side he can make his image swing, and then by timing his movements correctly, he can swing higher and higher. He wonders, can he do a 360? After considerable, frantic effort, he succeeds.

The interactions I just described are between the VIDEOPLACE and the VIDEODESK participants. However, there will often be a small crowd of people watching. They will cheer when the VIDEOPLACE participant succeeds in making his image swing all the way around. They will also laugh when his image is knocked down. How often have you ever seen a computer used to make people laugh?

Goggles & Gloves

What relationship does the VIDEOPLACE medium have to the goggle-and-glove technology that is often considered the orthodox way of creating artificial realities? First, the instrumented glove is a way for the computer to see what the participant's hand is doing. The instrumented suit is a way of perceiving the articulation of the whole body. Video cameras are a far less obtrusive way of accomplishing the same results. While the VIDEOPLACE system currently only understands the movements of the participant's two-dimensional silhouette, using additional cameras to understand the participant's movements in three dimensions is a straightforward, if difficult, problem. As long as the glove or the suit do not provide tactile feedback, there is no great advantage to them.

Similarly, the purpose of goggles is to completely immerse the participant in a computer-generated world. Admittedly, one video projector does not do that. However, it would be quite easy to use several projectors to surround the participant. Alternatively, light-weight glasses, recently designed for viewing 3D movies, could be worn. These glasses block one eye and then the other as the appropriate stereoptic view of the scene is projected. These

glasses are far less encumbering than current goggles and permit high-resolution graphics to be used.

Typically, the dominant mode of interacting is through the glove alone. One points to indicate the direction one wants his point of view to fly. Of additional concern are the wires that tether the participant to the computer. You are concerned about tripping on the tether as you walk about. Since you cannot see it, you know that you are in the dark about the real world even as look around the graphic one.

In the long run, the reality goggles will become less encumbering. Eventually, they will be the same size as standard eyeglasses or even contact lenses. With such a convenient display, wearing instrumented clothing will be even less attractive. Our expectation is that when such goggles are available, it will be natural to use video cameras to perceive the participant's body. Thus, the VIDEOPLACE medium may be combined with the head-mounted display.

Currently, the VIDEOPLACE system responds far more rapidly than the goggle-and-glove systems, in spite of the fact that analyzing a person's image through a video camera in 1/30 second is a more difficult problem than monitoring bend sensors worn on the participant's joints. The reason is that VIDEOPLACE is a specialized parallel-processing system dedicated to perceiving human images while the goggle systems use off-the-shelf computers running time-sharing operating systems.

The difference in performance is based on an important philosophical difference between the implementers of the different systems. An interactive experience is compelling because it responds in interesting ways to the participant's behavior. Its authority does not derive from the realism of the graphic world portrayed. Similarly, theater succeeds because of the dramatic human interactions depicted, not because of the stage craft. Indeed, there are types of theater in which sets are not employed. Of course, graphic realism will be of interest in the future. However, it is currently achieved by sacrificing the immediacy of the experience. Thus, when you are wearing goggles and turn your head, there is a very noticeable lag (sometimes as long as a second) before the graphic world catches up with you. When you move your hand, your graphic hand hangs in the air for a long moment before it moves. These lags are very disturbing. They instantly alert you to the fact that the experience is not real. They are also avoidable with current technology. Simple graphic worlds can be rendered more rapidly than complex ones. By way of contrast, the VIDEOPLACE participant is represented by his silhouette image, not his full-color video image. However, the participant never asks, "Is that me?" Instead, when they see CRITTER approach their silhouette's head, they duck. In the STEP LIGHTLY piece that I did for the SIGGRAPH Art Show in 1990, a laser mounted on the ceiling drew simple graphics on the floor that responded to participants' movements around the room. The most successful interaction showed a fish that swam after participants as they walked about. The graphic fish was very crude, but no one complained that it did not look like a fish. Its reaction to their movements was so immediate that its behaviour was realistic, even if its appearance was not. Visitors reacted instantaneously to the reality of the experience by running away and laughing the ex-

perience was very funny. The primary concern should be the quality of the interactive experience, not how it looks in still pictures.

