THE HUMAN INTERFACE
IN THREE DIMENSIONAL COMPUTER ART SPACE

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Section I

Introduction

The interactive bridge cannot be reasoned with, cannot be communicated with in human terms, and by its very nature is capable only of repetitive rigid responses. It is a link, a location between two situations. An Interface is a surface regarded as the common boundary of two bodies or spaces. It is the study of these bonded bodies or spaces that enables us to understand what happens to each when they interact.

We use our sensory impressions that reach us from the external spatial world surrounding us to construct the mental model of our universe. This includes all that we think, all that we create. Human output spawns from the same universal sensory pool. It is this pool of human perception that ties together relationships that appear, at first encounter, relatively un-associated. With this raw material we compile, associate and communicate.

Our most identifiable source for self-identification is locating our physical beings in a spatial context. The second is the psychic understanding of that context.

Physical constituents which link us to another person, object or idea, are not, in and of themselves, interactive, but merely the structural bond or surface interface. It requires the passage of the creative psyche across this bridge to create what we have come to know as The Human Interface.

. . .

Defining 3D Space

Physical Computer Space

The spatial qualities of a computer begin with the system itself. The computer is, of course, a physically embodied machine and, as such, cannot violate natural law. Internal rivers of electrons flow through banks of resistors, clippers, and signal boosters, placed in rows on circuit boards inserted into slots of the machine. Memory is organized as a system of cells which represents each bit of data, making computer space ultimately composed of discrete data points. There can be no space without matter. The machine not only occupies space, but also formats memory in even geometric patterns. In most machines, every byte or word has a number associated with it, which is called its address.

Computer memory can also be thought of as a bank of randomly accessible and variable information. The processor need not know which portion of data it wants, but identifies with a simple vector style coordinate system to locate the needed information. In either case, the computer is a workspace or region of storage that can never quite break free of its physical or spatial origins. It is therefore only natural to think of a computer as having a logical area that has plasticity and dimension.

Logical Programming Space

The addressing, or numbering of space is derived from analytical geometry, and is as old as Descartes, at least three centuries. His numbering system awoke spatial perception from a bodiless, finite, culturally defined state into the pure extension of idea. Ideas could be associated with numbers, and numbers associated with ideas. The duality of computer space requires that a programmer think in both physical terms and abstractions, pragmatically and philosophically.

> "The computer programmer lives in two worlds simultaneously: his space is a logical entity (like the space of the topologist), and yet it is logically realized in the transistors of storage. In this way... it resembles Einstein's space which is mathematical and abstract and still claims to be the space of the world of experience."
>
> <Bolter 84>

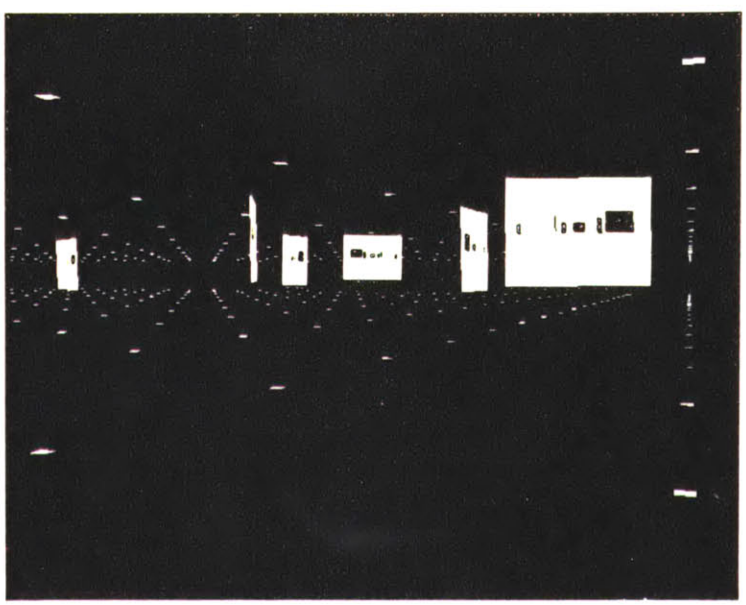
The physical space of the machine is subject to terrestrial limitations, yet the logical properties remove it from its mechanical origins. Mathematics, intertwined with physics, allowed the mechanics of Newtonian geometry to be put into correspondence with algebraic numbers. As in Euclidean and Riemannian spaces, numbers could then be evaluated in relation to each other in linear and graphic terms. Mathematical space had become a coordinate system.

Impressed Graphic Space

> "Elements of data cannot be manipulated endlessly; they cannot remain forever in the central processor. At sometime, they must be deposited."
>
> <Bolter 84>

As long as computers use devices such as **hardcopy** and the **cathode-ray tube**, they will continue to output all graphics onto the two dimensional world of paper and silvered surface. Here an image is virtually denotated. Dimension is implied by the apparent convergence of space taught to us by the Renaissance masters Piero Della Francesca and Michelangelo.

Figure 1.



It is on this designed surface that optical interpolation occurs. Monocular cueing is not an inherent function of human optical perception, but is easily learned at an early age. <Benton 84> The creation of this type of impressed exhibition space is the melding of apparent optical depth and human understanding of those laws.

Perhaps the genuine spatial reality of 3D computer graphics lies, literally, behind the tube. As in vector or raster scan, the convergence of rays upon the screen emanates from the tube's **yoke.** This will be the only time prior to reception, when the information will obtain any sculptural dimension as an optical phenomenon. Beams of light are shot from the yoke at the same time as the viewers project their own ablility to receive and perceive onto the surface, meeting and causing a common interface plane.

One of the only display devices available today that exploits the potential of 3D graphics is the hologram. The procedure for acquiring the data from the computer is surprisingly simple. A display screen can be thought of as a **porthole** or **viewing zone** into the digitized world of the computer's graphic reality. First, the viewing zone is algorithmically fixed, much like choosing the proper lens for a camera. When this area has been defined, the programmer can place computer-defined objects into the pre-designated arena. This is only one of an infinite number of angles that these objects can be viewed from. By moving the **camera** or **viewport**, and recording each new perspective, the true dimensionality of the space can be tapped. This technique is known as "keyframing", and is used often in animation. The difference here is that instead of displaying each consecutive frame in time, all the information is recorded onto the same piece of emulsion. This emulsion is then used in the holographic technique instead of a **real** object. The product is a display that takes advantage of our ability to see with two eyes and works on an optical function known as visual disparity.

