IMAGES OF HUMAN MOTION:
CHANGING REPRESENTATIONS OF HUMAN IDENTITY

by

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ABSTRACT

Human motion as a subject for visual representation is an issue of human self-image. Who and what we think we are is interdependent with both the pictures we make and our picture-making hardware.

Our technical capabilities for recording and display of three-dimensional motion phenomenon have been improving. Simultaneously, intellectual insights are providing us with a new concept of human nature. We have found that our lingering traditions which separate mind and body, body and environment, are incorrect. We are the sum of the interaction of our physical nature with our cultural and physical environment. One way we reveal ourselves in this way is through our physical motion.

I am looking for mediums and methodologies which would provide a contemporary American audience sorely needed new insights into their own nature.

I see the possibility for revealing a different kind of self knowledge by revealing patterns manifested by body motion. For the moment, film and video have been a place to begin. Interactive media which are just becoming available are going to be far more satisfactory.

Thesis Supervisor: Richard Leacock
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What is an Image: Consider the Family Snapshot

Consider the family snapshot. It is a portrait of a group at a certain point in time, in a formal arrangement with formal expressions. The arrangement and the expressions are nearly identical copies of similar snapshots world-wide and historically precedented by generations painted in these poses long before the camera. People stand in this way only for this ceremony. So already before the shutter has recorded this moment the portrait group has reorganized daily life for purposes of making an image about their life.

The resultant image serves to jog the memory and the thoughts and makes us consider what is associated with this image. Each time it is viewed, it reinforces a set of thoughts associated with it. These may include pangs of strong wistfulness associated with golden ideals

of family, or a reminder of personal history in contrast to present surroundings.

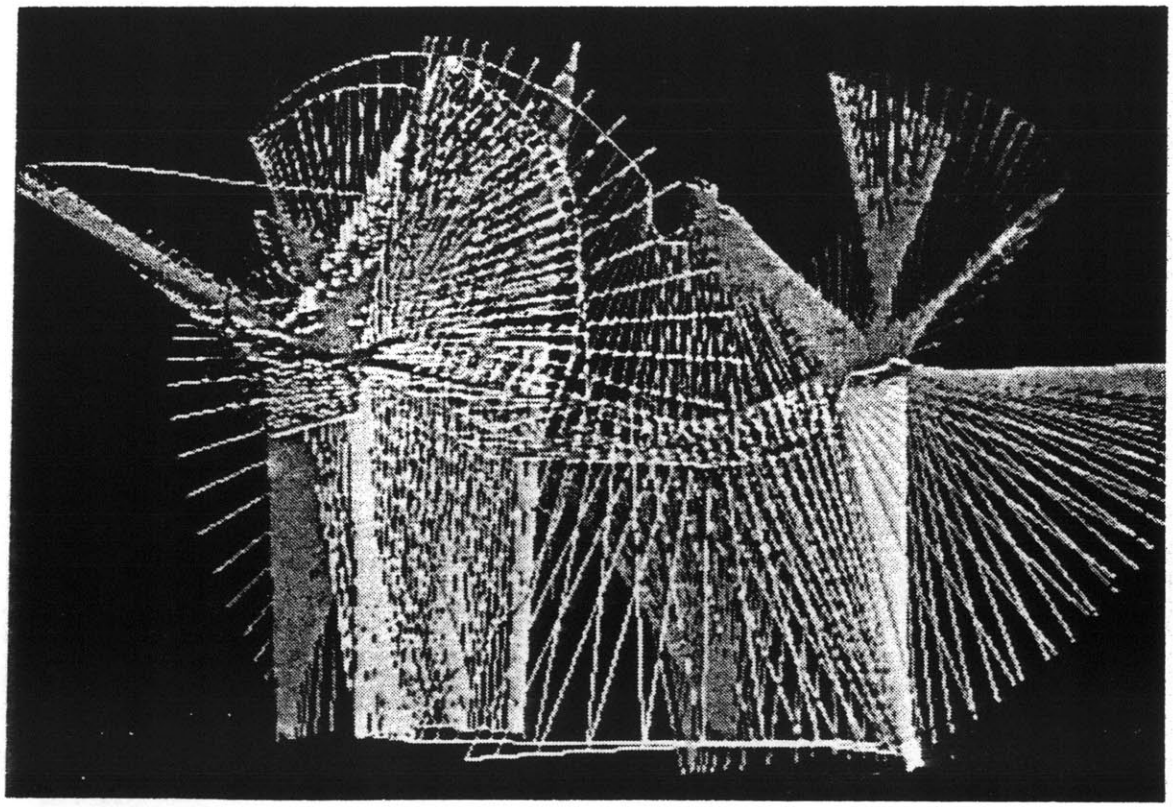
Such an image may be said to be an extension of our thoughts, an external memory. By reviewing the portrait many times, something more happens. The portrait develops an identity of its own. Memories of each time it was viewed become overlaid. The original meaning may be reinforced or modified. In turn, this altered meaning may influence our attitudes towards the subject of the image. Subsequent images are influenced by our attitudes towards subject and image.

The advent of home movies did not initially precipitate a new kind of portrait. Many early movies depict the family standing ceremonially as usual, but waving at the camera. Family rituals: weddings and birthdays are a common subject, perhaps because the ritual activities can be consciously anticipated. Daily activities present dilemmas to the home movie maker not equipped with a model form to relate to. We also find movies constructed like feature films, with little plots.

It is difficult to invent new images because our new self-representations and our concept of self is so bound up in traditional image forms. Attempts to make changes in form may have unsettling results which do not depict "life as we know it". Image-making is an activity directed by our preconceptions about the subject, our preconceptions about the image form, the capabilities of the image-making equipment and how we use the equipment's capabilities.

Review of the Literature

Traditional Western assumptions about human identity have been altered by intellectual developments within the last 100 years. The following section is a summary of some of the ideas which most radically transformed my thinking and formed the basis of my current interests.



Cybernetics

"Communications", "Information Theory", or "Cybernetics" as it may be know variously, is of course a well-known shared foundation for much current work going on at M.I.T.. Developed by interdisciplinary scientific and technological developments at M.I.T. and elsewhere, and delineated clearly by Norbert Weiner in The Human Use of Human Beings, the allegory of rephrasing all questions in terms of an information exchange is useful as a model for looking at the universe with fresh eyes.*

> " It is the thesis of this book that society can only be understood through a study of the messages and the communication facilities which belong to it..."**

The theory is based on the modern intellectual assumption that the universe is total chaos -- or alternatively, maximum information without order. Weiner suggests that all entities exhibiting some sense of organization or purposeful action in an otherwise chaotic universe which would wear it down -- in his words "fighting entropy"*** should be considered together. This includes: living organisms, machines, relationships of organisms and machines, and social organizations of living organisms.

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* Weiner, N. (1950), The Human Use of Human Beings, Houghton Mifflin, Boston, Chapter 1, "Cybernetics in History".
** Ibid., p. 25
***Ibid., Chapter 2, "Progress and Entropy"

pattern

What we recognize in a system like an organism is its pattern, organization or plan. The actual substance of things may change over time without loss of identity.* Cells die and are replaced. Is a machine different if a fuse is replaced? The P.T.A. is the P.T.A. no matter who its members are.

relativity

A message implies relationship and vice versa. Putting himself and his idea in historical perspective, Wiener states in the preface his debt to statistics and probability theory as well as to Einstein.** Any observation predicates a relationship between a observor and the observed. Experimental error is assumed implicit. One assumes that that observor affects the observed and that the observed affects the observor, in all cases, by definition. Another, more psychological term for this principle is "subjectivity".

feedback

Weiner distinguishes between two kinds of purposeful behavior.*** One, simply following instructions: like a clock, once started, runs by itself according to prearranged patterns. Weiner uses the example of figures on a music box, animated by clockwork, but obviously not

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* Weiner, Ibid., Chapter 5, "Organization as the Message".
** Ibid., Preface.
*** Ibid., Chapter 1.

capable of varying their action independent of the clockwork, not capable of responding to anything else in the world. Two, in contrast, a great many things are capable of independent action which allows them to adjust their action relative to changing conditions in the external environment. Elevators equipped with electric "eye" safety features do not close their doors until people are clear of the doors. A person can catch a ball by adjusting muscle activity relative to visual input of the moving target. Information returned to actuators for purposes of making adjustments in action is called feedback. In actual practice feedback is an iterative loop. The ball is seen and one begins to run for it, immediately receiving sensory feedback from the muscles, giving information on position and rate for comparison with visual feedback giving information on where the ball is located. Adjusted action is taken and the cycle repeated.*

> "Consider a man felling a tree with an axe. Each stroke of the axe is modified or corrected, according to the shape of the cut face of the tree left by the previous stroke. This self corrective (i.e. mental) process is brought about by a total system, tree-eye-brain-muscles-axe-stroke-tree; and it is this total system that has the characteristics of immanent mind."**

oscillation

Oscillation is what happens when a feedback loop isn't working smoothly. Rather than correcting the error correctly, the error is allowed to get progressively bigger until it is as big as the system

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*Ibid.,

**Bateson, G. (1972), Steps to an Ecology of Mind, Ballantine Books, N. York. "The Cybernetics of Self: A Theory of Alcoholism", pp.317.

will allow before trying to correct it back the other way.

A pendulum swing is an example of oscillation, it is a fluctuation around its stable position. Oversteering an unfamiliar auto with power-steering it is easy to set the motion of the car in an oscillation from the desired trajectory.*

> "Man is immersed in a world which he perceives through his sense organs. Information that he receives is co-ordinated through his brain and nervous system until, after the proper process of storage, collation, and selection, it emerges through effector organs, generally his muscles. These in turn act on the external world, and also react on the central nervous system through receptor organs such as the end organs of kinasthesia organs is combined with his already accumulated store of info to influence future action. **

memory

Even more effective a strategy for dealing with a changing environment is memory, such that feedback can be compared to past experience and action adjusted according to this stored information as well as current experience. In this way computer memory enables repetition of different tasks requiring the same operation. For instance, practise reduces misses in a batter's swing.***

why this interests me

Pattern, subjectivity, feedback, oscillation and memory are characteristics of human mentality. I want to create experiences which would demonstrate these behaviors of the mind by evoking them.

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*Weiner, Op.cit., Chapter 10, "Some Communication Machines and their Future".
** Ibid., p.26
***Ibid., Chapter 3,"Rigidity & Learning: Two Patterns of Behavior".

The undeniable preoccupation of human beings with pattern, particularly repetitive pattern with slight, variations, leads me to presume that we are responding to something familiar, to our internal clockwork.

Presentations should emphasize rhythm and variation. Ideally audiences should be engaged in creation of variations, and in completion of incompete patterns.

Subjective viewpoints would be apparent through experience of contradictory views, all of which appear to be correct.

Interactive mediums could directly engage the audience in a feedback loop. Allowing the loop to go into oscillation would be one way of bringing it to the audience's attention.

Progressive error must be involved in the way the mind seizes at an idea, and also in the way emotional response builds up progressively in time and tends to fluctuate.

Through a long history of use, our landscape, tools, images, etc, become a form of collective memory. Not only do objects or places take on known symbolic meanings, but I believe, they elicite similar responses on an unconscious, perceptual, and behavioral level. In appreciation of this, Winston Churchill argued that a new building to house Parliment would irrevocably alter British Government.*

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* I cannot remember where I heard this great line.

Physiology

"All ways meet in the eye, and there, turned into form, lead to a synthesis of outward sight and inward vision."*

human perception of human motion

Johansson's well known studies of human perception of biological motion involved illuminating the joints of walking subjects, resulting in tapes or films of white dots moving on a black field. Viewers of these moving images could reliably assert the nature that the movement was made by a human walking, running or dancing, even when reduced to only 5 points representing hips and legs.**

The perceptual system maximizes coherent structures in the constant blur of the visual field. Elements moving at the same rate are perceived connected,or more generally, connected if they display equal simultaneous motion vectors. This includes pendulum motions, and motions seen in perspective.***

Johansson's work was repeated at Wesleyan by Cutting and Kozlowski. They found that the type of motion (walking, running, etc.) as well as the gender of the moving person, could be identified, provided the playback speed was near normal rates, the gait was not too abnormal, and the viewing period too short.[1]

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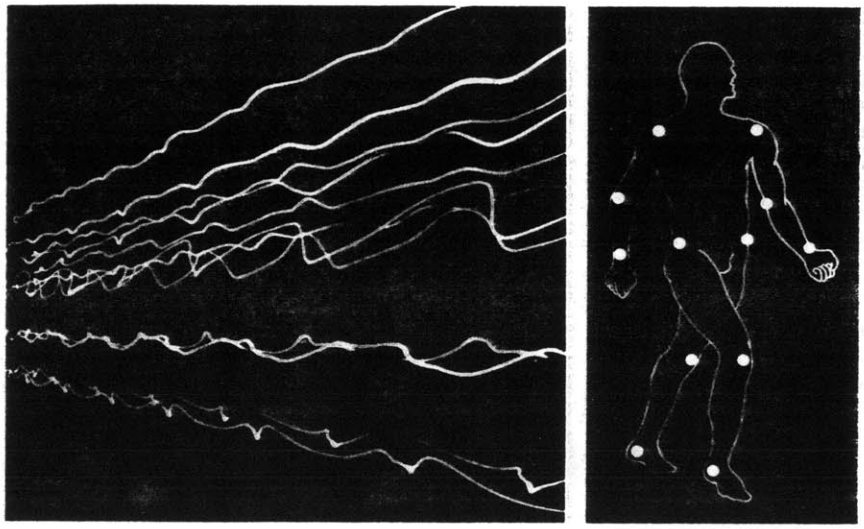
1. Cutting,J.E., Kozlowski, L.T. (1977), "Recognizing friends by their walk: Gait perception without familiarity cues," Bulletin of the Psychonomic Society, Vol. 9 (5).

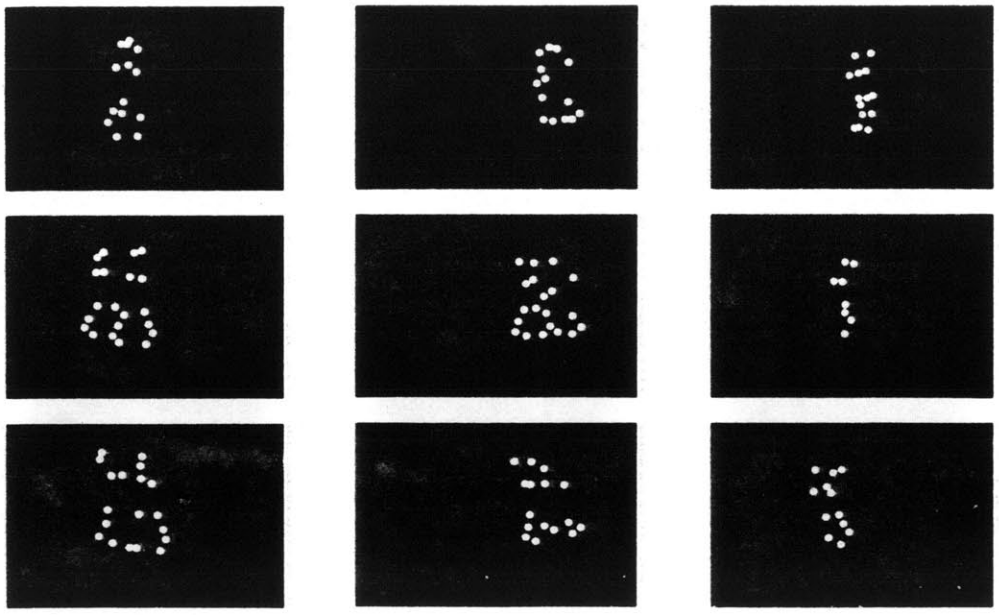
*Klee, p. (1964), The Thinking Eye, George Wittenborn Inc., New York, P. 67.