Content

In the late 1960s, it was common, particularly among intellectuals, to portray technology as threatening. One goal of my early exhibits was to provide the public, especially those beyond formal education, with a brief experience that communicated the possibility that computers could be benign.

Today, after 10 years of personal computers and video games, that message is no longer novel. However, there are points that are made by the exhibits that are still fresh. First, the world of the intellect, rendered sedentary by Guttenberg, now permits you to participate physically. Second, perceptual experience rather than abstract symbols will be used to communicate concepts. Third, computers are going to perceive you not because of malevolent government, but because we wish computers to be aware of us as other people are, as human beings with bodies and faces. Fourth, computers will be used to create artificial entities like CRITTER that will interact with us. Whether these creatures are truly intelligent, does not matter. People will impute intelligence to anything that behaves. Fifth, simulation is a central scientific and technological strategy. Increasingly, we will make our mistakes in simulated worlds so that we may "do it right the first time" in the real one. Sixth, telecommunication will create a place in which we feel like we are together rather than communicating between two disjoint locations.

In addition to illustrating broad concepts, artificial realities can provide more direct educational experiences. In a 1976 proposal to the National Science Foundation, I proposed that VIDEOPLACE be used to create an artificial reality that would be explored by elementary school students who would be assigned the roles of scientists landing on an alien planet. They would enter this world individually and later compare their experiences. They would find that different children had observed different phenomena. They would note that different behaviours had elicited different consequences. They would discover that some children were able to describe what they had observed clearly, whereas others were uncertain themselves about what they had seen. They would disagree about the causal relations that were operating in the graphic world. They would seek a means of determining who was correct. They would conceive critical experiments. In short, they would invent the scientific method the process of science as opposed to the vocabulary and mathematical puzzle solving that are so often confused with science. It should also be noted that it is the students, not the teacher, who are doing the talking.

Certainly, the technology can also be used to deliver explicit content. Since we had very little time to test the software before the STEP LIGHTLY exhibit opened, we had decided to have the fish pursue the center of gravity of the participants if several were present. We were concerned that this would lead to an uninteresting interaction. To our surprise, we found that Ph.D. researchers, while fully aware of the mathematics involved, had no intuitive sense of what the concept meant and were delighted to have it made palpable. Since

VIDEOPLACE is a completely composable medium, a universe of such experiences could be directed at specific content.

Another instructional use was demonstrated in the Tomorrow's Realities Gallery at SIGGRAPH 91 in Las Vegas. Two **VIDEODESKs** were connected together. A gallery visitor sitting at one of the desks was instructed in the use of a gesture-operated application running on a Silicon Graphics VGX340 workstation. The red hands of an expert user (in fact, a student volunteer with 15 minutes instruction) at the other desk demonstrated the use of the fingers to operate the applications. The student could ask questions, using his blue hands to point. Then, the instructor would show all ten fingers on the screen. This gesture would cause her hands to turn blue and the student's hands to turn red, indicating that the student could now use his hands to operate the application. Now, the teacher could use her blue hands to point to the next menu item to be selected or to demonstrate the action that the student should be performing with his hands.

Two of the applications were of particular interest. These were novel in that the current two-dimensional **VIDEOPLACE** interface is used to operate in three dimensions. The first illustrated a problem in scientific visualization, specifically depicting the flow of gases. The user's hands were projected onto a sample plane in a three-dimensional volume. Particles released from the fingertip followed the path dictated by the simulation. Two fingers were used to define a line and the air that flowed through the line defined a surface that was then distorted as if flowed around two skyscrapers. The sample plane could be oriented and positioned anywhere in the volume. In the second application, the same interface was used to create three-dimensional sculptures. Graphic material was extruded through the user's fingers as he changed the shape of the aperture.

The teletutoring exhibit demonstrated a means of sharing information that was invented in the **METAPLAY** exhibit in 1970. The teletutoring function was extremely successful. If **VIDEODESKs** were placed in school libraries, students could talk to Museum staff about text, graphic, or animated image information just as they would if they were sitting side by side. For often-asked questions, animated gesture-plus-voice answers could be triggered by the staff member who would then assist another student at another desk.