This is a fine technique for creating a 3D artificial reality. Basically, it is a reality of a collection of patterns and process, the latter being capable of producing, destroying, and modifying the former <Newell/Simon 82>. The most important properties of these patterns are that they can designate objects, process, or other patterns, and that when they designate process, they can be interpreted. It is a microcosm unto itself. The question that arises is, does this finite interpretation of reality have the same intrinsic capabilities as the world in which we exist? Has the nature of the world within the creator's mind been captured by the computer process perhaps through some underlying and universal law?

Neurological Representations

The instruments that we make are, naturally, extensions of ourselves both physically and psychologically. When using instruments skillfully, we internalize aspects of them in the form of kinesthetic and perceptual habits. In this sense, they not only become extensions of our perceptions, but modify them, thus altering the basis of our effective relationship to ourselves. The creation and rendering of an artificial reality has not only ornamental significance, but symbolic as well. We make in our own image and likeness, and looking at what we make is like holding up the proverbial mirror. From these representations, we construct modified internal representations or models in our brains, revise conceptions which continue to alter our approach to making sense of the world.

> "The basic idea of cognitive science is that intelligent beings are semantic engines - in other words, automatic formal systems with interpretations under which they consistently make sense."
> <Haugeland 82>

Given this premise, it is then possible to understand the physical correlation between humans and machines, yet somehow, it is difficult to accept that a human as a machine is a reasoned principle. Simply put, we have not yet made a machine that comes anywhere close to bioelectrical potential.

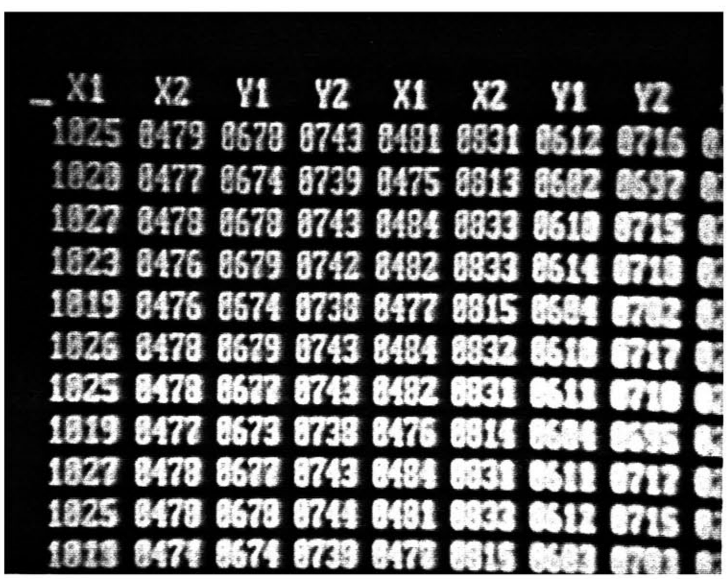
The model of human as machine helps us understand ourselves better only when we take a conscious part in the act of the computer's decision making processes. Machine works as model system only when it is used in conjunction with people. In Biology, the **compartment theory** provides sophisticated methods for cases where reactions of open systems are compared with conventional closed systems. Open systems show inherent characteristics which seem to contradict the usual physical laws as they produce huge quantum leaps in logic. These gaps are often considered to be the vital characteristics of life, explainable only by introducing soul-like or entelechial factors into the organic happening.

Artificial intelligence does not have the vital force or principle directing growth and life. It is a model once removed by algorithm to the real thing. Moreover, creativity in people can be perceived as being irrational or illogical behavior to a machine. A computer can never be creative because it systematically claims information. Without the human interface, the computer's best effort is inherently psychol, a misrepresentation or illusion of life. Intelligence is not theory only, it is also action. Intelligence is not merely a real Software String Searcher, which is apparently conceptually smart, but physically no more than a jukebox, that is, no more than a mechanism for finding matching electrical impulses and outputing them appropriately. **Dualism** is the concept that mental states are states of the soul, i.e. the human's moral and emotional nature. Feelings like anger and elation come from the soul. And the physical manifestation of these emotions is how the soul interacts with the body. Once again, you cannot relax the laws of physics.

Computer as Artifact

We can think of computer memory as an artifact, a socially constructed space that usually functions in predictable ways in order to serve our technological society. Artifacts are almost always less sophisticated than the leading researches of science because they must be built upon ground that is already intellectually quite simple. In this sense, electronic space is used for ornamental and predictable symbolic significance.

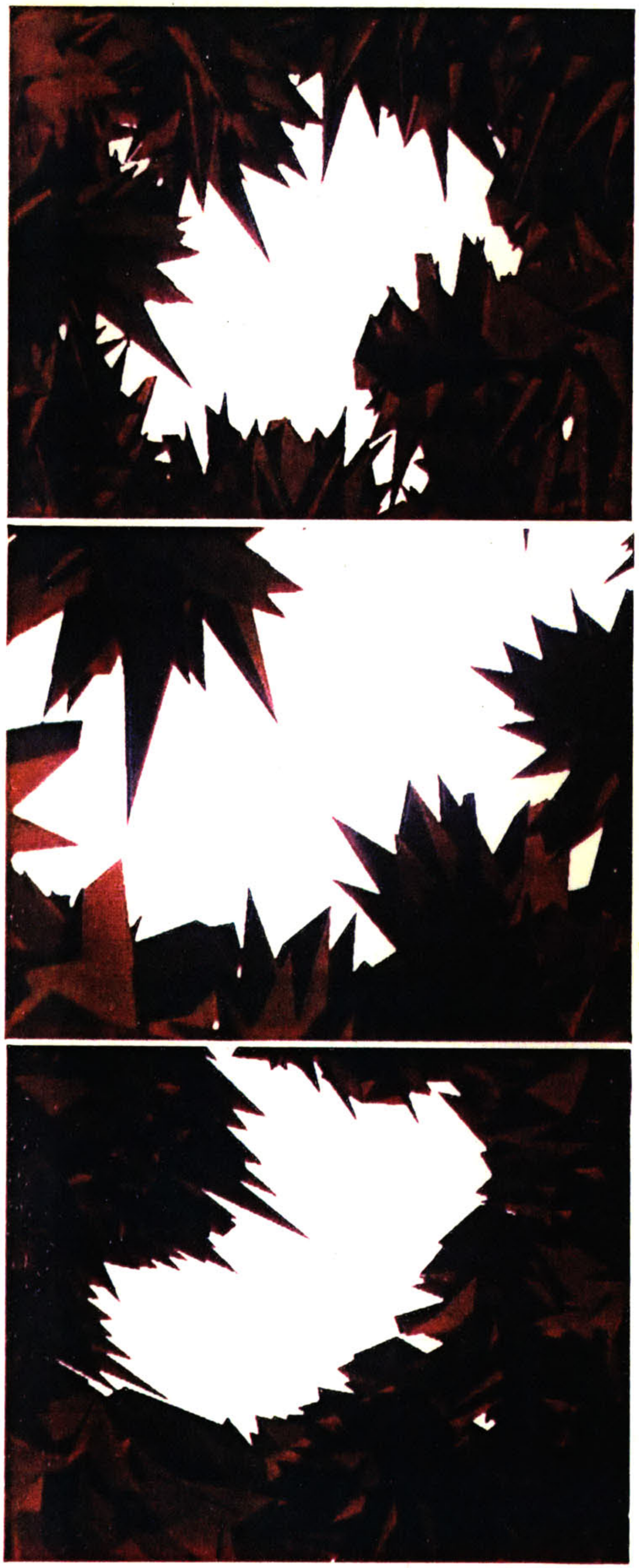
Figure 2.