**Johansson,G. (1973), "Visual perception of biological motion and a model for its analysis," Perception & Psychophysics, Vol. 14 (2).

***Ibid.



LIGHT TRACKS OF WALKING PERSON (*left*) are recorded by making a time exposure in a dark room of a subject fitted with 12 small lights at his principal joints, as is shown at the right. The continuous streaks generated in this way have no obvious interpretation. If, however, the moving-light patterns are recorded on motion-picture film, one can see instantly when the film is projected that it portrays a person walking. Motion-picture frames of two similarly lighted subjects dancing in the dark appear on page 69.



*Johansson, G. (1975), "Visual motion perception," Scientific American, Vol. 232 (6).

They also claimed success in viewer recognition of the identity of the subject if the subject was previously well known to them.[2]

Here at M.I.T.'s psychology department, Rhea Gendzier has collected a set of similar stimili for testing a hypothesis about cognitive development curves for recognition of individual differences, such as familiar faces.

In preliminary subject testing, the moving dot patterns do not seem to be recognized as individuals. However, subjects do consistently identify the type of motion as human, just as Johansson, Cutting and others have described.*

I have noticed a similar immediacy of recognition with computer graphic representations of ballet motion with which I have been working at the Architecture Machine. Passers-by joke casually about the abstract patterns, "What's this, ballet?". It is impossible to reliably identify anything else about the motion, such as what limbs segments are involved, or what kind of ballet motion is represented. The sense of familiarity seems undefinable. I am very curious to know more about this.

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2. Cutting,J.E., Proffitt, D.R., Kozlowski, L.T. (1978), "A Biomechanical Invariant for Gait Perception," Journal of Experimental Psychology: Human Perception and Performance, Vol.4 (3).
* conversations with Gendzier - no published material as yet.

there are no "pictures" in the brain

> "The eye has no shutter, and yet a moving world does not appear as a blur. The visual system works not like a camera but more like a computer with a program of specific mathematical rules."*

Simple experiments prove we cannot focus near and far simultaneously, and yet everything appears sharp and clear. Donald MacKay suggests we might think of the world as continuously "scanned" by the foveal area of the eye, but he cautions that we cannot find any structures inside the brain which might store a one to one correspondence of object in the world and mental picture, no large frame buffer, or television screen. Rather, the brain seems to deduce algorithms about the operational implications of its visual data.**

The young child develops successively more complex stratagems for interacting with the external world of objects and yet does not have capabilities for pictorial representation until symbolic processes, like language, are already well developed.***

When a sensory nerve receptor is exposed to a stimulus of sufficiently greater than its sensitivity threshold of sensitivity, the nerve discharges an electrical signal. It then experiences a refractory period in which it recovers from the discharge. If the stimulus is then still present, it fires again. Hence, a constant

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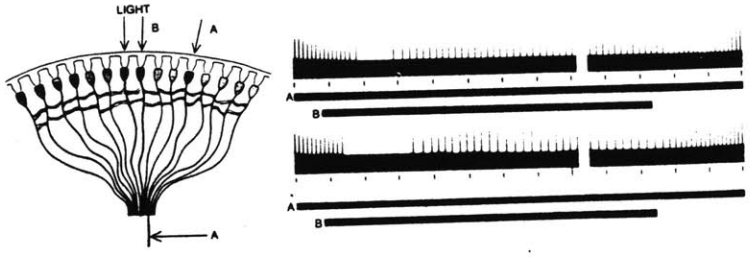
***Piaget,J. (1948), The Child's Conception of Space, W.W. Norton & Company, New York, p.5.
**MacKay, D.M. (1981), "What Does It Mean to Perceive?," lecture, Massachusetts Institute of Technology, Department of Psychology.
* Johansson, Scientific American, Ibid., p. 67.

stimulus is a train of electrical impulses at regular intervals. We can measure this as a standard electrical signal of a given frequency. The discharge rate, and hence, frequency, varies with stimulus intensity.* A stimulus generally activates a great many neurons simultaneously. How many are activated, the type and threshold level, their locations relative to each other and the strength of stimulus on each results in a complex pattern of coded impulse trains to the brain.** Electrical activity exhibiting measurable frequencies and coded patterns is also detectable in the brain, and has been correlated with specific stimuli.***

Fig. 14.1b *Inhibition of receptor, A, steadily exposed to moderate illumination is produced when neighboring receptors, B, are also illuminated. The beginning and the end of the records show the initial and final rate of impulses by A. The solid bars indicate duration of light signals. The upper record shows the effects on A of moderate-intensity illumination of B. The lower record shows the effect on A of high-intensity illumination of B. The stronger the illumination on neighboring receptors, the stronger the inhibitory effect. (Source: Contour and Contrast, by F. Ratliff, in Scientific American, 1972, 226, 93. Copyright © by Scientific American, Inc. All rights reserved.)*



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*M. Zimmermann, "Neurophysiology of Sensory Systems", Fundamentals of Sensory Physiology, pp.31-35.

**Schiffman, H.R. (1976), Sensation and Perception, John Wiley & Sons, New York, pp. 228-229 .

***Ibid., pp. 179-180.

****Ibid., pp.228.

The character of coded patterns resulting from the co-influence of signals from many individual neurons begs comparison to other phenomenon exhibiting interference patterns. It makes sense, suggests Pribram, that we propose to consider the brain by the model of a hologram.* A hologram is the storage mechanism for the interference patterns of light waves. No representational "picture" of the object is recorded, however, light waves passed through the recorded interference pattern will reconstruct the visual form of the original object that caused the disruption. Just so, says Pribram, a stimulus may reactivate the brain storage stytem: networks of nerve circuitry.**

The critical structure of memory would reside then in the various possible interconnections across synapses of varying electrical potentials. A stimulus would re-activate a net of memories. The theory is claimed to explain many unexplained mental and super-mental phenomenon, especially the ideas of synchronicity between people, insights, resonances. It also helps to explain why memory in the damaged brain is not destroyed. If any part of the memory survives damage, it all survives. In a hologram, any small part of the pattern reproduces the whole.***

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*Pribram,K. (1978), "What the Fuss Is All About," Re-Vision, Summer/Fall, pp. 16-18.
**Ibid.
***Ibid.

interdependence of perception and action

> "Strictly speaking, we cannot study man's motor system at the behavioral level in isolation from its associated sensory mechanisms. We can only analyse the behavior of the entire receptor-neural-effector system."*

Proper development of cognitive skills is dependent on perceptions experienced in conjunction with muscular activity. Early experimental work with active and passive kittens exposed to the same visual stimulus (Hein-Held 1963) demonstrated retardation in passive animals with regard to depth discrimination. Eye-hand coordination also requires active learning, and relearning as the young animal grows to adult size. (Hein-Held 1967). **

We know the world by moving within it, not merely by looking at it.

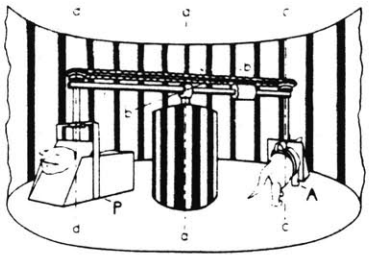

Fig. 19.1 *Carousel apparatus for equating motion and consequent visual feedback for an actively moving (A) and a passively moved (P) kitten. Movements are about the axes labeled a—a, b—b, c—c, and d—d. (Source: Held & Hein, 1963, 56, p. 873.)*

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*Fitts,P.M. (1954), "On Human Performance", J. Exp. Psych 47, pp. 381-91.
**Schiffman, Ibid., pp. 340-351.
*** Ibid.

biology as the basis for all human qualities

> "The major point raised by this experiment (Held-Hein 1967) is that movement per se, in the presence of a stable optical output, is inadequate for normal visual motor development; rather, variation in visual stimulation concurrent with and systematically dependent on self-produced movement is essential for the normal development of visual motor coordination and visually guided spatial activity."*

Piaget believes all cognitive functions including abstract thought and the search for truth and beauty derive from biological mechanisms. No organism is passive relative to the environment but rather actively modify their environments as well as learn from them, modifying their own behavior.

All living organisms have regulatory mechanisms which control "homestasis" or static internal environments and also which maximize the maintenance of healthy life by making adjustments relative to the environment. In higher animals, the nervous system is the organ which regulates both the internal and external processes.**

Intelligence equips human beings with the capabilities for surviving the most hostile environments. Humans build housing, raise food crops, and make plans against disaster. The brain which is responsible for such intelligence has evolved out of the same brain which causes mice to build safe, warm nests. The brain, including all its extensions throughout the body, known collectively as the nervous system, is responsible for monitoring the present condition of the

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* Ibid. p. 31.

**Piaget, J. (1971), Biology and Knowledge, The University of Chicago Press, Chicago, pp. 26-37.

body, anticipating the future condition of the body, and affecting appropriate measures for ensuring continued health and safety of the body.*

> "Cognitive processes seem, then, to be at one and the same time the outcome of organic autoregulation, reflecting its essential mechanisms, and the most highly differentiated organs of this regulation at the core of interactions with the environment, so much so that, in the case of man, these processes are being extended to the universe itself."**

Piaget describes this hypothesis as "banal in the extreme", and suggests that "people have not gone nearly far enough in the consequences that can be derived from it". ***

> " We never cease living in the world of perception, but we go beyond it in critical thought, almost to the point of forgetting the contribution of perception to our idea of truth."****

Culture

The Hindu's describe the perceived world as "Maya", land of illusions. Given the functional limitations of our physiology to interpret the world, we can never be sure that what we think we see is changeless and dependable information. Optical illusions may momentarily confound us in the course of daily life, but their contradictions are revealed by closer examination. Longer term perceptions do not offer us such opportunities.

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*Piaget, Biology & Knowledge pp. 26-37.
** Ibid.,p. 26.
***Ibid., P. 26.
**** Merleau-Ponty, "An unpublished text by Merleau-Ponty: A Prospectus of his work", Primacy of Perception, Northwestern University Press Evanston, 1964.

Clearly differences exist in fulfillment of biological predilictions. Different expectations may influence the interpretation of perceptual information. Cultural background (circles of shared knowledge and history) is surely responsible for tuning the sensitivities of the mental-perceptual system. It may be quite likely that not only do we interpret images differently, but at some more basic level we actually see images differently.

spoken language

After a long study of Native American languages, Benjamin Lee Whorf concluded that one's language was responsible for forming one's view of the cosmos, of all reality, of the relations between all things.* Not only does this go quite beyond superficial difficulties in translations between languages, but in the ultimate impossibility of really seeing eye to eye between two cultures. People are not at all alike, they literally do not see things the same way.

The Hopi have no words to associate institutional function with a specific building such as School, Hospital, City Hall, etc. Any space might house such activity. To a European, the characteristics of the building are necessary for fulfillment of the institutional function. To be forced to hold a function in a space not specifically designed for it is considered a hardship.**

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*Whorf, B.L. (1956), Language, Thought, and Reality, MIT Press, Cambridge, pp. 246-270.

** Ibid., pp. 199-206.

The Hopi have no words for past, present and future in the english sense. The idea of living by a clock is inconceivable and meaningless. Time is dependent on the observer and refers to relative duration of events.*

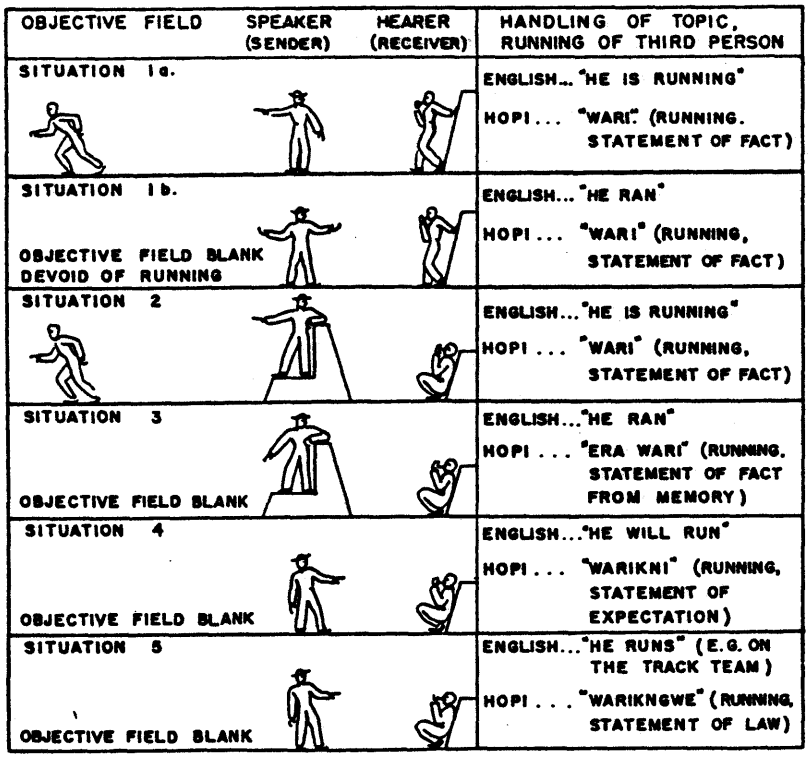

Figure 11. Contrast between a "temporal" language (English) and a "timeless" language (Hopi). What are to English differences of time are to Hopi differences in the kind of validity.

* *

* Ibid., pp. 57-58
** Ibid., pp.213.

Whorf structured his comparative study of languages after linguistic theories of Edward Sapir, a method which attempts to break down language into its structural formulas, from patterning of sounds to the structure of logical propositions and of meaning itself.*

kinesics

Spoken language is only one channel as multichanneled human communication which involves use of all the senses -- sight, sound, smell, touch, taste. Analysis of body motion concurrent with speech might be expected to be governed by complementary linguistic hierarchical structures.**

Popular versions of these studies released under titles of "body language" and coffee table books by Desmond Morris capitalize on the sensationalism and the readily believable, suggesting "read your friend like a book". Illustrations in such books generally show symbolic gestures as they vary between cultures, which are broad categories high up in hierarchies of meaning.*** Such gestures are indeed important as shared language and where they are well known, they may even be substituted for verbal language. However, just as familiar words, such symbols are rich in connotations and inconceivable out of context.****

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*Ibid., pp. 134-159.
** Birdwhistell, R.L. (1970), Kinesics and Context, University of Pennsylvania Press, Philadelphia, pp. 114-120.
***Morris, D. (1977), Manwatching, Harry N. Abrams, New York.
**** Birdwhistel, Ibid., pp. 65-79.

Birdwhistell points out that the military salute can be presented in such limitless form as to be brilliantly applied to express one's attitude towards many varieties of experience. Variation on a shared theme is basic to all communication.*

Grammers and root elements are buried well beneath the level of day to day symbolic use. Such things as rhythm, emphasis, pattern repetition and variation, space utilization** and the like, are more fundamental and determine subsequent interpretation of shared common gestures.***

A critical aspect of all interpersonal communication is apparently "synchronicity" or the tendency to fall into shared patterns during an exchange. Participants modify their own physical behavior, including breathing and other rhythms to match or harmonize with each other.****

These physical manifestations have purposes in the communication of meaning by marking, or qualifying units of meaning. They are employed hierarchically and consistently, certain small marks for words or phrases, larger marks for sentences, still larger for framing a single arguement, again larger to indicate a whole train of thought. Marks may be as small as an eye blink or as large as a major change in posture or literally - a shift in position.#

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* Ibid., pp. 80
** Hall, E.T. (1966), The Hidden Dimension, Doubleday & Company, New York, pp. 123-153.
*** Birdwhistell, Ibid., pp.99-100
**** Scheflen, A.E. (1974), How Behavior Means, Anchor Press/Doubleday, New York, pp. 67-79.
#Ibid., pp.20-34.

Head movements as markers

I'm going to go downtown ..... and then I'm going over to Bill's ....

... Then I'm going home ..... What are you going to do?

Eyelids as markers

... Then I'm going home ..... What are you going to do?