The Future

My new book, *Artificial Reality II* (Addison-Wesley, 1991) considers a variety of futures for my work. For instance, **VIDEOPLACE** technology could be extended to provide 3D perception of a participant's body and to permit movement of many people through 3D worlds. For years, its use for aesthetic, practical, and telecommunication purposes has been impeded by funding limitations, not technological difficulties. However, it is but one of a variety of interactive media, including head-mounted displays, laser floors, and interactive buildings, that will permit full-body participation in computer-generated experiences. The future will demand a variety of interactive forms rather than a single dominant one, for interactivity itself will be the universal medium.

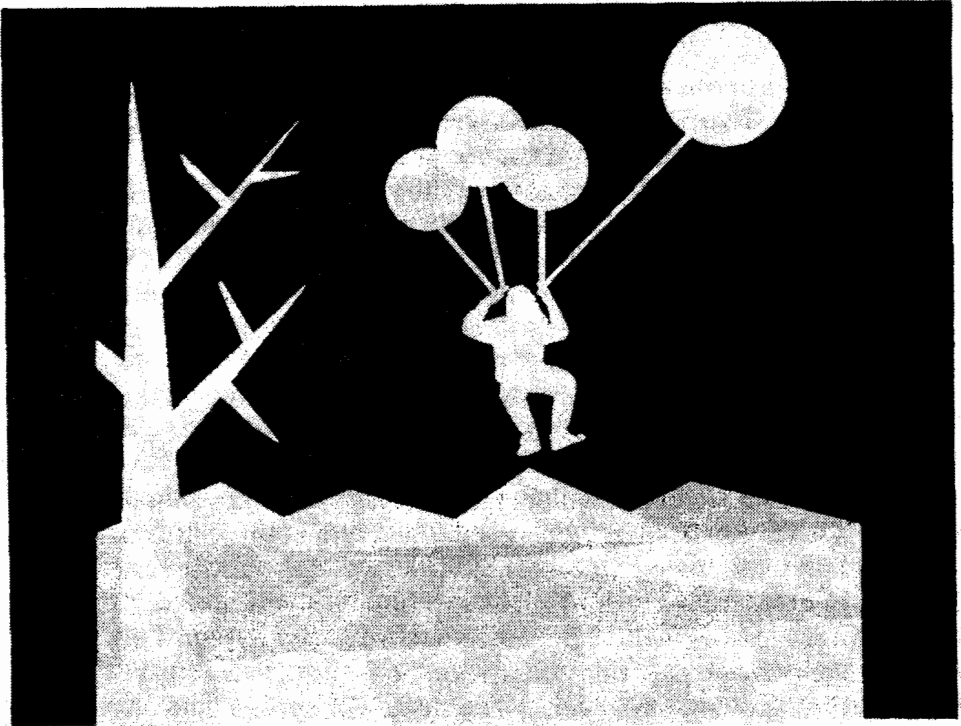


Figure 1. Parachute

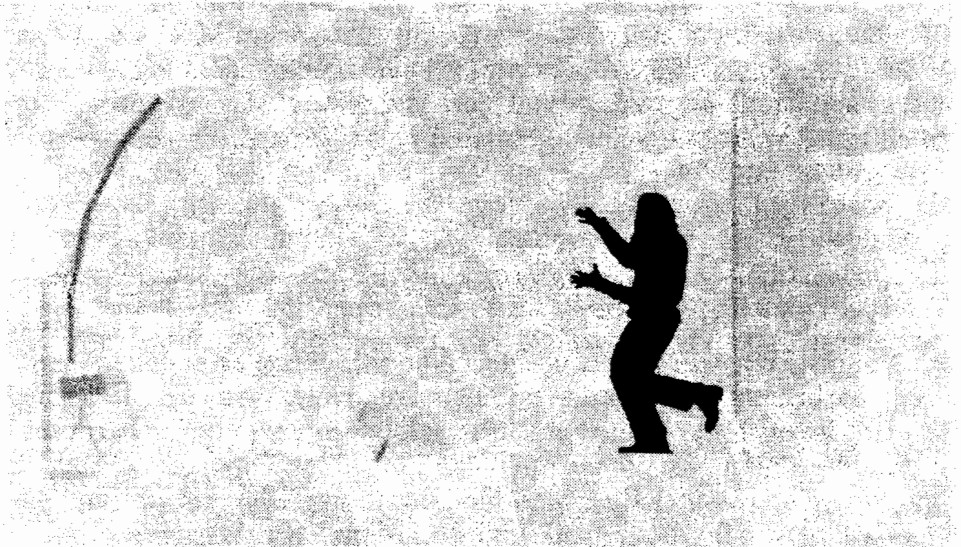


Figure 2. VIDEOPLACE Installation



Figure 3. DIGITAL DRAWING

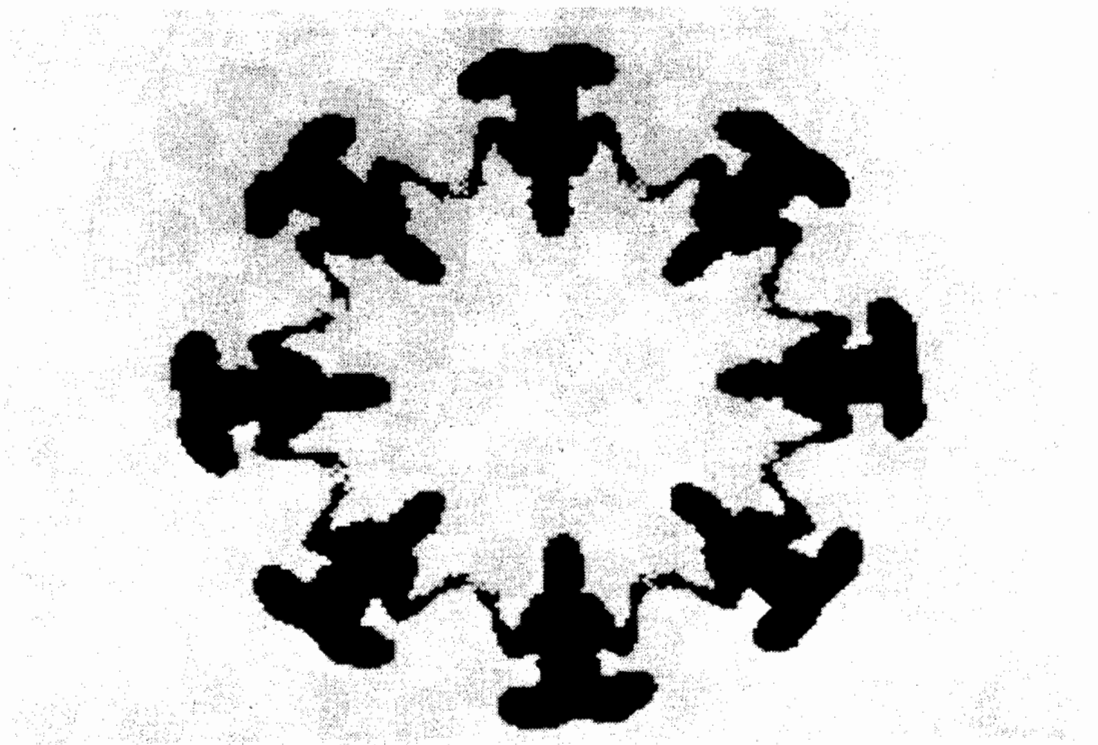


Figure 4. MANDALA

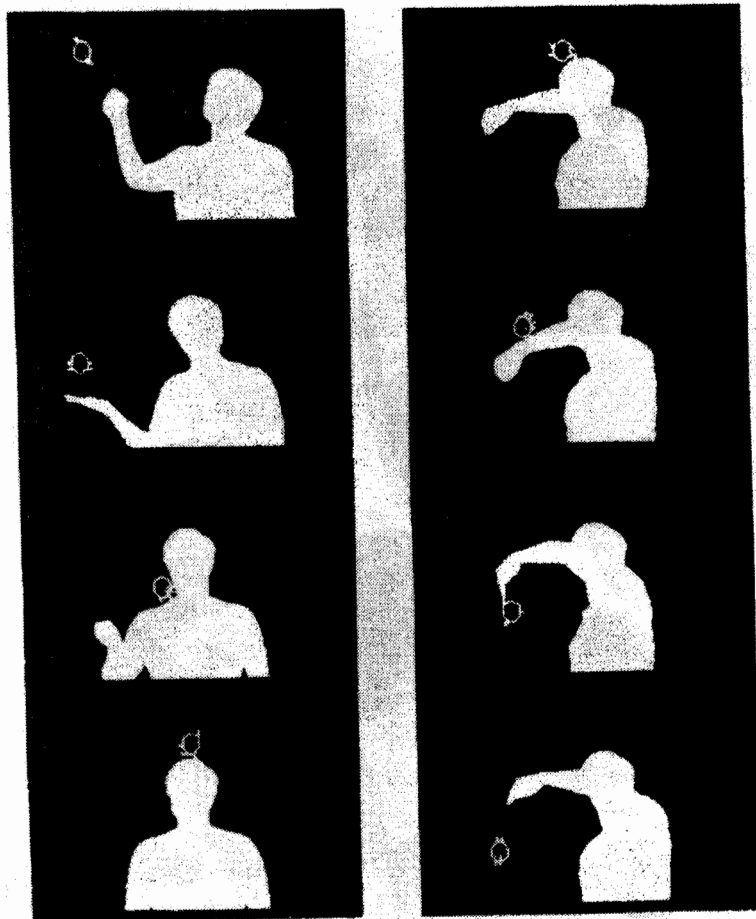


Figure 5. CRITTER



Figure 6. VIDEODESK installation

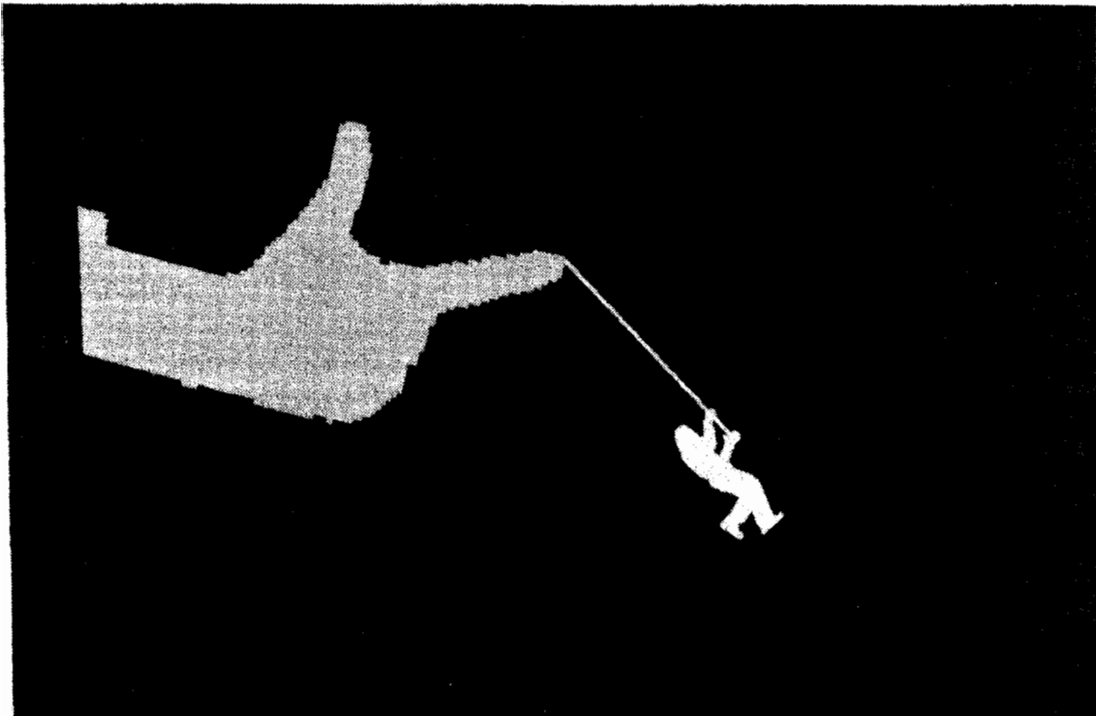


Figure 7. HANGING BY A THREAD