We can also see how computer memory has properties that, collectively, can take us back to even more intuitive notions of what an artifact means. For instance, numbers in computer terms are as discrete and corporeal as even a pythagorean of ancient times would have them. Moreover, all aspects of internal computer space is finite, like the universe in most cosmologies.

Yet through all the universal attributes, the **process** of computing is usually experienced as a relatively private and personal affair. The **act** of personal computing is one of intellectual and spatial seclusion. It is during these computer intimacies, that an emotional bonding to the machine occurs.

Figures 3-5.



During this bonding period, our bodies along with our minds, are blended together, and move towards a hodological experience of space <Lewin 74>. Here we connect to our machines through sensoral techniques by creating a mental map of our destination. In this case, the destination is the computer as object, as surface, and as philisophical surrounding. This is a cognitive mapping technique which offers the participant a metaphoric state of multi-layered transmission procedures.

Figure 6.

The language through which a programmer commands a machine is selectively opaque; it masks absolute addresses but allows the exploitation of variable names for representing or addressing the subject. The region or workspace in which memory is stored is an enigma, for it becomes virtually transparent. In other words, the physical shell of a computer and its peripherals are designed to be as invisible as possible.

Figure 7.

This duality between opaque and transparent structure makes a computer workstation a wonderous locale. The CRT can become the visible expression of an intellectual or emotional condition while the physical presence of the hardware remains a symbol in and of itself.

Figure 8.

We have carefully programmed ourselves to make the physical structure of display apparatus transluscent, remaining only as a conceptual frame for outgoing information. In time, our frames become less and less obvious, leaving us conscious of only half the icon. But in fact, each aspect of the artifact, the invisible tool and the visible manifestation of that tool, makes up the total experience of these machines.

Machine Vision

Qualitative Considerations Of Machine Vision

Machine vision, which is, literally, the acquisition of information external to the computer through optical sensors, is one sensory technique that bridges computer language and the world outside the computer's reality. This type of interface helps remove computers from their own internal **modeling** of human behavior, and, instead, uses the acquisition of **real**, or outside, information, ultimately producing a more accurate account of spatial perspective. In physical terms, machine vision helps create a more dynamic or **sensitive** system.

In only a gross technical analogy does machine vision work the same as the vertebrate's organs of sight. Both use lenses to focus the image, disparity to interpolate the three-dimensional world, and, perhaps most crucial, are peripheral to a more important central processing area.

But at closer comparison, the similarities end abruptly. We find that there is no machine technique available which accurately simulates the spectacular craftsmanship of the human eye. The computer has no external associated structures such as the eyelids, and eyelashes, to screen quantities and qualities of light falling on the retina, which together, aid in the overall function of "seeing." Within the internal in the overall function of "seeing." Within the internal structure of the eye, light converges upon the thin wall of the retina through the fluid vitreous body. This delicate, multi-layered photosensitive device detects electro-magnetic radiation, sorting and converting wavelengths to neuro-electronic pulsed information. Today's machine vision is equipped with no such subtle features, nor is the process as elaborate.

The use of relatively crudely ground lenses and inadequate photosensitive devices will eventually be replaced with equipment of finer properties. High quality translators could, in theory, produce machines with sufficient speed to examine detailed syntactic rules by installing large dictionaries and look-up tables. Many machine vision experts feel that the quantitative factors of refined hardware, sufficient speed and sufficient detailed syntactic rules make **true** machine vision an unrealistic endeavor.

Even if a technically equivalent machine vision peripheral could eventually be produced, the machine's interpretation of the outside reality would, compared to bio-mechanical optics, fundamentally remain inadequate. Though it would draw its information from external sources, data would still be processed or understood from the context of its own internal natural language. The computer will never truly understand the difference between synthetic and externally derived data. When a computer receives optical information, it **understands** the visual scene in purely syntactic structure, and relates to the process in the same linear logic. The machine exercises its intelligence in problem-solving by modifying symbol structures until it produces a solution structure. Solutions will therefore remain as represented symbolic constructs.

The conclusion is therefore three-fold. First, the creation of realistic simulated worlds is within the reach of a machine's ability. Secondly, the accuracy of an artificially intelligent machine to adequately mirror the world in which we exist remains that of a heuristic hypothesis. Thirdly, optical hardware for data acquisition is used when the simulation or facsimile of real world space is not acceptable.

Gesture Analysis

People/Machine relationships are empirical kinships where, naturally, we expect the computer to become the extension or additional compiler for our own bodies and psyche. In turn, we are, however, also extending the physical space of computer as well. If the computer could externally obtain raw data from the physical world, there could be a blending of the physical world into the digital reality of computer graphics. Optical peripherals help the computer literally reach out beyond its own hardware boundaries making the machine's physical space potentially as large as its field of vision. In the case of body tracking, the performer can be thought of as actually becoming part of the computer, i.e. of the machine, not just the hardware, but the programmed living machine. In this case, the living machine is an extension of both the human's and the computer's capabilities. In a philosophical sense, it certainly is appropriate that machines **look** to their creators for the acquisition of their data.