Hand movements as markers

... Then I'm going home ..... What are you going to do?

FIGURE 1-1. Some postural-kinesic markers of American syntactic sentences[2]

[2] The drawings are reproduced from the author's article on posture in communication which appeared in *Psychiatry* 27:316–31 (Nov. 1964). It is reprinted by special permission of the William Alanson White Foundation, Inc. These markers were described to me by Ray L. Birdwhistell.

*

"...for us the body is much more than an instrument or a means; it is our expression in the world, the visible form of our intentions..."**

People come together to engage in common activities. In addition, to the daily routines of meals, maintenance and business, there are social events and holidays, and problems which must be addressed involving many people. Familiar, ritualized routines exist which facilitate activities, so much so that people who have never worked together before can quickly assume appropriate roles. If all members of a group do not share the same understanding of what is required, there is sure to be nothing accomplished except general disruption

* Scheflen, Ibid., pp. 21.
**Merleau-Ponty, Ibid., p.5.

and displeasure until either that person is eliminated or "trained", that is "aculturated" using the term loosely.*

Predictable social behaviors are culturally imposed but may be more deeply rooted in human biology. Predictability of external environment is advantageous to an organism. By being familiar with behavior patterns, it is possible to anticipate consequences of one's actions, and imagine goals and behaviors by which to attain them. Humans, as many other species, are social animals and from early on in human history, smooth coordination of group dynamics was crucial to survival. Human physiology may facilitate such behavior and determine its characteristics.**

Drawing from the insights provided by cybernetics, it is assumed that a system maintains its equilibrium.*** In a system of people, people are subservient to the system which will shelter, provide and otherwise serve them only if the system survives. This is a most abhorrant point to view to most of us. In America, the belief that we direct our own lives is a major argument used against consideration of our imbeddedness in our human environment.

Basic assumptions about individuality, self-determination, objectivity, truth and reason which are characteristics of the European/American myth system and not universal to all peoples.**** Psycho-sciences, for example, examines personal motives of the aberant

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*Bateson, Ibid., pp. 61-72
**Scheflen, Ibid., pp. 193.
*** Weiner, Ibid.,
**** Scheflen, Ibid., pp. 105-106.

individual.*

Experience in couple therapy, family counseling, and social work, revealing that troubled individuals are often manifestations of broader failures within the larger system of which they are merely a cog.**

built environment and instrumentation

The human species has altered the natural environment with agriculture, cities, interstate highways, dams, mines, missile launching sites, sewage treatment plants, suburbs and so forth to facilitate life. We also build equipment which extends the capabilities of our physical bodies by allowing us to move faster, to fly, to see what cannot be seen by the unaided eye.

These alterations or extensions are also as much a part of us as language or biology.# Extensions, such as the telephone, the car, plumbing, knives and forks, vacuum cleaners, wrist watches, luxo-lamps and heating affect how we think. What we build next is dependent on what we think now. The concept of dividing time into precise increments preceeded wristwatches. The evolution of human instrumentation is a slow, self-determining process.

Hall, Ibid.
* Scheflen, Ibid.
** Scheflen, Ibid., pp. 4-5.

Mediums of Recording and Display of 3D Body Motion

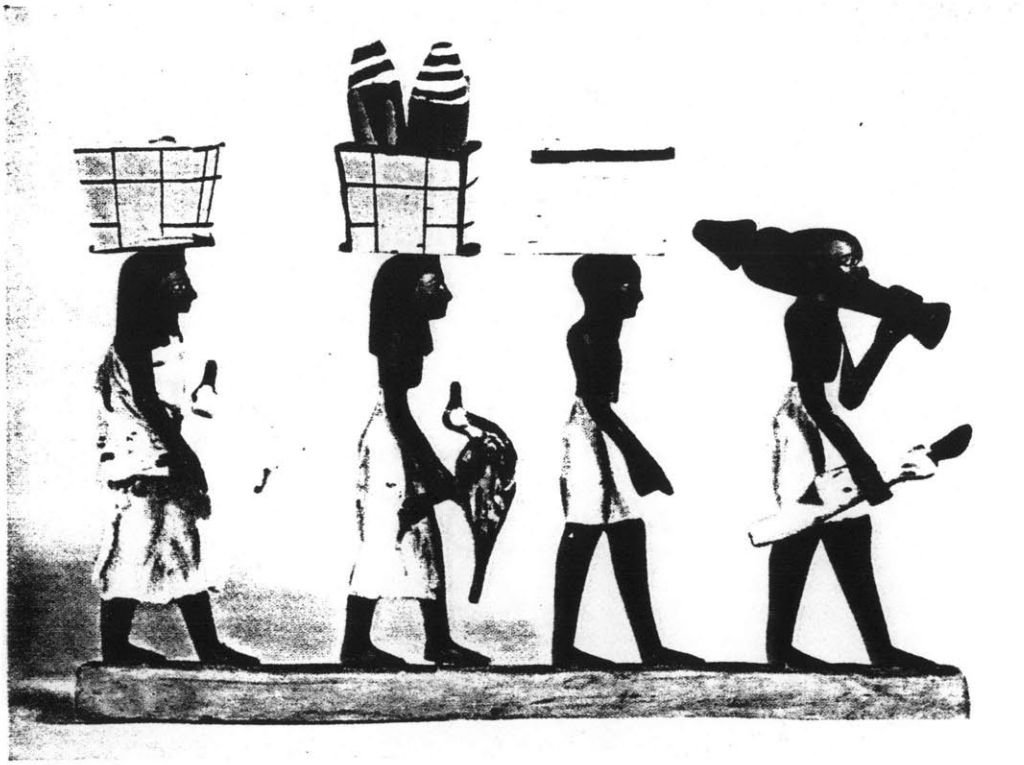
the body

The earliest, most elementary and by far the most effective medium for both observing, analysizing, recording, and display of human body motion is the human body itself.

There have always been individuals who have made a special career out of their abilities to translate and represent body motion. Not only actors and athletes, and their trainers, but teachers of all kinds. A coach or acting instructor uses descriptive language, manipulates the bodies of students, imitates by exaggeration correct and incorrect motions. The coach cannot motivate muscles of another person. Anyone learning new movements must be able to interpret the instructions and allow him/her self to be influenced into

correct imitation.

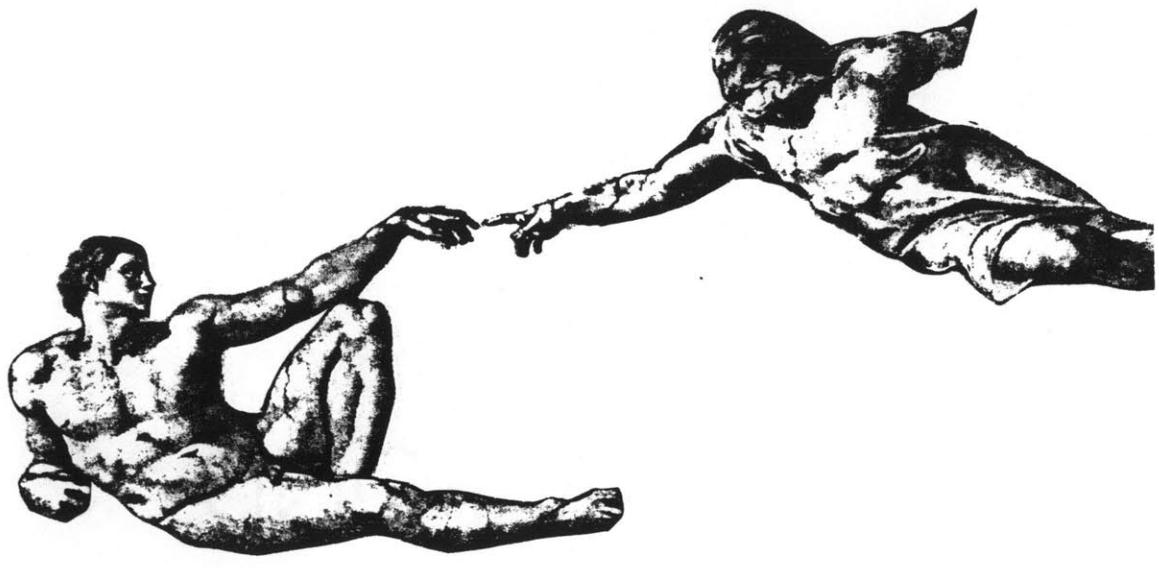
Such a medium is limited to the presence of a particular individual. Despite traditions which pass down methods of playing and teaching through generations, no emulation of an individual style can be an exact replica.



painting and sculpture

Egyptian paintings depict stages of daily work. The same themes are repeated in small sculptures. Bakeries, stables, palaces, libraries, all replicated in detail, show people in the process of doing things. Motions of daily work are represented in the poses of figures engaged in various tasks.

The art of the Greeks, the Romans, the Renaissance exaggerate human form according to anatomical function. The body is engaged in athletic or sensuously physical details of the human form are glorified.



* Michelangelo - The Creation of Adam, detail of the Sistine Ceiling

In the illuminated manuscripts of the early middle ages, human form is a small motif among many other animals and symbols, subservient to a larger pattern or symbol. Humans and animals are shown in postures of combat, biting, eating, and servitude. Among these peoples, humanity serves, or is lost in, a nature greater than itself.

Ancient people were no less interested in motion than ourselves, but we can know their interests only from static forms. Different cultures representations of human form reflect their cosmology, not their skill.

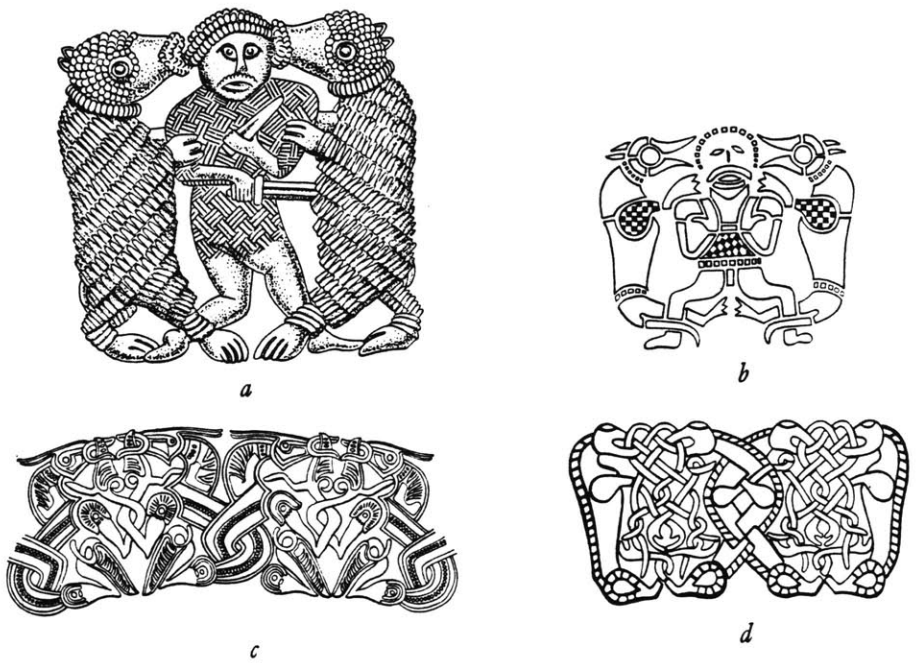
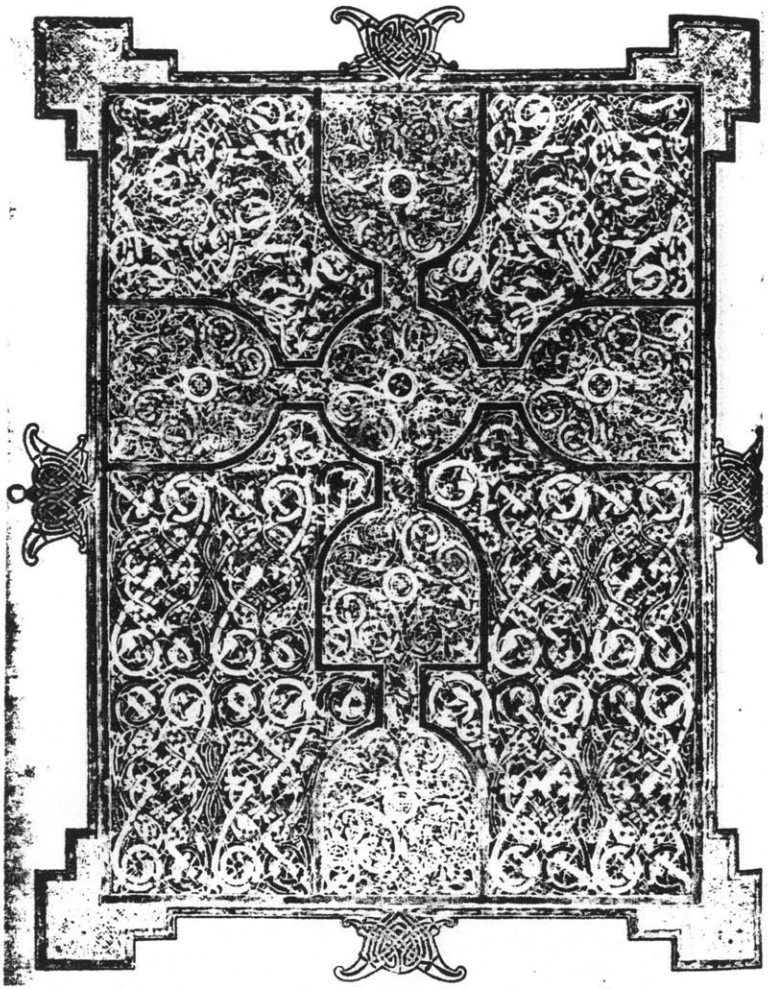


Figure 29. Man and animals motif: (*a*) from Torslunda, (*b*) from the Sutton Hoo purse-lid. (Scales, 1/1.) Linked pairs of confronted animals with interlacing limbs: (*c*) from the shield-boss, (*d*) from the purse-lid. (Scales, (*c*) approx. 2/3, (*d*) 1/1.)



Cross Page, from the *Lindisfarne Gospels.*
c. 700 A.D. British Museum, London

Detail of figure upper right corner

movement notation

Exact specification of a sequence of human motion is a complicated problem. Movement "exists in space as well as time and the body itself is capable of so many simultaneous modes of action."* Some characteristics of motion which one might want to describe accurately are:

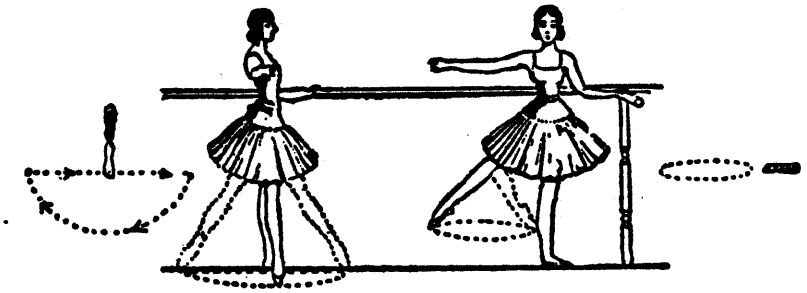
1. what is the end position of a moving body or body part?
2. what is the path of motion between one position and the next?
3. what happens anatomically in the joints and muscles during motion?
4. what is the visual design or appearance of a motion?
5. what is the purpose of the motion (as for instance -- to pick up and carry something).
6. what happens to the center of weight or balance?
7. what is the quality of movement, is it fast or changing in rate?
8. what is the rhythmic pattern or timing?
9. what are the relationships of moving parts to the room, direction of motion, and to the body itself?**

Hutchinson describes three ways these aspects of movement might be described. It could be described thematically, pinpointing the "motivation,...idea, aim or intention." This approach is commonly

*Hutchinson,A. (1954), Labanotation , Theatre Arts Book, New York. PP.1.