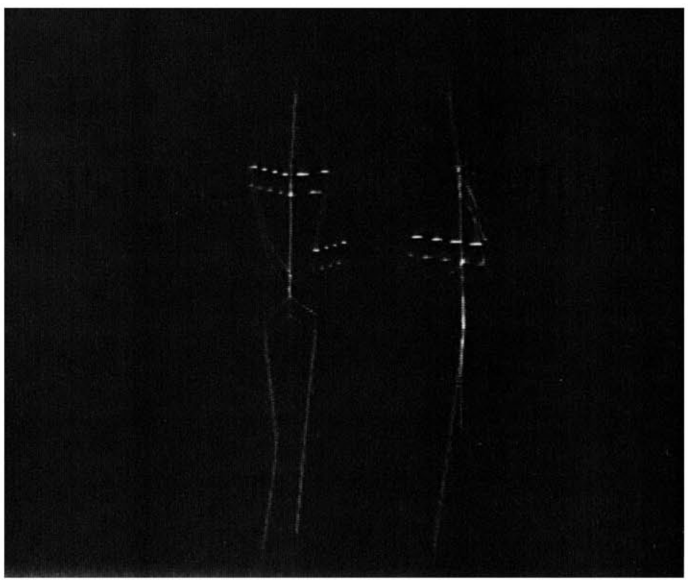
Computer Constructed Motion

An early attempt to record human movement such as **Labanotation** used a pictogram method for recording dance. This was the predecessor to techniques used in computer simulation today.

The **Dynamic Technique** starts with a simulation of force of muscle and the mass which it moves <Hatze 81>. A graphic representation reacts to a pre-designed set of rules that are addressable by changing programmed variables such as force, speed and theoretical physical limitations. The product is a reality of simulated constructs. The better the constructs the better the simulated reality.

Another widely used technique is one commonly called **keyframing**. The general packaging of this simulation concept is a line to line function. Literally frame by frame, interpolation between two pre-defined postures gives the model a route to travel in a predetermined amount of time. Used in conjunction with this, analytical movement descriptors such as Cutting's walking algorithm <Cutting 78> may be used. In this example, motion is determined by describing fifteen key points on a walking figure as a vector-valued oscillation.

Figure 9.



In 1980 movement on film was first analyzed by digitally grabbing frame by frame to deduce three-dimensional locations on key points <O'Rourke 80>. Highlights found on the subject constitute a mapping from object space to freedom positional information <Maxwell 74>. This technique, known as Pattern Recognition, as used in the **Moving Light Display** technique, was a first attempt to draw raw data from a real world source. The obvious flaw is that once the information is decoded onto the surface of film, all true three-dimensional definitions have been stripped away. Its strength lies within the computers ability to interpret changes in line and two-dimensional form.

Computer Controlled Tracking .

Towards the late 70's research began in the specification or tracking of articulated motion directly. Almost all of these techniques use stereoscopic triangulation from a pair of digitizing devices to determine spatial location. <Maxwell 82> Most of these techniques were developed specifically for use in tracking human motion. Now intermediate media such as film could be bypassed producing a closer, more accurate rendering of the subject.

One of these, the **Coda-3 System** monitors up to 8 landmarks or locations on the body at one time. Optical scanning sweeps 3 fan-shaped beams of light across the field of view to sense reflection. Another, the **Selspot System** uses light emitting diodes worn on the human body to locate each critical limb in a spatial context. The lights are then picked up by cameras connected to the computer. It is from this technique that The **Op-Eye** system for tracking the body was developed.

Body Tracking

Body Tracking For Imagery

Generally, most three-dimensional human scale digitizing systems have been designed for use in the fields of biomechanics, neurology and sports mechanics. With current research in robotics, tracking systems are being considered within the study of high resolution static displacements and attitude in wind tunnel operations. The prime purpose of these researches is to acquire data for the statistical analysis of human motion.

The following project uses similar techniques as those mentioned above with one fundamental difference: the **act** of body tracking is an imagery-data acquisition tool which helps produce an imagery-based product.

Optical Body Tracking research is an offshoot project of MIT's Graphical Marionettes Project <Bolt 81/ Maxwell 82/ Ginsburg 83/ Purcell 84/ Lewis 84>. Its prime purpose is the creation of trackdata for the animation of computer generated figures.

Hardware/LEDware Overview

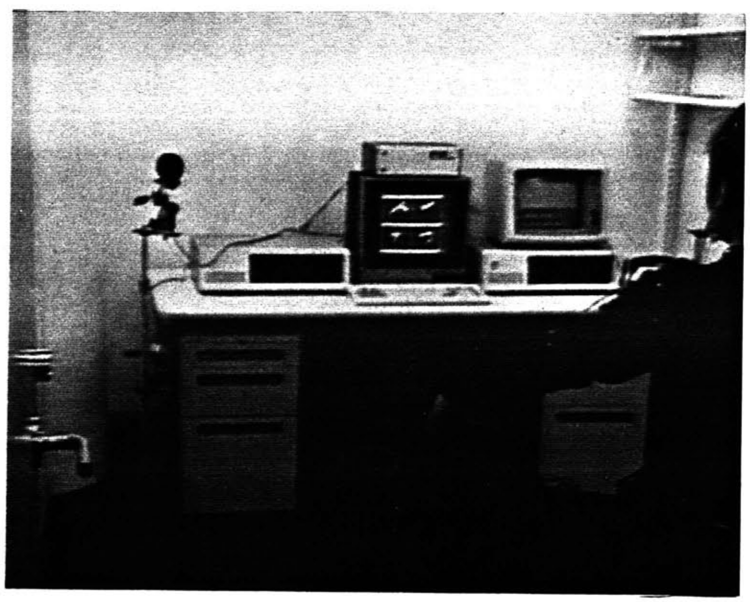
The Op-Eye Body Tracking System offers an inexpensive alternative to the Coda 3 or Selspot systems, providing a similar three dimensional coordinate system to the computer. In this case, the system tracks the corresponding position of the joints (nodes) in the human body. The **performer** wears a suit which has light emitting diodes (LEDs) sewn into the fabric (LEDware). Each band of diodes emits a specific **signature** pulse which differentiates and locates each limb in free space.

Figures 10-11.

Figures 12-13.

Optical hardware consists of four two-axis lateral effect diodes made by United Detectors Technology. These sensors detect the position of a spot of light on its surface. Both the tracked LEDs and two-dimensional position information is then obtained via four electrode connections at the edge of each detector. Using LEDs and sensors sensitive to the infrared range avoids optical interference (optical noise) with existing or ambient light. This also avoids the complexity of a camera system that would demand further elaborate data processing and expense.

Figure 14.



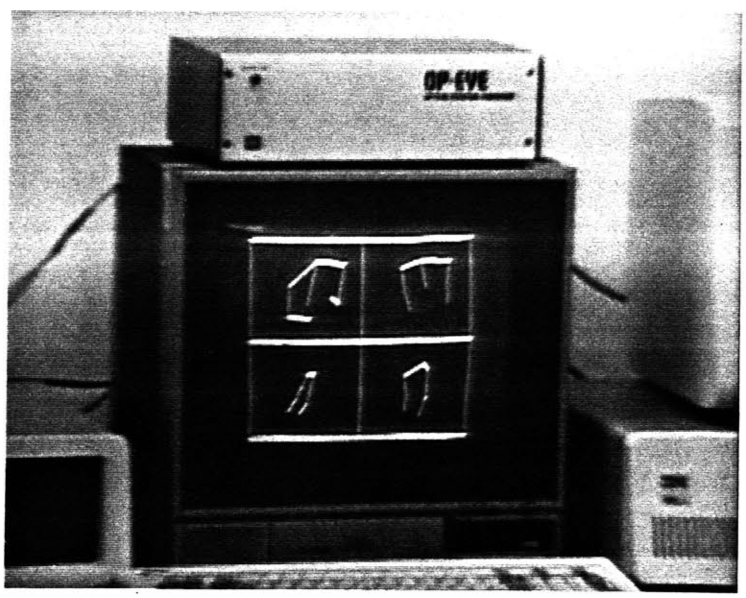
The sensors do not require precise focus as the detectors sense the **centroid** of the light spot on its surface.

The signals from each detector are fed to the central interface module, Op-Eye, where they are first amplified then digitized for processing in a manner compatible with the IBM PC series of micro-processors.

Graphical Marionettes/Scripting By Enactment

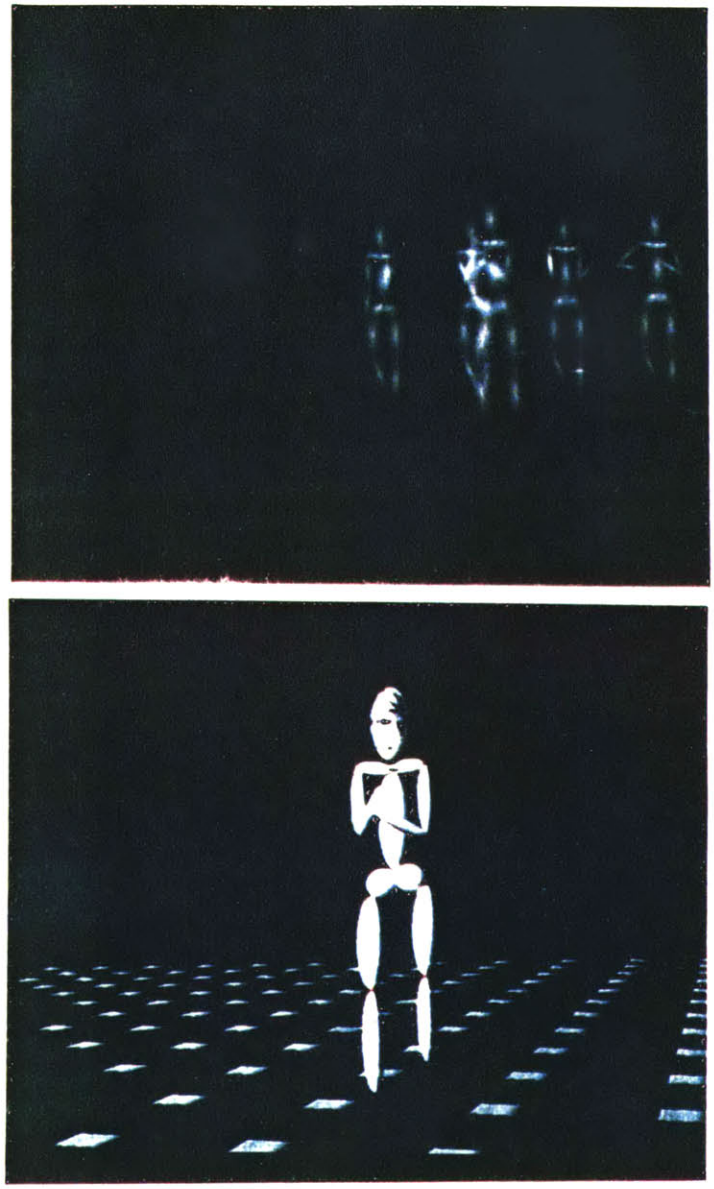
The Tracking Suit is used as an alternative to modeling motion of the human body. It is the animator's way of achieving fluid motion without the difficulty of motion analysis and tedious programming. The user wears LEDware to create motions that are optically received and stored as files within the IBM-PC. A real-time stick figure body is displayed to check continuity.

Figure 15.



These files can later be filtered and used, in conjunction with larger databases on mainframes, to create more developed animated sequences.

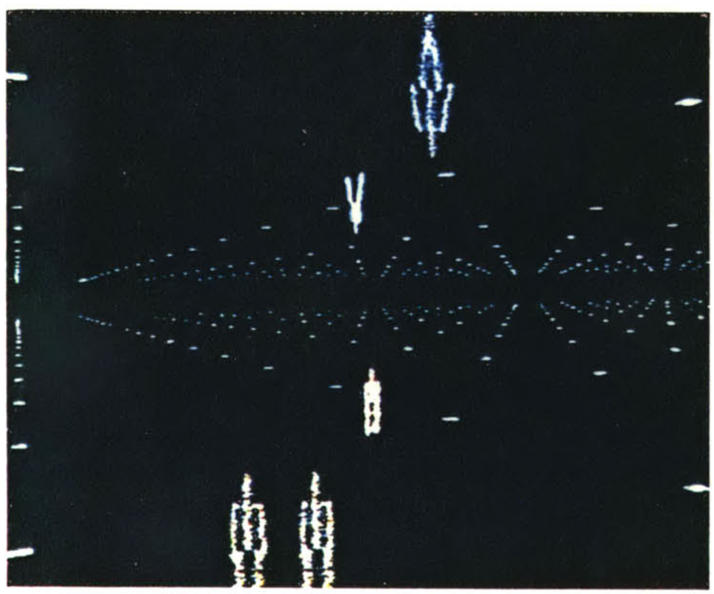
Figure 16-17.