** Ibid., pp. 15-16.

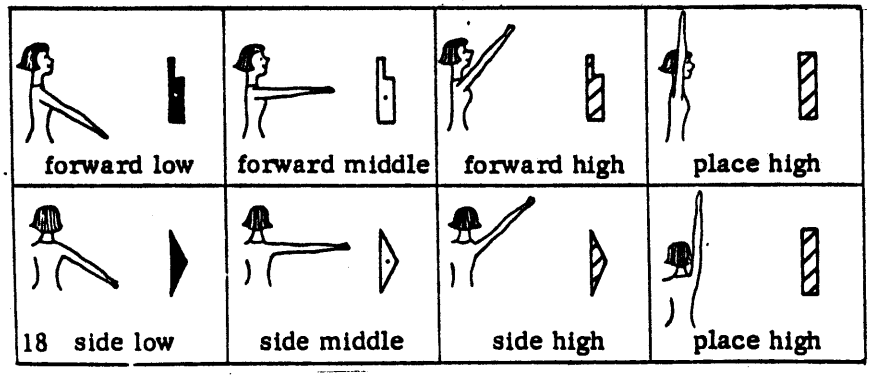
employed in teaching performance.* An actor might be instructed to walk like an old person, or to move anxiously. The effort-shape could be described, that is, the line of the movement of expression.** This is the way we might conceptualize the "line" of a tennis stroke.



23. Rond de jambe par terre and en l'air

***

A structural description would describe change in the orientation of the body segments as a function of space, time, dynamics, body mechanics. Labanotation, a dance notation system promoted by Hutchinson, emphasizes structural description for reasons of precision.****



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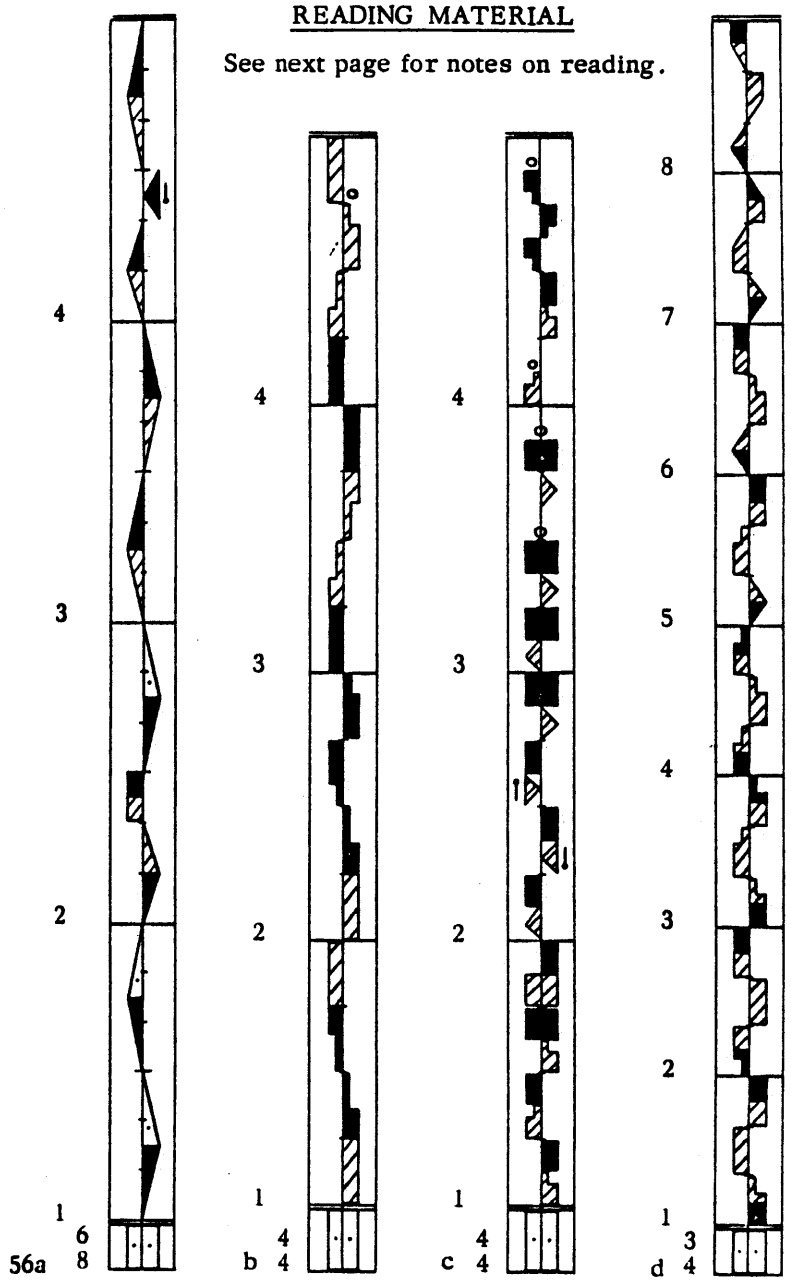
*Ibid., pp. 11-12.
**Ibid.
***Vaganova,A., (1946), Basic Principles of Classical Ballet, Dover Publications, New York. pp. 40.
****Hutchinson, Ibid., p. 12

READING MATERIAL

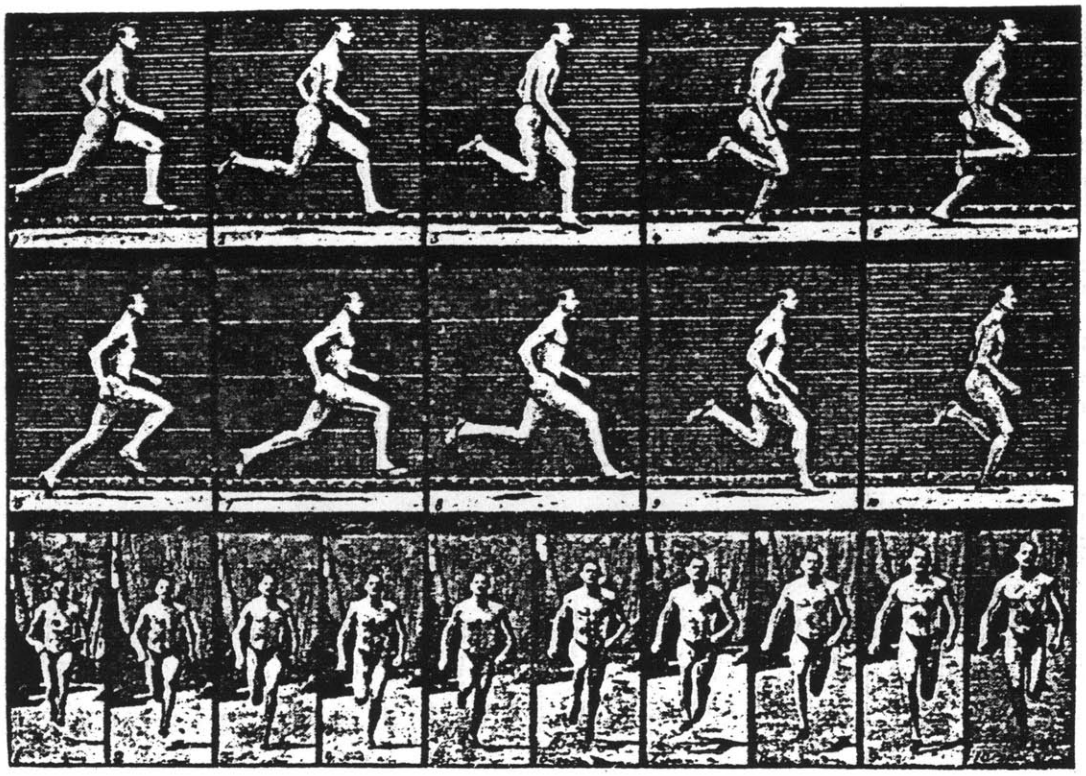
See next page for notes on reading.



* Hutchinson, Ibid., pp. 57.

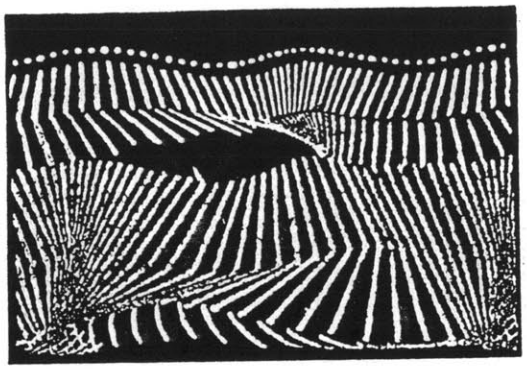
photography

Freezing time-dependent events in a static form wholly dependent on light and lens, photography practically eliminates human bias in the image-making process. Aspects of human life revealed by Cartier-Bresson or Robert Frank are different from what was revealed by the slow process of painting.



*Muybridge, E., (1955), The Human Figure in Motion, Dover Publication, New York.

From its earliest availability, photography was used as a tool for the scientific analysis of motion. Sequential photographs, such as were made by Muybridge, in the late 1800s are a convenient form for making measurements of the phases of human and animal movements. At the same time, Marey in France and Braune and Fisher in Germany were reducing visual information to the lines made by the motion of joints. Marey achieved this by dressing his subjects in black, taping bright lines along limbs and making multiple exposures during the course of a movement on a single photographic plate. Braune and Fusher illiminated joints alone with lamps that flickered to create similar time sampling during a single long time exposure.*



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*Bernstein,N. (1967), The Co-ordination and Regulation of Movements, Pergamon Press, Oxford, pp. 1-3.

**One of Marey's subjects and the resultant image. Movement is from left to right. The frequency is about 20 exposures per second.

In Russia, early in this century, Bernstein expanded on this technique by illuminating joints and recording on a single plate lines of motion broken by a rotating shutter whose variable speed was precisely known. Dissatisfied by the lack of depth information, Bernstein utilized mirrors to record two views of the subject for viewing stereoscopically..

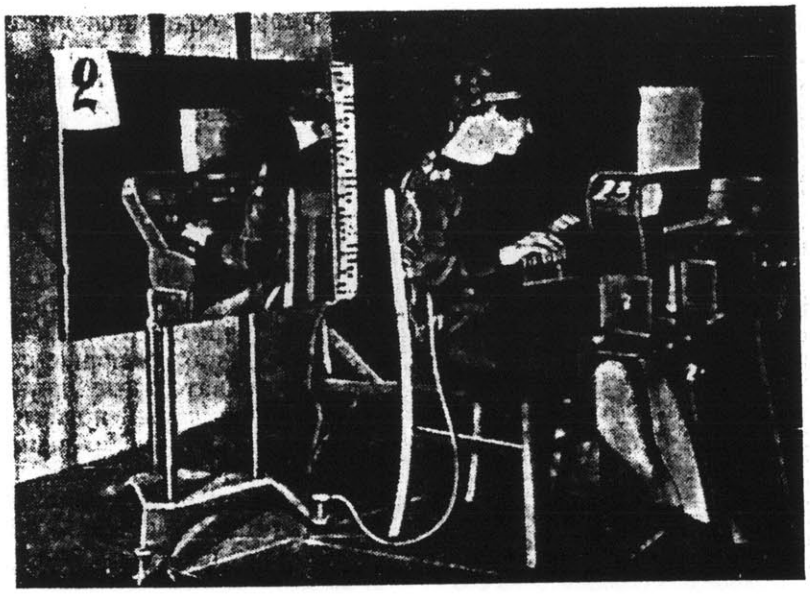

FIG. 10. Apparatus for mirror kymocyclography. The subject is operating a Powers perforator. On the left we have a mirror with a scale and the serial number (1929).

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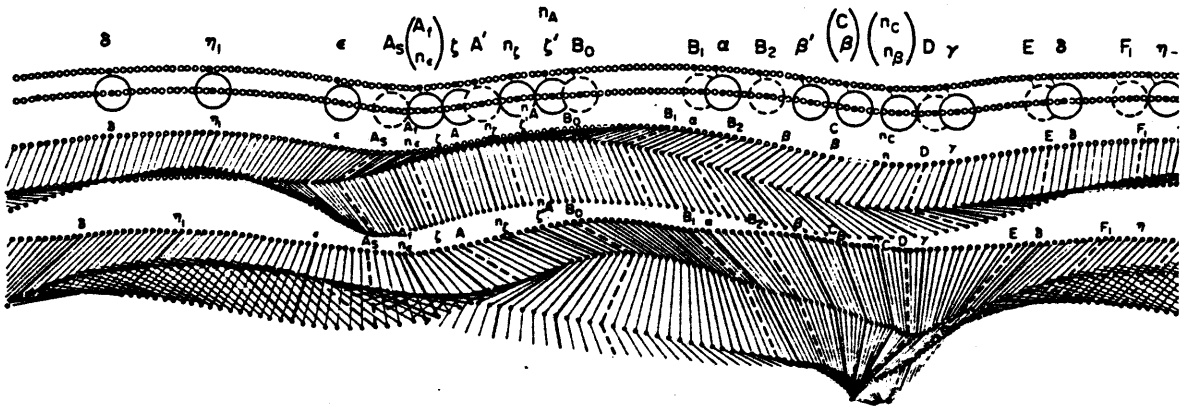
* Bernstein, Ibid., pp.12.



. Successive positions of the right side of T. Ladoumeg's body, taken at a frequency of 187/sec in experiment Heavy lines mark phases of the movement corresponding to characteristic dynamic phenomena. Continuous heavy lines indicate longitudinal dynamic elements. Heavy dotted lines indicate vertical elements.

Bernstein, Ibid., pp.84.

Ultimately Bernstein was most interested in discovering how the brain coordinated the complex activities necessary for smoothly integrated motion. He was convinced that the brain could not be organized to control individual parts of anatomy separately, but according to the patterns of movements.*

"...there exists in the central nervous system exact formulae of movement...or their engrams, and that these formulae or engrams contain in some form of brain trace the whole process of movement in its entire course in time.... The existence of such engrams is proved...by the very fact of the existence of habits of movement... If a guiding engram of this type exists (we refer to it as the motor image of a movement) it must have a dual nature; it must contain within itself...the entire scheme of the movement as it is expanded in time. It must also guarantee the order and the rhythm of the realization of this scheme..." **

Bernstein is utilizing the medium of still photography and he is looking at the movement of human anatomy, but in an entirely different way than the pictorial photographer. He is looking for clues as to the way the mind thinks of movement. Lines of displacement of limbs engaged in habitual tasks reveal repetitions of shape and timing varied slightly in response to changing conditions in the physical world. This, I suggest, has more to do

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*Bernstein, Ibid., pp. 21-51.
** Bernstein, Ibid., pp. 37-39.

with what human motion is about than more familiar pictorial representation. Further, referring back to studies of human perception of human motion, I believe this is also important to human visual perception of human motion.

Edgerton developed tools and methodology for accurate time sampling of motion phenomenon. Motion must first be made visible to photographic emulsions. This is not a trivial point. Sampling rate and duration of exposure, synchronization of exposures and movement event, enhancement of contrast and reduction of distracting detail, focal length and point of view, are critical issues which must be carefully addressed.