One long-term project is to create a filing system full of trackdata motions much like the cell animation system used at most animation houses. The difference is that all motions can be stored, tree-structure fashion, and easily called into memory for use. If the movement of a hand grasping a small, delicate object is needed, the animator goes to the HAND

Directory and checks for names like **Grasp** or **delicate.** Ideally, there would be a number of different grasping files found that can be loaded back into the micro-processor and looked at in the real-time stick-figure resolution. With a choice then made, the animator need only call up this movement by name, joint or node location, and speed within the scripting of the animation. Each movement can be used as many times, in as many locations, and speeds as desired without the need actually to create the movement again. The process of developing a computer animation then becomes a job of data cut-and-paste, a more natural form for creating an animated sequence.

Figure 18.



Another possible use for trackdata in the development of a total animation system is as an addition to a feedback technique called adaptive motion <Zeltzer 85>. This process gives power to certain hierarcical software that drives the potential configurations of a motion. In other words, a certain amount of spatial knowledge can be given to an object or figure existing within dataland. This object or figure can be trained to maneuver throughout the constraints of that environment. Such examples of automatic collision detection are currently being implemented in software. But to avoid a collision, information about the physical nature of the object in motion is also important. If the object has any of the kinematic and behavioral complexities of a person, it might be better to have help from an example. If the problem of, for example, the performance of joint motion under a certain set of involved conditions exceeds the knowledge base of the implemented software, trackdata could help establish the rules of behavior.

Theoretically, the allocation of searching through and finding the appropriate trackdata file could be all done in the task-level of the software. By checking similar trajectories between the motion in software, and the trackdata file, the animation could try to repair an awkward or incorrect motion by altering it with a trackdata alternative.

The ultimate goal would be to have hierarchical software that would allocate tasks to other portions of the system making possible the simulation of more complex motions. This would be accomplished by having the **task-level** offer the **guiding-level** a few alternatives to all questionable motion before the data reaches the **scripting** or **animator-level.**

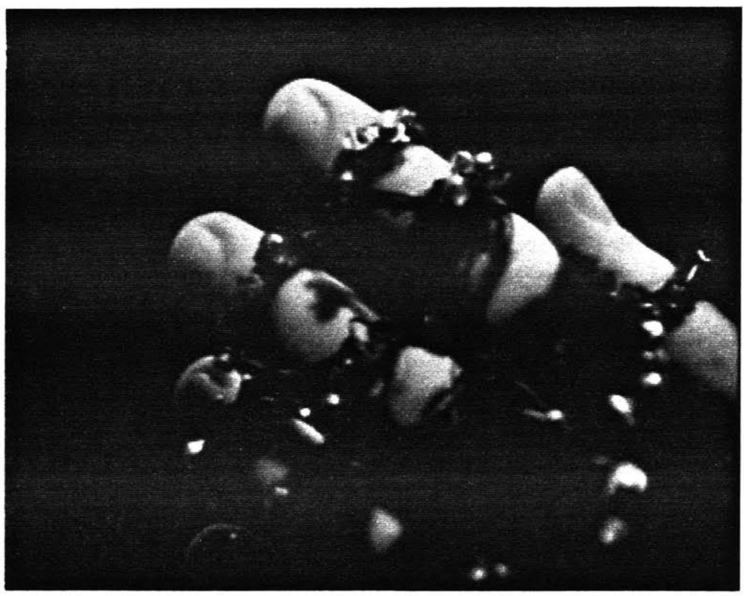
The fundamental difference between Computer Constructed Motion and Computer Controlled Tracking lies in how **natural** the final product looks. Each of these techniques is attempting to arrive at the same **naturalness**, but are starting from polar opposite positions. Constructed motion strives to best simulate the workings of the body while the tracking technique attempts to retain the initial life qualities of the data as it is digitally processed. The assumption is that it is better to begin with the natural form of motion to produce a better product.

Signing As Computer Input

Personal computation by definition should be a private process. A goal in developing these systems is to retain this element while enabling the system's interactive capabilities to mature. The use of a gestural glove can help minimize physical inhibition with the hope of seeing a more personalized interchange.

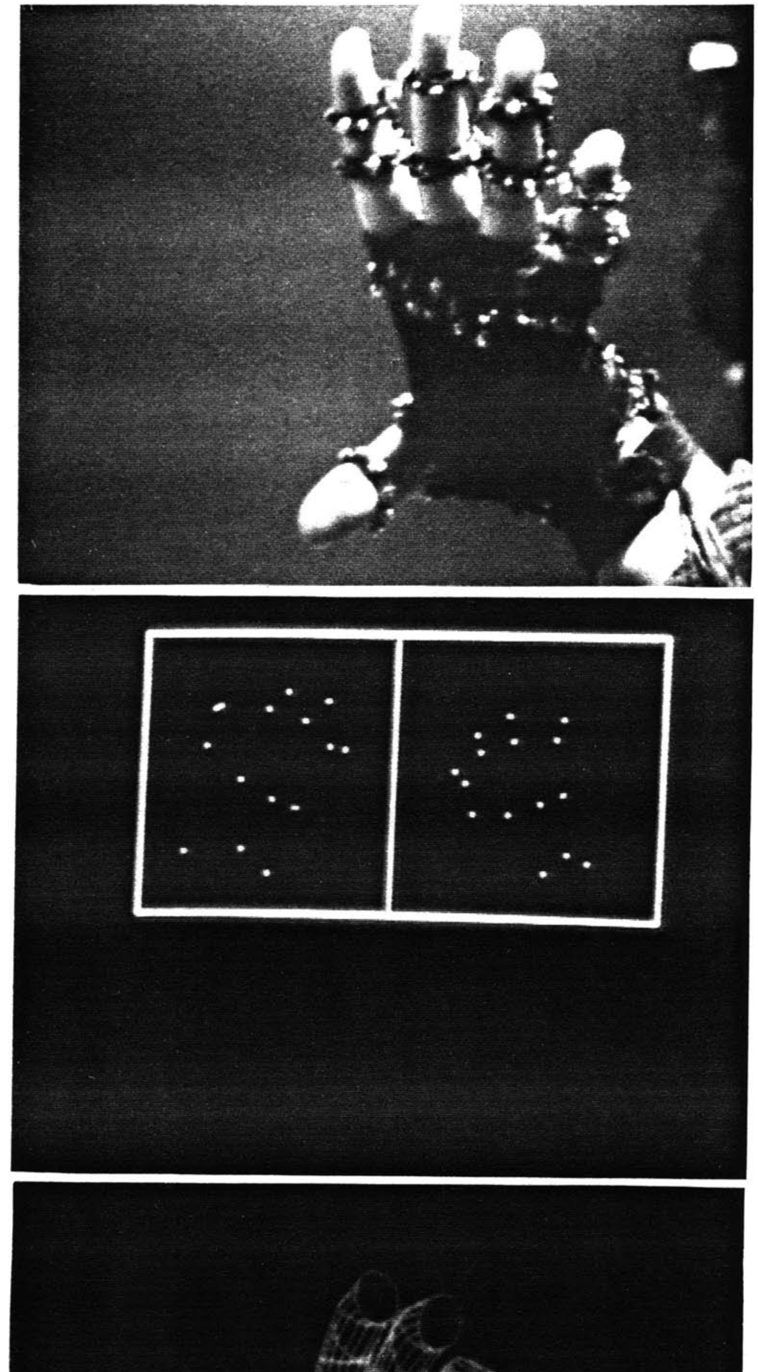
This Body Tracking tool is geared toward the handicapped as both a learning and a communications enhancer. Software has been designed to help teach the student of sign language, especially those with fine motor dysfunctions, by using a simple and intimate setup. The student wears the glove to practice hand positions in front of a graphic monitor equipped with sensors.