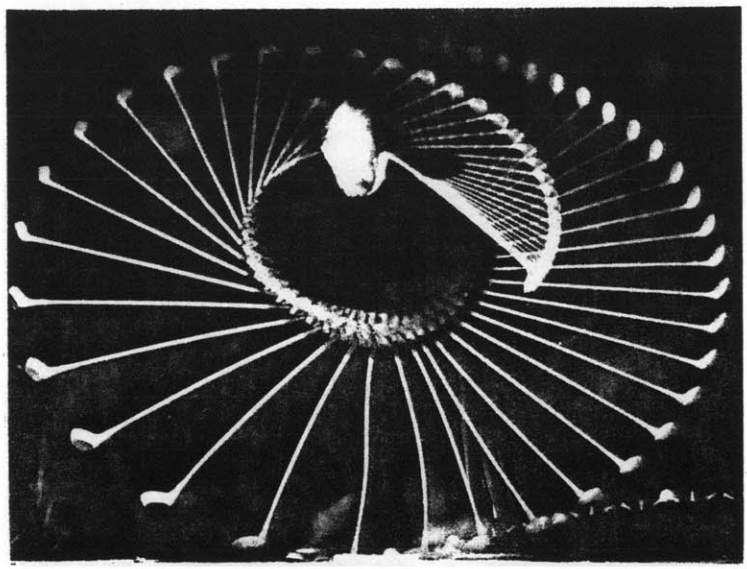


Fig. 9-37 *A golf drive at a 120-sec rate. Note that the club hit the ground before it hit the ball. The camera is on the floor for a low-angle view and the golfer is wrapped with black velvet material so that his picture does not confuse the golf club pattern.*

Edgerton, E.H., (1979), Electronic Flash, Strobe, MIT Press, Cambridge. pp. 214.

By making this technique widely available, Edgerton has made images of high speed motion commonplace in journalism as well as in scientific and declinical applications. Such images are characterised by minimal blur that allows us to see great detail not ordinarily visible to our eyes.

Fig. 6-6 ***Photograph of William Fritz, Charles Beetham, and Charles Quigley taken at the BAA track meet in the Boston Garden.*** **(Photograph by Bill Jones of the *Boston American.*)**

*

Edgerton, Ibid., pp. 110.

Film and Video

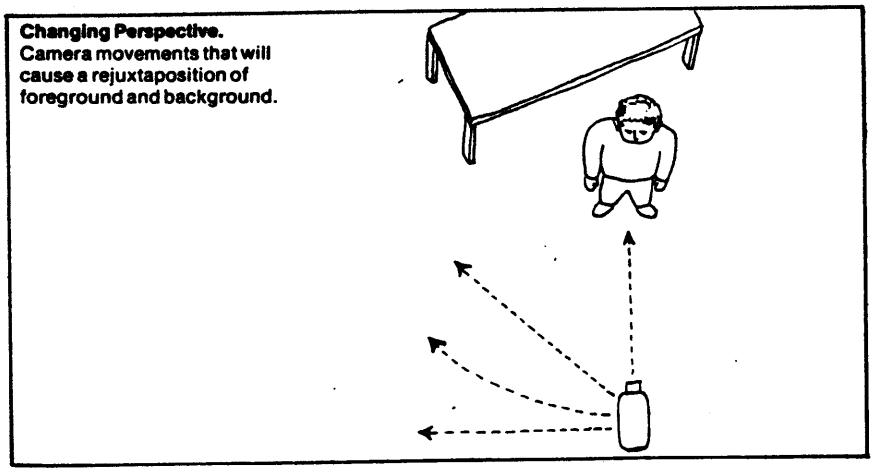
technical considerations

Film and video share certain fundamental technical constraints although their technologies vary greatly.

1. They are both sensitive to light in the visible range.
2. Both are limited to a static, rectangular, flat screen.
3. Both sample time at a rate just high enough to deceive human perception.

They are also utilized in similar ways as storytelling mediums which represent human activity by selective framing, point of view and by breaking down duration and sequence of time. This is accomplished by camera position and motion, lens, and editing.

> "When the camera itself moves through the subject, depth and and fluidity are imparted to the shot."*



*Pincus,E. (1969), Guide to Filmmaking, New American Library, NY. pp. 70.

Translating dance to the screen raises special problems. Gene Kelly developed guidelines to enhance the illusion of depth in a flat medium, by emphasizing motions towards the camera, and by using many vertical elements in the background to exaggerate the impression of side-wise motion.*

The illusion that the dance is continuous is made so pervasive that you have to strain your eyes to notice the editing. The camera itself was choreographed in long, fluid motions which were not strictly dependent on the sequence and timing of the music, nor did they precisely correspond to the dance.**

> "Film time and space are created in the editing room...the sequence of events as they happen in real life or as they are acted out is not necessarily the way those events will appear on film."***

The continuity of editing in Gene Kelly movies is carefully contrived by cutting from one shot to the next on the motion of the actor. The attention of the audience is drawn to physical motion, particularly if it is a definitive gesture. If the gesture is continued in the next shot, the audience interprets the scene as seamless.#

What is more extraordinary, and has become a fundamental characteristic of all filmmaking, is that the audience will accept a sequence of different shots having occurred in the same time

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#Pincus, Ibid., pp. 124.
* from a New York Times article on Gene Kelly after the movie "Xanadu" was released.
** from Rachel Strickland's course "Film and Space", spring 1981.
***Ibid, Pincus, pp. 65.

and space.*

> "The most-often cited example of this, an example that teaches us much about film acting, comes from the Russians. We have one shot of an actor which lasts several seconds. We divide the shot into two parts alternately placing a shot (i.e., cutting in a shot) of a bowl of soup, a girl who is in pain, and a gun. When the sequences were shown to Russian film students, they all remarked on the fine acting...how in the first shot he looked hungry, in the next pitying, and the last afraid. Yet he had the same expression on his face in all three cases."**

The three shot sequence which this exemplifies is basic to film editing. First we see someone looking, second we see what they are looking at, third we see the person's reaction.*** Becuase the human mind is capable of making these assumptions, film, and video, are good mediums for story-telling.

> "The Americans were the first to discover in the filmplay the presence of peculiar possibilities of its own. It was perceived that the film can not only make a simple record of the events passing before the lens but that it is in a position to reproduce them upon the screen by special methods, proper only to itself."#

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* Pincus, Ibid., pp. 120
** Ibid.,pp.120
***Ibid., pp. 120
#Pudovkin, V.I., (1949), Film Technique and Film Acting, Vision Press/ Wehman Bros., Hackensack, pp. 229-258.

Nick Fury, Agent of S.H.I.E.L.D. A beautiful story board, edited by Stan Lee, written and illustrated by Jim Steranko and inked by Joe Sinnott, from Vol 1, No 1 of the comic book.

Fear not. Nick wasn't offed — it's his robot Doppelganger lying there in the last panel (Marvel Comics Group)

This storyboard illustrates film storytelling through edited shots of varying camera orientation.

film-acting

Story-telling has been a tradition of actors. Actors are trained to utilize the body as the medium by which to imitate or exaggerate the physical behaviors of a character not their own. Acting fails if it relies on spoken language alone. Body language in particular must be utilized with its local or foreign characteristics as might apply to the character, and also to the interpretation by audiences of different cultural backgrounds. To be realistic and not mechanical in movement, the actor must select behaviors that will not be too unnatural to his personal ways of moving, though they may be atypical of daily habit.

> "The image that has to be worked out is conditioned not only by the intention of the play as a whole, but also by the nature of the actor's self...The final object is to convey to the spectator a real person, or at least a person who could conceivably exist in reality...expressed not by a set of words, gestures, and intonations dictated by formula or whimsy and mechanically repeated, but as a result of the subjugation and re-expression of the actor's own living individuality."*

*Pudovkin, Ibid., pp. 240-242.

Film-acting is different from acting in the theatre on several counts. The final creation of the story at the editing table creates difficulty for the actor to maintain cohesiveness and believable motivation in the performance of his role.*

> "Actors...hold that they lose every possibility of feeling the unity of the image, every possibility of preserving during the process of shooting a sense of live continuous individuality, owing to the fact that they act the end of their role to-day, the beginning to-morrow, and the middle the day after. The various bits are tangled, they are terribly short; from time to time somebody photographs a glance that relates to something the actor will be doing a month hence when somebody else has photographed a hand movement that has to do with the glance.**

Actors on a stage remain uniformly distant from the audience, but in film they often play in intimate proximity with the camera, a facial expression or minute gesture may fill our entire field of view.

> "(the stage actor)...learns, in short, to move and speak in such a way that he can be seen and heard distinctly from the last row in the gallery. But the broader an acting gesture, the less it can be shaded."***

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* Pudovkin, Ibid., pp. 243.
** Ibid., pp. 251.
***Ibid., pp.232-233.

> "On the screen we have long-shots and close-ups. Therefore the actor must exactly adapt his behaviour in front of the camera to the requirements of these various camera-angles."*

This is not only a matter of legibility over variable distances, but effects how the audience subjectively interprets the apparent physical presence of the actor.

The distance between people is a function of social rapport** and movies can utilize camera distance as a variable reference. Secrecy or sexual intimacy can be implied by the extreme closeup. Potentially dangerous situations become alarming when they are within the distance from which we might not be able to escape them. There are different culturally shared social behaviors expected at every given distance between people.*** The physical motion of the actor relative to the framing of the camera might vary accordingly. A good director must take all these elements into account.

> "As an example, the trial scene in Griffith's Intolerance. Here is a scene in which a woman hears the death sentence passed on her husband, who is innocent of the crime. The director shows the face of the woman: an anxious, trembling smile through tears. Suddenly the spectator sees for an instant her hands, only her hands, the fingers convulsively gripping the skin. This is one of the most powerful moments in the film.... Not for a minute did we see the whole figure, but only the face, and the hands."

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* Pudovkin, Ibid., pp. 255-256.
** Hall, Ibid.
*** Ibid.,
**** Pudovkin, Ibid., pp. 93.

filming "real life"

Similar technical and subjective issues face the documentary filmmaker. By the elimination of actors and other constructed artiface, events in the real world signify themselves. A documentary must be constructed from shots of events selected from all which goes on in the world. It becomes important to be able to identify what is important to shoot, and how to shoot it.

> "(Dziga Vertov) wrote of his cinema as being a branch of science and of each film as an experiment... 'To combine science with cinematic depiction in the struggle to reveal truth..to decipher reality'"*

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*Mamber, S. (1974), Cinema Verite in America, MIT Press, Cambridge, pp.6.

"' A story must come out of the life of a people'" *
-Robert Flaherty

Richard Leacock's films reveal his personal concern with daily ritual and his fascination for the infinite variety in the performance of similar tasks. In recent years he has been rather mesmorized by snapshots and super eight films of such activities, such as how different people eat their breakfast eggs, wash their hands, express enthusiasm, exhibit foibles.

He has often employed the empathy of a third person, enlisting a woman filmmaker to serve as the object of address for a female subject, and allowing some trivial conversation to proceed until a profound confession slips, or an astonishing character revelation is evoked by the mere circumstance of the presentation no matter how mundane the topic.

* Mamber, Ibid., p.10

In order to facilitate this kind of filmmaking, Leacock was instrumental in the development of portable sync sound technology.

Leacock's techniques are masterful, but they prove difficult to emulate, or to learn. His personal charm and ability to provide reassurance obviously have an enormous influence on his subjects.

> "One of the things that distorts things the most is that people usually are basically trying to please us. So they tend to do what they think you want them to do, which is why you have to do a great deal of not filming, because you have to wait until they get that out of their systems. And if you don't film and don't film and don't film, then they finally say, "Oh, screw this idiot. He doesn't know what he wants anyway." And they go back to doing what they have to do."*

> "We (Leacock and Sarah Hudson, who took sound) became members of the household. We spent a lot of time going swimming and listening to music, eating together and enjoying each other, and to heck with cameras. We became an accepted part, an enjoyed part, of the scene we were invading. We were not people who were aggressively tring to get something out of him. Filming, in a sense, almost became secondary, which resulted in a very different level of intimacy than you normally get. Often this tends to sound arrogant, but it's terribly important and seldom understood. If you come barging into a room, I don't care what's going on, and you behave like technicians, a lot of people retreat. These technicians like to be festooned with braces and supports and look like sort of a zombie. They really do. A lot of people hide behind this. And I'd rather not have a camera at all. Just be there."**

Dependent on the personal qualities and insight of the filmmaker, and on the response of subjects to the filmmaker, it is evident that film cannot be an unbiased record. This is in accordance with assumptions of relativity from cybernetics as well as behavioral

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* Mamber, Ibid., pp. 197.
** Ibid., pp. 201.

sciences mentioned earlier.

Nobody has stated this contradiction more clearly than Margaret Mead, although nobody has been a stronger advocate for film as a tool in anthropology. "All films are propaganda, all my life I have made propaganda." "Fact", she said, was dearly beloved by Americans as a measure of truth, however the "facts" often do not tell the truth, and explanation of the "truth" may distort the facts.*

Bathing Babies in Three Cultures is a film Mead made for the armed forces during WWII for use in familiarizing recruits with foreign customs. However, without a full understanding of the life styles and value systems of foreign peoples, it is easy to interpret the American example as "the most civilized". The mothers from Bali and New Guinea appear inconsiderate to their children, to whom they attend in concert with other daily chores. It is difficult to perceive that these children quickly become full participants in society, living harmoniously in crowded living conditions, while the American child (in Mead's film) treated like a king, will continue to be sèlf-centered all his life, and his mother cannot have a life independent of her child.

This is an example of unconscious, uncontrolled, cultural associations of human actions with their greater meanings as social behaviors. A filmmaker must be aware of potential misreadings. It

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* Margaret Mead, at the Margaret Mead Anthropological Film Festival, American Museum of Natural History, New York, Fall 1979.

may be possible to construct a "false" picture to make a "true" statement in the eyes of the film's beholders. This brings us back to storytelling.

Jean Rouch, the anthropological filmmaker reknowned for his films on the life of the Dogon people of Africa, is also concerned with daily ritual and its greater meaning. To create film documents , Rouch works together with his subjects to decide what should be shown, and how it should be shown. He has known his subjects by living among them for many years. It is a great challenge to discover if a single film might reveal truth to audiences of two disparate culture, but it is preferable to conceding to the misinterpretation which is now rampant in both directions.*

He comments that every tiny village in Africa has a movie projector and ready access to American films, particularly films of the 50's starring Doris Day. These they interpret according to their own system of social behaviors. These films have more political impact than the discourse between diplomats.** Rouch looks forward to the day when Africa produces filmmakers and anthropologists who will comment on western culture in African terms, for then we will have a mirror in which we will not recognize ourselves.

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* Jean Rouch at lectures locally at M.I.T. Film/Video, and at U.F.S.C. Summer Institute, various years.

** Rouch, locally

acting in real life

Every human individual is an actor in the world, playing various roles in public, private and professional life which are variations on culturally shared themes. Some of these themes are developed by feature film actors to significant iconic proportions, and re-shared with the public from which they originated. Such a theme is embodied in John Wayne, for instance. An actor carrying such a theme never wholly shedds it as a private citizen but is always "on stage". Americans overseas who share some aspect of the John Wayne image may become it to foreigners who know it only from films.*

This role in particular was discussed by Goddard in his film Letter to Jane . The American look of concern" is evidenced by Jane Fonda and others when they encounter phenomenon outside their comprehension. Another film dealing with the confusion of public and private roles is Jane by Drew Associates focuses again on Fonda, this time in a documentary.

> "Continually present is the obvious contrast between her on-stage acting style and her off-stage manner. We must, then, consider the possibility of an on-camera and off-camera difference... Jane Fonda was interviewed a year after the film was made, and she said:
>
> Jane was a nightmare because I was filmed rehearsing and acting, and there were moments when I didn't know when I was acting and when I wasn't. There was the camera all the time, from start to finish; it was very strange. It was only when I saw the film, a good time after, that I understood what I hadn't

*Midge McKensie at University Film Study Center, Summer Institute at Hampshire College, Summer 1977.

realized during the experience. The film was truer than the experience itself...My terms with the play were false and ambiguous. Thus on the whole, in a sense, this film was a false thing about a false thing, and it is that which was true...I learned many things as an actress from this film. I saw that the best way to make something happen is to do nothing (my italics.)*

Crisis: Behind a Presidential Commitment. Burke Marshall, Robert Kennedy, and John F. Kennedy.

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* Mamber, Ibid., pp. 90-91
** Ibid., pp. 109.

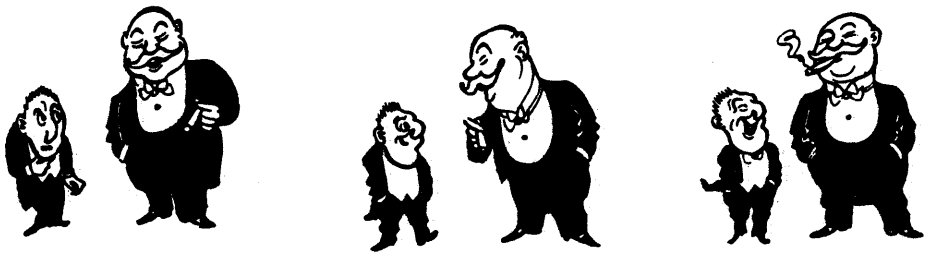
Fonda, as a professional actress, can consciously confront ambiguity of roles with its attendent ambiguity of personal identity. We all play a multiplicity of roles throughout our lives.*

The dilemmas resulting from multiple roles have long been the subject of fiction, and of some narrative film as well. One of the interests of documentaries is the possibility of seeing "how things really are" rather than how things seem from "the outside". This might be interpreted as revealing private roles usually hidden from a public audience. I am interested to discover means to reveal to an individual his/her roles, or self-images.

instruction of foreign languages

I was delighted to discover some unedited videotape shot recently by Midge Mackensie of Harvard French Professor Wylie. Professor Wylie's teaching techniques involve the whole body. From his own training in mime he has developed exercises for his students to move like French people. He uses videotape as a tool for improving self awareness and breaking down self-consciousness, sometimes isolating body parts, omitting the face, or closing in on the mouth to provide a mirror which effaces the individual enough to prevent embarassment. He stresses that people of any culture have distinctive ways of thinking and moving. Language students can benefit by aping the cultural mannerisms. For Prof. Wylie, video has made a substantive difference in both the method and content of teaching.

* Hall, Ibid.



animation

Caricature is as old as humanity. Exaggeration of gestural mannerisms seems to be more readily understood intuitively than photographic images.*

Walt Disney and other motion picture animators have investigated the limits of simplifying and abstracting biological motion. In order to save labor, animation techniques have significantly reduced the number of "in-betweens" drawn, and the number of body parts permitted motion. Even the sparest representations of motion seem to provide acceptable facsimiles.

Much work is currently being done in computer graphics animation to upgrade "in-betweening" by utilizing the computer to average between end-points, and produce in-between frames. There are definite limits to what appears biologically normal. Biologically based motion transforms for various body parts might conceivably be more life like.

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* This was discussed by Becky Allen in her masters thesis (M.S. unspecified, M.I.T., 1980 or 81) and in personal discussion

talking masks

Data on computational theories for biological motion perception, and minimum requirements for believability in "in-betweening", would significantly aid the "Talking Head" project which is now under development at the Architecture Machine. This project looks forward to transmitting computer automated masks of important officials or corporate executives on narrow-band communication channels.

The obvious implications is that our machines and routine business functions whould become more anthropomorphic. Based on presumptions of how the english language functions, this research seeks to codify kinesics and natural language by constructing a limited facial gesture vocabulary. Much of the work is intended for international applications, and I am curious whether a controlled kinesic vocabulary will reduce or increase misinterpretation of meaning. The implications for overt or subtle charicature raises questions of the necessity for interactive manipulation of the mask by the senders.**

** Students involved with this project include: Bill Parker, Susan Brennan, Steve Gano, Howard Eglostein, Peggy Weil

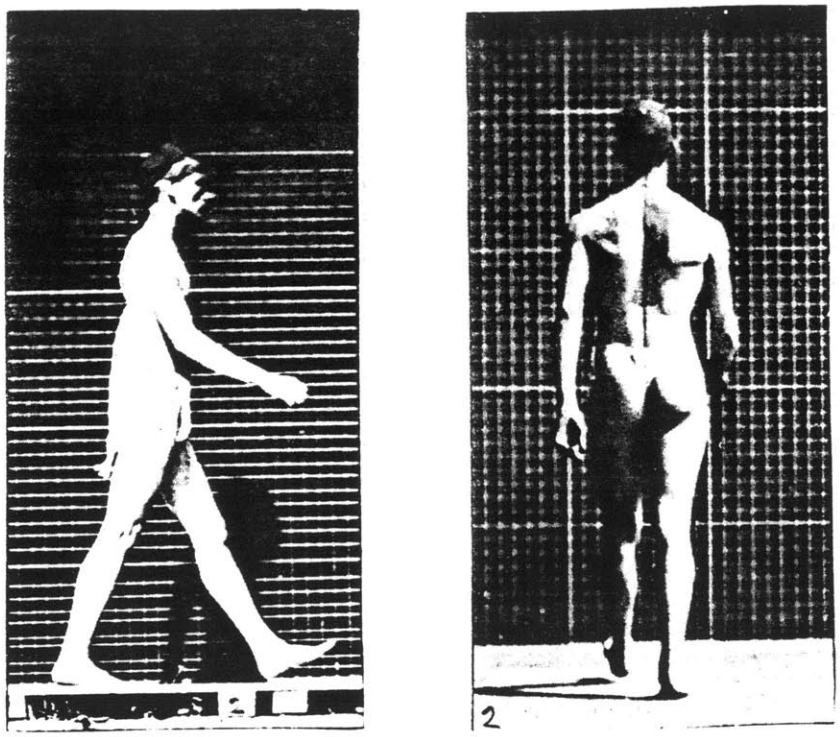
Three Dimensional Imaging Strategies

New visualization techniques are continually being developed in hard sciences and applied technologies. It is the intent of science and technology to come to terms with a universe of three-dimensional time-dependent phenomenon. The problems of data collection, analysis and display of such phenomenom are absolutely critical to the progress of research and development. Efforts to understand human physical nature have led to the development of a number of new visualization techniques for observing human motion.

muybridge updated

Science and technology require quantifiable data (numerical measurements), which can be accurately compared. Muybridge and Marey were making measurements off sequential images of known time intervals, exposures and distances. (Notice the grid in Muybridge photo background). By looking at front and side views, they were able to get some sense of three dimensionality.*

*Bernstein, Ibid., pp. 1-14.



Analysis is improved by high speed cameras providing sampling rates of 200 to 400 stills/second with little blur and accurate registration. Correlation between views is now practical by utilizing a computer. The basic method involves projecting single frames of film footage onto a tablet or grided screen. Two dimensional joint locations are input to the computer by hand using a light pen or similar device. By comparison of simultaneous views of the same points in space, such as horizental and vertical position in one picture (x,y), and depth and vertical in the second (z,y), simple geometry allows location in three dimensional space to be identified (x,y,z). This would be very tedious mathematics to do by

hand. Computer filtering and averaging corrects for human or other error in data collection, and provides for mathematical analysis and display. This method is in common use in many bio-mechanics laboratories throughout the world.* #

more tricks with lights

This is another new wrinkle on an old approach. Marey, Braune and Fisher, and Bernstein, mentioned earlier, all used lights mounted on their subjects to reduce information about gait to essential mechanical components.**

The Human Mobility Lab at M.I.T. utilizes the "Selspot" system. "Selspot" tracks a sequenced series of up to 30 infrared LEDs detected by two special cameras sensitive only to the infrared emitted by the LEDs. The cameras yeild not a picture, but an instanteous "x" and "y" location at up to 315 hertz with resolution of one part in a thousand.***

Unfortunately, the Selspot requires interface to one's own general purpose computer, and success varies. The data is noisy and cannot adequately be used real-time, but must be heavily filtered. Also, there is a limit on the segment of time which can

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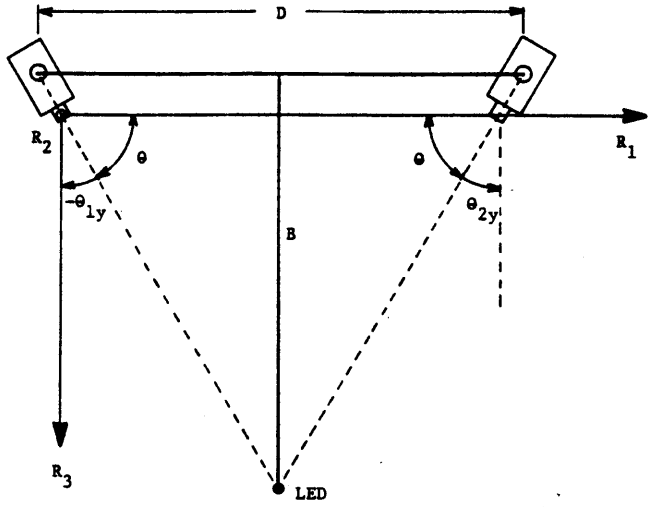
* July 9-12, 1981 author visited Coto da Caza Research Center in Trabuco Canyon, CA. This film analysis method was demonstrated.
# Conati, Ibid., pp. 19.
** Antonsson, E.K. (1978), "The Derivation and Implementation of a Dynamic Three-Dimensional Linkage Analysis Technique," S.M. Thesis, Massachusetts Institute of Technology, pp. 11-12.
*** Ibid, pp. 12-14



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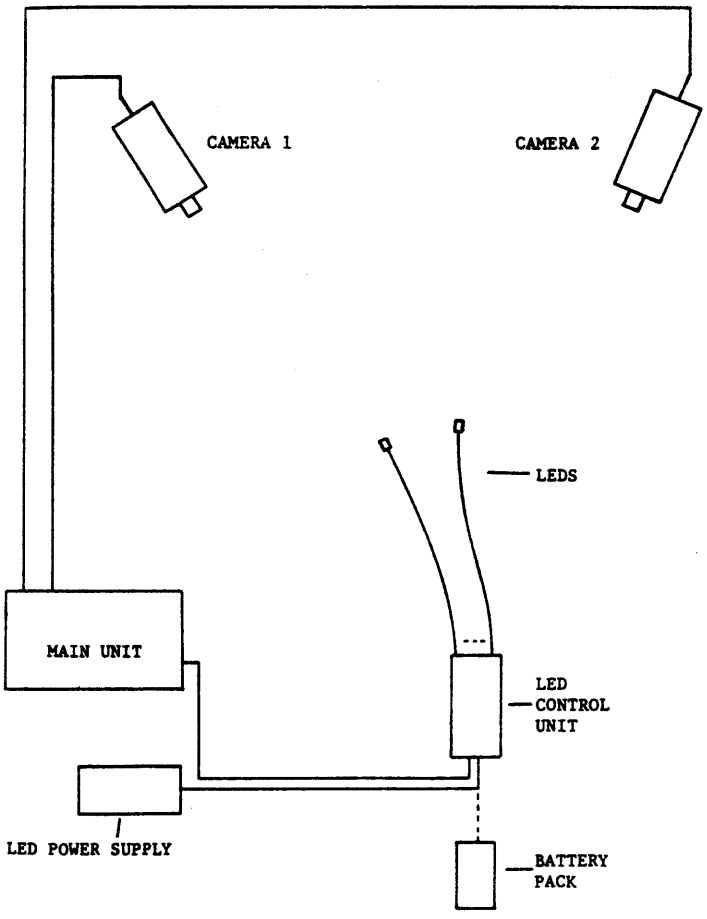


**

Conati, Ibid. pp.26
Ibid, pp. 115

be observed which depends on the size of the computer.*

Tools for kinematic study remain rudimentary and difficult, and have slowed the progress of research.

> "The lack of reliable and complete quantitative information is a serious impediment to human-related biomedical research. As an example in the area of human gait research and analysis, one finds a dearth of complete three-dimensional kinematic data for the lower torso. Instead, studies are invariably limited to planar analyses or are observations of only a few body segemnts."**

a magnetic real-time tracking system

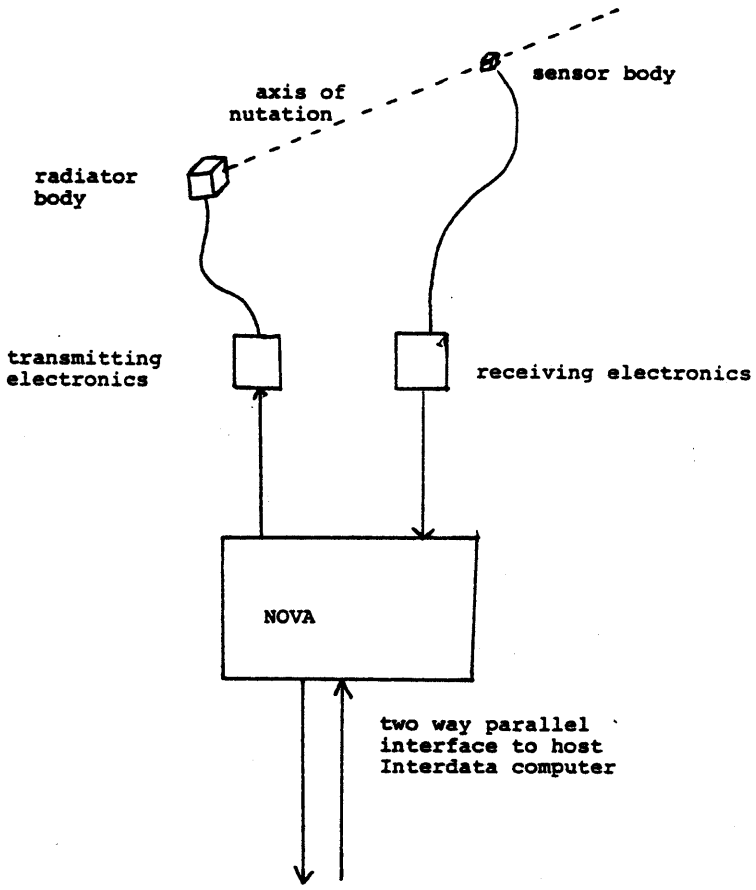
Research applications require high resolution data at a high sampling rate which can be analysized after the fact. Military, industrial, and clinical applications require real time localization of spatial position.

A system developed by Polhemus Navigational Sciences detects the position and orientation of a sensor within an electromagnetic field. Two three-axis magnetic coils serve as sensor and receiver to deliver "x", "y," "z" and 3 euler angles at 40 points/second in a four foot radius hemisphere relative to the receiver. Greater distances are possible with increase in size and decrease in resolution. Freedom of movement is limited by cable connection between the computer and sensor. Accuracy is reduced in scattering from metal surfaces, but is unaffected by obstruction by the users body.#

* from the authors observation of the experience of Coto Da Caza Research Center utilization of the Selspot as demonstrated by Gideon Ariel, and the system at the Mobility Lab.

** Conati, Ibid., pp. 12

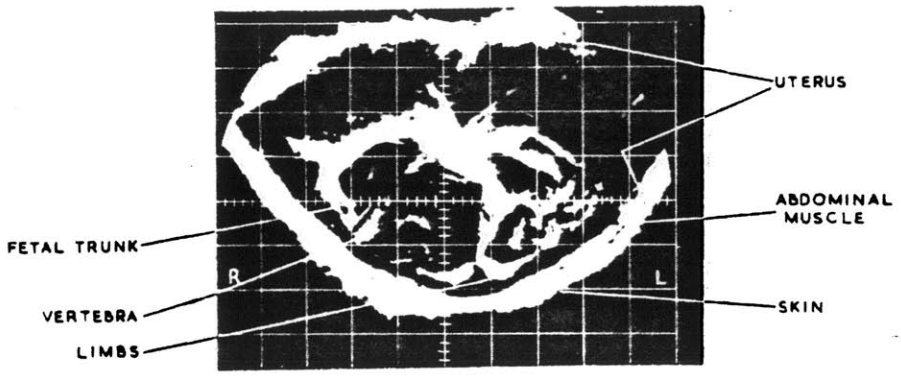
Schmadt, pp. 7-9 Ibid., and visit to Polhemus by the author September 10th, 1981 reveals the newer system runs at 60 points per second.