Figure 19.



A Real-time stick figure representation of the hand's position simply mirrors the student's attempts. When a hand position closely resembles a letter of the alphabet or word stored in the software look-up table, that letter or word is printed on the screen. In this fashion, sentences and paragraphs can be constructed as fast as the student can sign.

Figures 20-22.

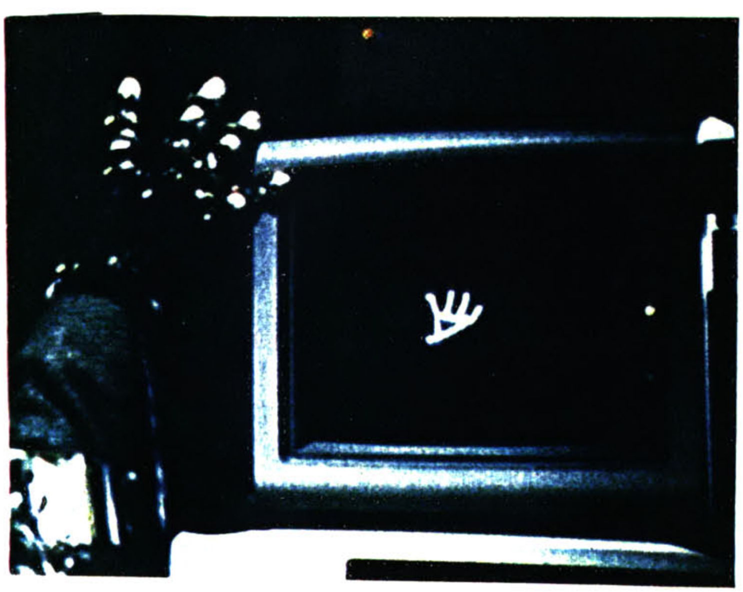


Concept

Series of resistors, capacitors, and other electronic devices are used to make a physical model such that the electrical elements produce a set of electrical qualities. These currents and voltages behave isomorphically with the variables of the body and its motion. In this case, the relation between physical element and conceptual element is explicitly abstracted. Both the human body and its electronically reflected image is preferred in a general and "felt" analogy.

> **IMAGE /'IM-IJ/**
>
> N 1: A likeness or limitation of a person or thing. 2: A visual counterpart of an object formed by a device (as a mirror or lens). 3: A mental picture or conception; impression, idea, concept.
>
> VB 1: To create a representation of. 2: to bring up before the imagination.

Figure 23.



Conclusion

Generally, we can think of all we make as a physical and phychic extension of ourselves. Being the territorial creatures we seem to be, extending personal and collective territories has obvious logical advantages. The more we make the more we can validate our own existences. Whether our tools be utilitarian or symbolic (such as a cooking bowl and its aesthetic design, respectively), their function is to transmit our own nature into our surrounding reality.

Computers not only carry the logical formats found in pure mathamatics, but appear to display discrete levels of interactive responses which, until now, have been attributed exclusively to living organisms. We expect these machines to receive, assimilate, and output correct solutions, which also until now, has been attributed exclusively to thinking organisms. We have given them artificial vision, speech, touch, smell, taste, and motor functions. They are able to reproduce their own kind. They have even produced reasonable attempts at making **intelligent** correlations between their internal and external worlds. We continue to build these tools in our own image and likeness, yet they **still** don't have the characteristics that we attribute to true life qualities. Ironically, we have given computers attributes which simutaneously mirror and transcend the logic of our own existance.

Illustrations

Figure 1.

Mirror Cell

Frame from a computer animation.

30 Seconds.

Inside a three-dimensional computer environment flat surfaces spin in free space. Reflected from these surfaces is the landscape sceen from the viepoint of the camera. As the camera travels through the environment and the flat surfaces rotate, the images reflected in the mirrors are constantly updated.

Figure 2.

Data Display

Data monitor displaying two separate sets of two-dimensional locations, received by two separate sets of optical sensors. The sensors are receiving data at approximately 40 hertz, therefore, the screen is being refreshed with a new set of data points about once every 30th of a second. This data will be saved into a file that will later drive objects and figures for animation.

Figure 3-5.

Pulsating Orifice

3 frames from a computer animation

5 Second loop

The wall of the animated orifice is driven by scripted software. Each individual 'clot' rotates in X and Y around their own origins. The camera receives its location from trackdata. The trackdata was created by the author by placing her chest against the face of a monitor located next to optical sensors. The final product is a kenetic wall of red polygons and a camera that heaves into the space in the middle, and then out.

Figure 6.

Computer Pulsed Island

detail, computer installation

Orifice Animation on a gold-leaf monitor reflects onto the chest of a stylized women's body.

Figure 7.

Computer Pulsed Island

detail, computer installation

Computers painted red, black and white, sit on an island of white sand. Graphics which pulse from the center of the screen outwards, change from black to red, and back again.

Figure 8.

Computer Pulsed Island

computer installation

. White monitor in foreground displays a digitized picture of a women's body which echos features from both the black stylised body towards the left, and the pure white sand beneath it.

Figure 9.

Stick Figures

Two overlayed frames from a test animation.

Figure 10.

Model in LEDware

Collecting upper body trackdata for Marching Band Animation.

Figure 11.

Model in LEDware

Collecting upper and lower body trackdata archives.

Figure 12-13.

Dancer in LEDware

Collecting upper and lower body trackdata for animation.

Figure 14.