*

This system was originally developed to tract a pilot's head within the small range of the cockpit for preliminary alignment of surveillance equipment, gun-mounts, etc. by approximating the pilot's "line of sight".** It is a reasonably useful device at close range and is currently being used with success at the Architecture Machine for real-time interaction with data file systems. *** #

* Schmadt, Ibid., ppl 8
** Polhemus visit
***Schmandt, Ibid., pp. 11, 12
#Negroponte, N. (1981), "Media Room," Proceedings of the SID, Vol.22 (2).



ultrasound

Point set data is appropriate for analysis of mechanical linkages, and single point tracking but inadequate for tissue characterization and analysis required by medical science. Sonar has been used in many technological applications, including biomechanics. Boundary layers at various depths are detected by measuring the relative delay of echoes returning from increasingly distant surfaces. By active exploration with a narrow beam of sound pulses, information can be built up about a large volume. Boundary layers of organs as they move are clearly visible as large spikes of echo activity on a standard oscilloscope. Distances between spikes can be accurately measured to determine critical dimensions of internal structures.

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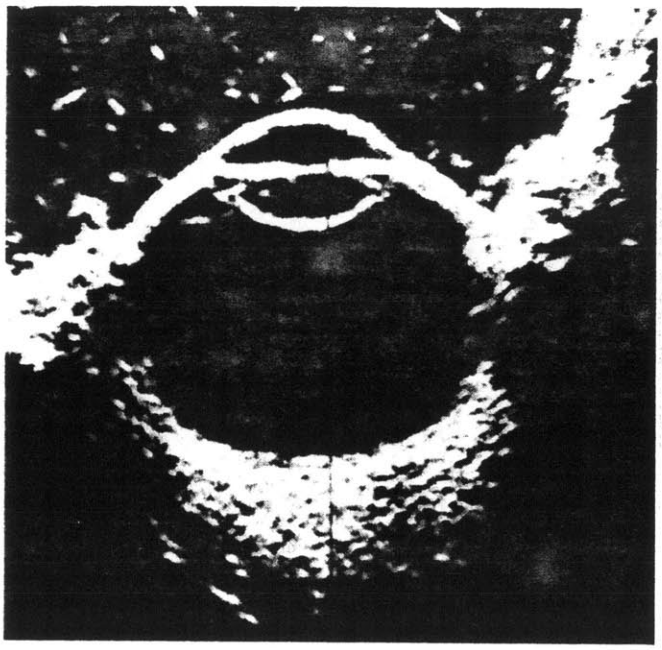
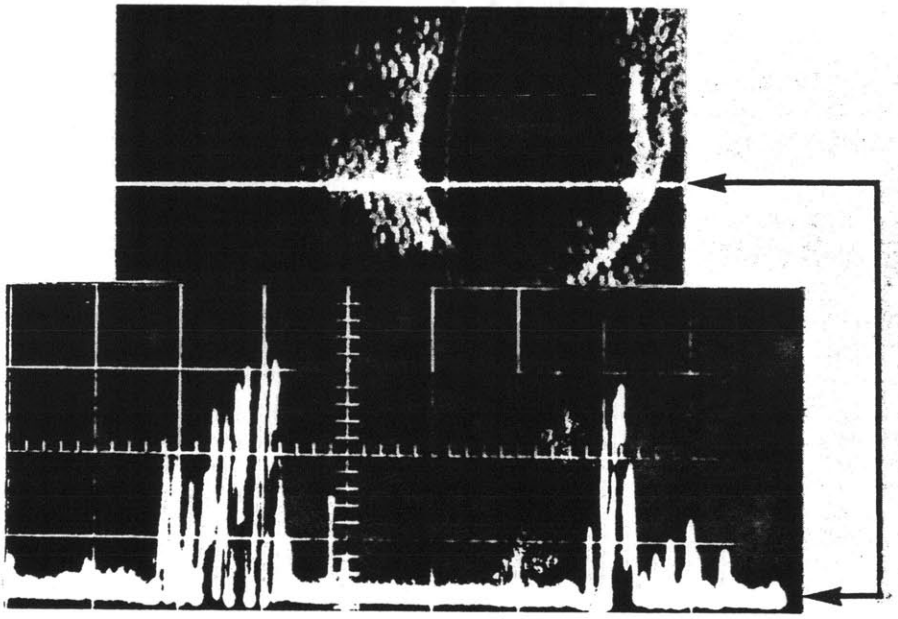


A compound sector scanned intensity modulated ultrasonogram of a human eye @ 15 mc.



The upper part of this illustration is a simple sector scan of a human eye. The scan was stopped at the point indicated by the heavy trace line and the ultrasonograph shown below was photographed on the face of the monitoring A scope. Five hundred ultrasonographs from a single point of reference are required to produce a single tomogram of the eye. Usually 24 or more serial ultrasonic tomograms are required to examine the entire eye. This would be the equivalent of 12,000 ultrasonographs of a single eye, from a single position of observation.

The single compound scan shown in Fig. 1 is a photographic integration of four simple sector scans, so that a single compound tomograph consists of 2,000 ultrasonographs and a set of serial compound scans of the eye consists of 48,000 ultrasonographs.

Systematic sweeping of the beam along a plane can provide the kind of scanning data required for a television picture. It is now common in hospitals to image the live fetus in the womb and the pumping chambers of the heart. The tv picture does not provide measurable data, but a pictorial representation. In practise, the operator hand-holds the transducer which produces and reads the beam, moving it across the body over known organ locations. The "feel" for the size and shape and location of internal abnormalities is quite dramatic. The effect is as if the structures were illuminated in the dark by the beam of a moving flashlight.

Real-time evidence of internal organs in motion as a common experience has tremendous repercussions for self-knowledge. Transparency of our apparently solid bodies reveals labyrinths of activity.

Ultrasound is coarse in resolution. Structures deeper than a couple of inches are not very clear. Motion improves recognition of the image based on apriori knowledge. Knowledge about volumes is built up in the mind by exploration with the transducer, but the system is not three dimensional.

tomography and tissue labeling

Resolution of deep structures in the body is improved by administering to the patient a "contrast agent" which will be absorbed by the tissue of interest differentiating it from adjacent tissue. Time sampled, or "gated" images provide information on change in time or motion, such as of the heart. Ultrasound, x-rays, or some other energy spectra to which the body is translucent, can be passed through the body to make images. Alternatively, the tissue may be labeled with radionuclide tracers which emit their own radioactivity. The desired tissue is imaged clearly without too much shadowing from other structures. Different perspectives may provide some sense of three dimensions.

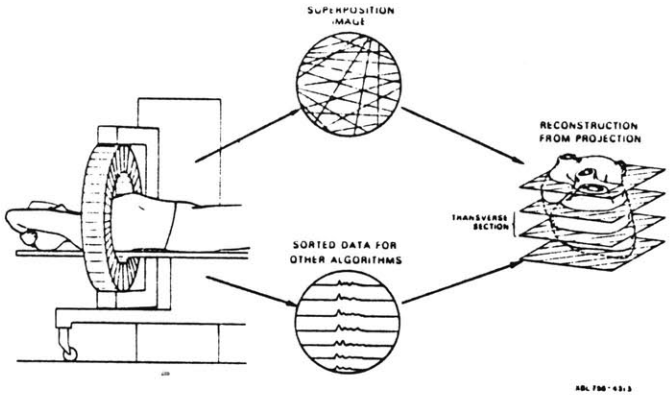
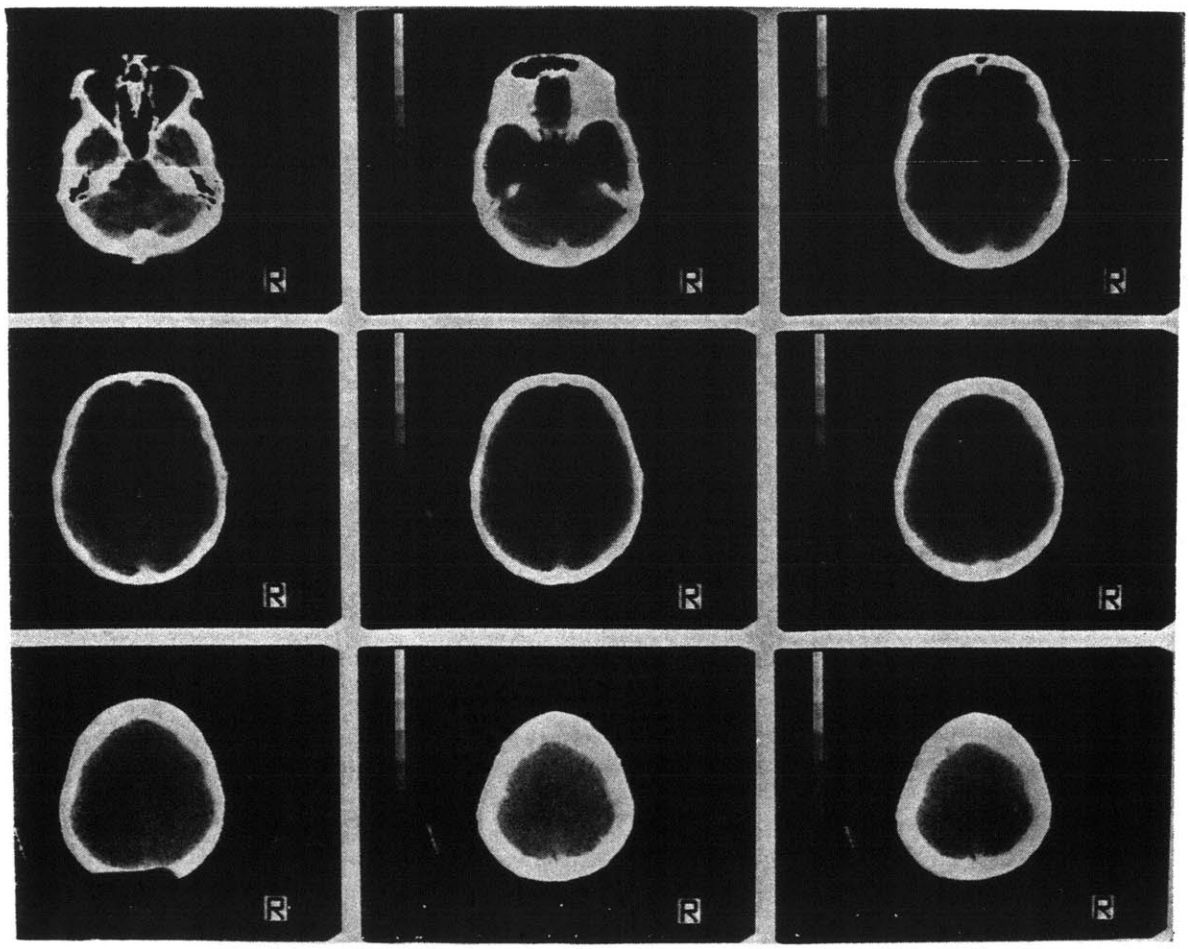


Fig. 8. Schematic of a ring detector system for transverse section reconstruction.

Tomography is a method which may be applied to any spectral modality. Its basic principle is to collect sequential density readings around the circumference of an object. Reprojection of the various density readings back across the paths from which they were taken provides a sort of shadow reconstruction of the original subject. Filtering mathematics eliminate the effects of overlapping data of the same spot.

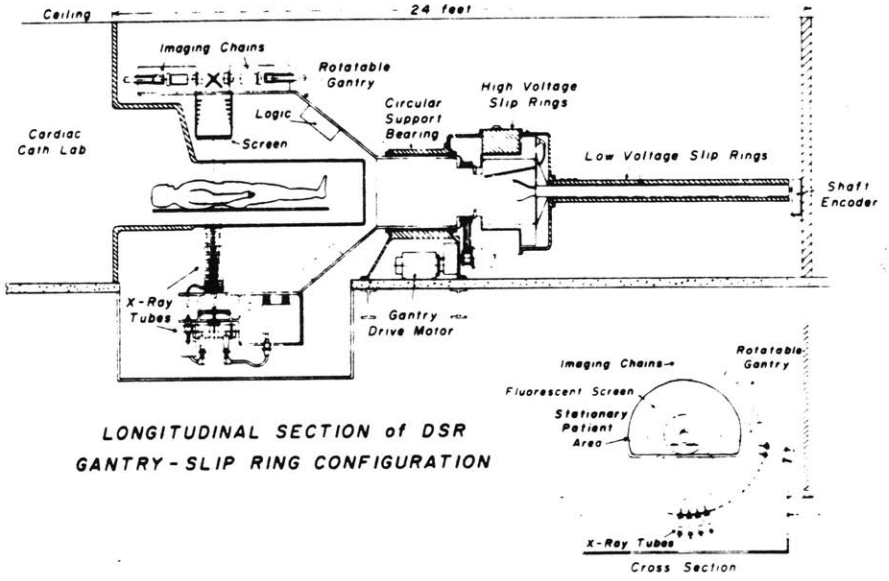
The CAT scanner or : Computerized Axial Tomography is now in common use in hospitals for obtaining series of slices through brain or heart or abdomen at one instant in time. These are viewed individually as two dimensional pictures similar to x-rays, with a gray scale.



Dynamic Spatial Reconstructor

The Mayo Clinic has developed at enormous cost, a tomographic device for real time three dimensional observation of moving structures inside the body. Sampling at rates high enough for real time cinematic motion or better, the "DSR" scans the entire volume of the body from head to toe, in 4 seconds.* This special purpose system will provide new insights into internal motions of the human body. Methods to display the data are being simultaneously investigated.

Many attempts are in progress to project lines into volumes, such as variably focusable lasers into suspended reflective particles (like fog or smoke).



LONGITUDINAL SECTION of DSR
GANTRY-SLIP RING CONFIGURATION

* Rusher, R.F. (1979), "Alternative Futures for Biomedical Research: The ALZA Distinguished Lecture," Annals of Biomedical Engineering, Vol. 7 (1).

displays

Bolt, Beranek and Newman have produced an interesting device called the "spacegraph". A viewer focuses to different depths on the reflection from a circular mirror which alternates (vibrates) between its extreme concave and convex positions. By reflecting the scanned image from a television monitor, the mirror effectively "draws out" the image in space as it varies in time on the monitor. The apparent depth is greater than actual depth, and relative perspective changes with observor position. To achieve a flicker rate of 50 hertz (which is just barely tolerable), the device depends on a CRT monitor which traces several times faster than normal television, and requires a fast decaying phospher to prevent smearing and blur. This limits the image to a line drawing of a yellowish color.* Still, the future possibilities for such technology are interesting and Mayo Clinic may, in fact, be utilizing one.**

Other approaches have investigated the possibilities of individual control of a three dimensional volume of lights, or liquid crystal, a 3D version of the Fenway Park scoreboard, but this is outrageously cumbersome.

A successful future technology must overcome the cumbersomeness of individual handling of millions of individual picture elements. Currently, picture processing utilizes fourier transforms to speed picture processing. When it is understood how to store and

*This information from author's visit to BB&N for demonstration of the spacegraph in connection with "Three Dimensional Display Techniques" conference held by the Institute for Graphic Communication, May, 1980.
** Rushmer, Ibid., pp. 14

display pictures by some similarly fast means, then we begin to have reasonable capabilities to record and display three dimensional time dependent phenomenon.

Interest in large data storage is part of the excitement of holography which is not yet in a form convenient for general use.

The Russians have been working on a holographic movie, but it remains cumbersome. When the computer can produce digitized images of the resolution required for holography, then we will be able to produce very astonishing images, not only of visible objects, but all phenomenon exhibiting frequency modulation, real or imaginary. Animation of such images could be possible.* This will not happen before major breakthroughs in the understanding of large data storage. Work in neuroscience and artificial intelligence is raising questions about the possible mechanisms of the human mind for handling huge amounts of information which may reveal some useful clue. ** #

In the meantime, we must rely on two dimensional display devices. This requires that we make use of familiar depth cues, which include perspective rotations about an object, stereo and relative obscuration of depth by atmosphere or focus degradation. These factors are improved with the use of interactive displays.