Model in LEDware

Checking stick-figure for continuity of motion.

Figure 15.

Stick figure in pieces

Real-time stick figure is separated into four sections. The top two squares are what each seperate sensor is tracking from the uppper body. The lower two squares are what they are tracking of the legs.

Figure 16.

Frame from Marching Band Animation

20 seconds

Each of the animated band members were assembled from trackdata in the scripting level.

Figure 17.

Frame from Eggman Animation

Eggman was assembled from trackdata in the scripting level, and then produced through the keyframing technique.

Figure 18.

Frame from Cloudpeople Cell animation
30 seconds

Both software and trackdata driven figures share this animated space where gravity is non-existant.

Figure 19.

LEDware/Glove

There are 15 critical joints in the human hand. Each joint has an associated strip of LEDs sewn into the glove.

Figure 20-22.

From real-world to dataland

The individual nodes of the hand are tracked and displayed on the screen with or without the connecting lines. From this information alone, the modeling of a more refined hand can be executed.

Figure 23.

Electronic window

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Section II

Appendix

General Comparison

The following is a comparative evaluation between the existing Op-Eye Tracking System (MIT), and The WATSMART Spatial Motion Analysis and Recording Technique available from Northern Digital, Waterloo, Ontario. The method of operation for both systems are quite similar as observed in the general functional overviews below. Fundamentally, they are both non-contact 3D digitizing, state of the art tracking devices. The important difference lies within how controlled the data acquisition technique is making clearer trackdata files. Is it worth upgrading existing Body Tracking hardware and software, or is it advantageous to buy into a pre-existing package such as the WATSMART.

Good trackdata is a function of proper triggering and synchronization within the data collection technique. What has been overlooked with the current system is the importance of camera setup and proper hardware calibration. Whenever one or more cameras/sensors are physically moved, the system must have the proper facilities to reconstruct its 3D mathematical constructs. There is no such updating technique existing with the OP-Eye system. This camera registration is done automatically by the Watsmart by use of a calibration program provided with the system and takes only a few minutes to run. The alignment procedure requires the placing of a tubular steel frame containing 22 pre-surveyed LED markers in view of all cameras in use. The calibration file produced by this procedure must be used as an input to the 3D linear transform process for all data collected by that particular camera setup.

This calibration technique was considered for the Op-eye, and is conceivable to some extent. There is, though, one major drawback. There are already too many arbitrary hardware devices built into the system, which makes it virtually impossible to correctly calibrate. In its initial conception there were no standards established for relative/absolute accuracy. These standards are traditional and critical to any optic lab installation. Existing trackdata files are, therefore, only accurate for gross motor functions. The raw data is extremely noisy and has to be low-passed filtered to such excess that the product is not accurate for analysis and barely acceptable for use in animation. The final evaluation must be made by direct comparison of trackdata made from each system.

The Watsmart also includes software to increase the 3D accuracy for modeling purposes. It is easy to obtain yaw, pitch, and roll of models as well as compute valid 3D data in situations where there are few or no markers within common view of at least two cameras. This is extremely important, for visual obscurity is one of the prime reasons for excess optical noise in the current system.

Unfortunatly, all optical tracking devices have the similar problem of background lighting and reflections. Many surfaces that appear as black in visible wavelengths are actually quite reflective in the near infrared light red region. Care must be taken in setting up an experiment so that all surfaces in position to reflect directly from markers into a camera are anti-reflective. Unobvious problems occur because the camera receives both the true marker optical signal and its reflection at the same time causing an apparent shift in the marker position measured. This is due to the fact that the camera averages all infrared light it sees, and therefore a reflection cannot be separated out from the objective image.

The Op-Eye Package was constructed over a period of two years. All technical specifications are averages between standards featured in the owner's manual and actual specifications obtained in lab findings of the Architecture Machine Group, MIT.

The Watsmart is a total package. All technical specifications are averages between standards featured in a preliminary technical description manual and the findings of The Center for Bioelectrical Engineering, MIT.

Op-Eye Package

Hardware

1) 4 bi-lateral effect diode cameras
2) LEDware
3) A camera controller and power chasis
4) -
5) A computer and controller board
6) -
7) Adequate cables to interconnect all the above

Software

1) -
2) Define the number of nodes and their location
3) Datacollection and storage of raw data
4) Raw data to 3D information using 3D linear transformation tecniques
5) Produce 2D stick figure graphics
6) -

Op-Eye Package

Technical Specifications

A/D Resolution: 12 bit. 1 part in 4096

Spectral Range: 350-1100 nano meters

Approximate Saturation Level: 10mW/cm2

Typical Position Linearity: 0.5% in central 25% of detector/ 3% in central 75% of detector

Minimum Detectable Intensity at Detector Surface: High gain (10 to the 7th ohms) 2uW =10v (full scale)

Programmble Gains 1,10,100,500

Watsmart Package

Hardware

1) One or more high resolution infrared cameras
2) Variety of infrared diodes (IRED)
3) Camera controller and power chasis
4) Marker strobing controllers (8 markers each)
5) A computer and controller board
6) A pre-surveyed calibration frame to facilitate quick camera setup and ensure positional accuracy
7) Adequate cables to interconnect all the above

Software

1) 3D re-construction/calibration used when the sensors are moved
2) Parameter software to define an experiment in terms of the number of markers used, the frequency (frame rate) of data collection, duration of collection, etc.
3) Data collection and disk storage
4) 3D linear transformation software that changes raw data to a more useable 3D format.

Watsmart Package

Software (Cont.)

5)Produces 2D stick figure graphics in real time

6) Perform general functions such as Butterworth of Spline filtering, velocity and acceleration derivation and graphical examination of both data and its derivatives.

Technical Specifications

Camera resolution: 1:406 or 0.00025 of field
Absolute accuracy: Corrected to 0.002 of full range (optional to .00025)
Field of view:35 degrees w/ supplied 22 mm custom lens (vert. and hor.) 45 degree diagonal angle. Optional 90 degree diagonal custon lens.
Distance: .75 to 10 meters, dependent on emission power if LED marker
Sensitivity: Infrared light in spectrum range 800 nanometers to 1050
Aggregate max.sampling rate: 8,000 markers/second/camera

Op-Eye Optional Position Indicator

United Detector Technology

3939 Landmark Street

Culver City, Ca. 90230

(213) 240-2250

Watsmart Spatial Motion Analysis and Recording Technique

Northern Digital

415 Phillip Street

Waterloo, Ontario N2L3X2

(519) 884-5142

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