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* Institute for Graphic Communication conference,"3D Display Techniques" May, 1980
** Pribram,K. (1978), "What the Fuss Is All About," Re-Vision,Summer/Fall
# Mackay, Ibid.

Interactive Media

Effective displays communicate to the viewer a strong sense of spatial and temporal relationships. Intuitive understanding is improved by viewer interaction with the data. Remembering Hein-Held's kittens,* knowledge is stronger if we are actively involved in acquiring it. We are learning about data in more than one way, by more than one sensory and cognitive process.

Interactivity gained prominence in gallery arts and avante-garde theatre and discotheques during the sixties. The general public, accustomed to restricted norms of self expression, were made very uncomfortable by situations intended to force participation in highly incongrous and politically charged situation. Interactive forms survived under the guise of "kinetic art", used new technologies, or hid out as special effects. Meanwhile, tremendous acceptance of interactive media has occurred where it is a natural development of industrial and military instrumentation.

Devices which act on behalf of a human or which extend the capabilities of a human have led to profitable developments in robotics, rehabilitation engineering, space and undersea exploration. All these things in use change our notions of who we are. Applied on a scale as large as the American military, they become part of our folklore, known to the world, and the background for Hollywood movies. This is exemplified by the image of the American fighter-pilot, as described in Tom Wolfe's "The Right Stuff", or fancifully, as the Bionic Man.

Schiffman, Ibid.

Large ventures, military, industrial or research, require aids for data manipulation, and presentation. All face problems of showing the progress in time of thousands of interrelated elements.

Development in these two areas: extensions to the physical body, and extensions for the mind or for perception, will lead to capabilities for future man-machine interface. It is necessary to consider both human engineering for physical utilization of equipment and to consider setting up data systems intuitively for the human mind. A current focal point of these considerations is interactive displays.

interactive displays: a form of data retreival

The limited gray scale of the standard television monitor utilized in medical imaging equipment has necessitated interaction with

the display on the part of medical personnel.

Tissue density is represented by a gradient scale of some two thousand increments between bone and water and water and air. The television screen can display only a small number of these increments. To observe the entire data acquisition it is necessary to "dial up" through successively less dense tissue or alternatively "dissolve away" soft tissues. The tactile "feel" of turning the scale nob provides a strong sense for the relative variation of tissue differentiation. For instance, bone appears immediately at the densest tissue, after some time followed in appearance by cartilege, then fibrous tissue. Slowly the soft tissue appears, then quickly many kinds of soft tissue, at last air cavities. The display provides visual information about only one cross-section. Another control dials up successive cross sections, exactly registered.*

The Mayo Clinic has utilized this approach for visualization interaction with data acquistions from the dynamic spatial reconstructor. A number of perspective views may be chosen of the subject, and by altering tissue densities displayed, the effect is to dissolve away an increasingly transparent body which is displayed, all this time, in motion, heart beating, lungs breathing, etc..**

Another example of interactive displays which allows for various representations of the data is from bio-mechanics. The computer knows the three dimensional positions of the joints of

* Prof. Brownell, Principles of Medical Imaging, Spring, 1980, and observations by the author on a tour of MGH imaging facilities
** Prof. Brownell's lectures

a tracked body through successive points in time. A stick figure can be drawn from these points and shown from every perspective, at any position, or any number of positions. These are functions of some vector scan displays "Megatek".

Any single point or group of points, any interconnection between the points is the choice of the viewer. On Gideon Ariel's system, position of the stick figure can be modified, and the resulting motion analysized for effect on performance. Analyses can be made of efficiency, velocity of body parts. These are functions of the computer.

When computer capabilities are readily applied to manipulation of displayed data, it is difficult to think about the image in the same way as some inviolate and complete entity. Such an image is clearly only representative of a phenomenon. Further insight into the data requires competancy and insight on the part of the operator and flexible, general purpose capabilities of the computer.

media environments

We are driving towards the creation of an environment which speaks in a responsibe manner, of the data storage system in which it is imbedded, and more largely, or the real world in which the whole data system is imbedded.

> "The concept includes total immersion of cognitive and sensory apparatuses into an information space, convincingly real or uncannily imaginary. The user is surrounded by presentational means sufficiently redundant to engage any one of a number of human senses for a particular message. Similarly, the user is offered many channels of input, with the conspicuous exception of a keyboard. The implementation is with television technology,

octaphonic sound, and numerous touch-sensitive surfaces."*

Man-machine interfaces should orient the user's attitude in a manner appropriate to the intended use of the system. The structure of access mechanisms to data files and communications links will affect user attitude and utilization of data.

> "... consider the parallelism of head nodding and shrugs of shoulders that suggest facilities to which we are well accustomed in human-to-human exchanges, but which, for some reason, seem silly or absurd in a computer context. It is about time to re-examine such absurdities."**

Instrumentation, data retrieval, computer utilization in general, should be simple and natural for human use. Light pens, tablets, touch sensitive screens, voice recognition, movement sensors, eye trackers, are becoming mechanisms for man-machine interaction. Video games, answering machines, washing machine timers, garage door openers have already entered our personal lives and alter our sense of physical limits.

Nicholas Negroponte has adopted an active role in demonstrating that computers can be forced to deal with people. By building toys which teach visiting corporate executives that this is possible, Negroponte has contributed greatly towards utilization of natural human modalities.

In a rather clumsy fashion, we all tumble towards a synthesis of futures. Many industries are developing methods to handle increasingly unmanageable data systems, and in doing so, there is much duplication of invention, and the suggestion is of simultaneous growth

* Negroponte, Ibid., pp. 109
** Ibid., pp. 113

toward shared capabilities.

interactive display with movement

> "We have proposed to build a lab jacket for use in our media room. Each button and epaulet will be a magnetic sensor, reporting displacement and all three axes of rotation. On the one hand this suggests poetic interaction with the space, mediterranean style discourse, lots of hand waving, and the occasion to literally swim through data."*

Current imaging technologies are limited, but some of the limitations exist in our heads. Our mental conception of who we are as humans will change when we have the means to look at it, as it has been through use of film/video applied to anthropology and motion analysis. Imagery is as much a part of an environment as our thinking. Motion is the manifestation of our relation to our total environment: physical, cultural, mental, images, machines.

Three dimensional motion input and display systems could provide real time feedback of our active motor responses. This is not only of interest for "swimming through data". Identification of human qualities and clarification of priorities must be addressed in the development of interactive media. As an art work, awareness of an audience could be heightened as to the interactive nature of all of life.

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*Negroponte, Ibid., pp.113

3d tracking device from Polhemus Navigational Sciences taped to lower leg of dancer from Joffrey ballet creates graphic representation of her motion on rear projection video image shown. facilities of The Architecture Machine Group.

an application of this thesis

An application of this thesis has been a feasibility study for real time interactive graphics based on human motion for the Joffery Ballet. The study was funded in part by the Council for the Arts, M.I.T., and was approached in association with Scott Fisher, whose interests and masters thesis in the arts and media technology program is on stereo imaging processes. Dave Shepard, through Undergraduate Research Opportunities Program provided programming assistance throughout the summer, John Correa assisted in the spring, and Dan Frangblau has assisted since August.

In dance correography, three dimensional design in time by human bodies is an age old tradition. To utilize this tradition as a means for designing three dimensional computer graphics displays seemed appropriate and useful. The possibility of utilizing such a system to project large real-time feedback exaggerating the dancer's motions in space and time was extremely exciting to Robert Joffery. Joffery perceived this possibility for himself when he visited the Architecture Machine in December 1980 and played with the interactive polhemus "paint" system. He would like to choreograph a piece with dancers and interactive graphics if only the device could be moved in to his rehearsal space soon. There is not a simple answer.

No satisfactory system for this purpose exists, ready engineered, anywhere, at any price. Biomechanics labs require devices with high sampling rates and high accuracies, and are willing to part with real-time for after-the-fact perusal of data. Interest in analysis

of human gait has led to ranges of two or three walking strides as adequate. Sports, rehabilitation, and even the military applications are expensive and unsatisfactory for this purpose.

An interim solution may be to utilize a two dimensional motion detector such as are available for surveillance applications. It is still necessary to custom build an interface and software to a graphics computer capable of sufficient speed to keep up with the dancer's motion. Custom built graphics hardware would be necessary to obtain graphic "brushes" other than rectangles or lines which will run fast enough. This approach is technically possible given current off-the-shelf technology and any competant systems engineer. Development would take a year.

Another project would be a kinematic analysis of a ballet or piece of choreography. This would be a means for obtaining more spectacular graphics (perhaps by animation) and the three dimensional dance analysis which was a matter of interest in this project. The dance would have to be photographed with biomechanical analysis cameras from several viewpoints simultaneously and laboriously input into the computer by hand. But it would undoubtedly have satisfying rewards, and is quite technically possible.

A final possibility for the near term is to perform within the setting of the research lab. Documentation of the performance both by kinematic and television technologies would be the only public record or the event. We have eagerly been awaiting the completion of the

the Mobility Lab since January of 1981 for this very purpose. Even this may still not be feasible before the end of the year.

An earlier attempt to work with a Joffery II dancer in the Architecture Machine Media Room met with limited success. The limitations of the sampling space were further hampered by reflections from metal surfaces and the general tightness of working space in that facility. Lack of an attendent choreographer who could interact with us to develop graphics proved especially limiting. Previous experience with Arlene Walaszek, a dance trainer and physical therapist, provided more successful results in three dimensional kinematic graphic design, if somewhat less accurate in execution.

Subsequent graphics development by Shepard were aimed at examining potentially real-time graphics devices and simulation of 3D dance data files.

A final report is to be made in October of this year accompanied by a videotape. Some of this work is contained on the videotape which accompanies this written thesis.

goals

Based on the ideas here described, I am interested in creating sensory experiences to communicate issues of human identity through human motion.

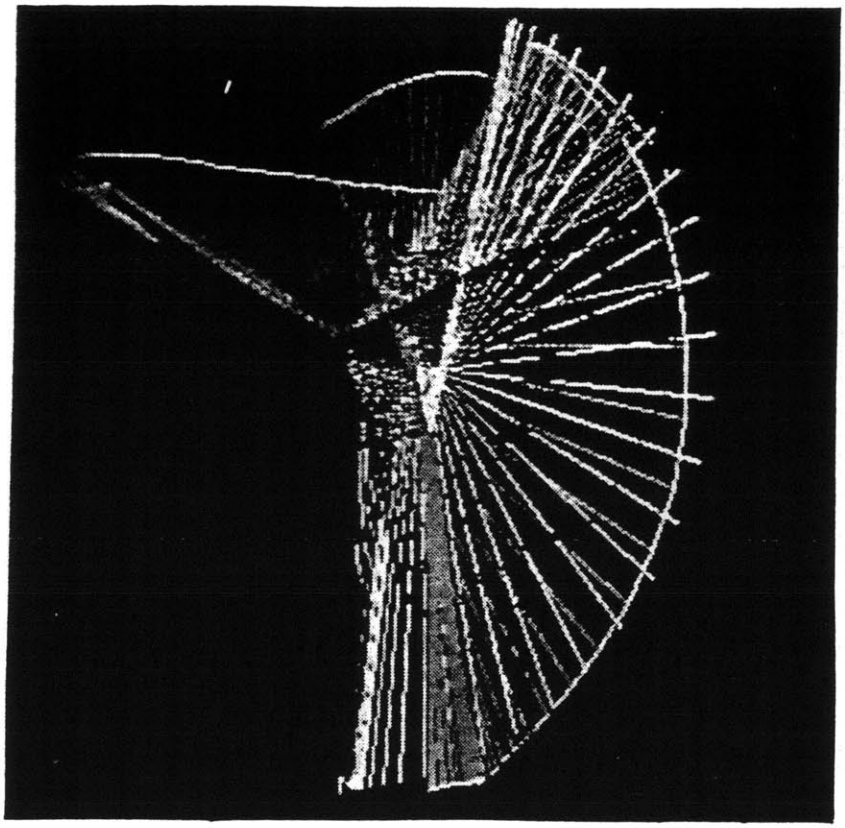
First, I want to make documentary films on people and work. In this, I want to emphasize pictorially the connection between worker and tools, environment and thought process. I have tried to do this

in my videotapes at M.I.T. for the past some years, as screened at Film/Video in June of this year.

Second, I want to create imagery which elicits strong visceral response to human motion and which ideally elicits active motion from an audience. I have begun to experiment with video for entertainment environments. "Intaglio Fuge", an experiment in visual "music" is included on the thesis videotape.

Third, I want to create spatial experiences which are not limited to film/video's linear. flat projection. The setting might be a Museum, the subject would be, once again, human motion, but though all participants are already moving through a space and would be required to move in order to "see the next thing", and it would be possible to emphasize the effect of environment on thought and sensibilities.

Fourth, environments, videodiscs, computer graphics must be facilitated by responsive devices such as tablets, tsds, voice recognition, and devices for three dimensional motion input from surveillance equipment, motion detectors, and the like, to instrumentation from biomechanical analysis laboratories. When such devices are identified software must be adapted that allows flexible use. This has been the role of labs such ans Negroponte's but there remains much in applications work for producing items of powerful communicative value.



computer aided rotoscoping from videotaped ballet performance created this line drawing of an arabesque

BIBLIOGRAPHY

1. Antonsson, E.K. (1978), "The Derivation and Implementation of a Dynamic Three-Dimensional Linkage Analysis Technique," S.M. Thesis, Massachusetts Institute of Technology.

2. Armes, R. (1974), Film and Reality, Penguin Books, Baltimore .

3. Bailey, W.H. (1980), "The Computer Interactive Videodisc," Filmmakers, Vol. 14, (1).

4. Barclay, C.D., Cutting, J.E., Kozlowski, L.T. (1978), "Temporal and spatial factors in gait perception that influence gender recognition," Perception and Psychophysics, Vol. 23 (2).

5. Bateson, G. (1972), Steps to an Ecology of Mind, Ballantine Books, New York.

6. Bateson, G. (1979), Mind and Nature, Bantam Books, New York.

7. Bernstein, N. (1967), The Co-ordination and Regulation of Movements, Pergamon Press, Oxford.

8. Birdwhistell, R.L. (1970), Kinesics and Context, University of Pennsylvania Press, Philadelphia.

9. Chao, E.Y., "Experimental Methods for Biomechanical Measurements of Joint Kinematics," CRC Handbook of Engineering in Medicine and Biology, Section B., Vol. 1, Feinberg, B.N. and Fleming D. G. (editors) pp. 385-411.

10. Conati, F.C. (1977), "Real-Time Measurement of Three-Dimensional Multiple Rigid Body Motion," S.M. Thesis, Massachusetts Institute of Technology.

11. Cutting, J.E., Kozlowski, L.T. (1977), "Recognizing friends by their walk: Gait perception without familiarity cues," Bulletin of the Psychonomic Society, Vol. 9 (5).

12. Cutting, J.E., Proffitt, D.R., Kozlowski, L.T. (1978), "A Biomechanical Invariant for Gait Perception," Journal of Experimental Psychology:Human Perception and Performance, Vol. 4 (3).

13. Edgerton, H.E. (1979), Electronic Flash,Strobe, MIT Press, Cambridge.

14. Fitts, P.M., Human Performance, Greenwood Press, Westport.

15. Goleman,D. (1979), "Holographic Memory: Karl Pribram interviewed," Psychology Today, February.

16. Hall, E.T. (1966), The Hidden Dimension, Doubleday & Company, New York.

17. Hutchinson, A. (1954), Labanotation, Theatre Arts Book,New York.

18. Johansson, G. (1973), "Visual perception of biological motion and a model for its analysis," Perception & Psychophysics, Vol.14 (2).

19. Johansson,G. (1975), "Visual motion perception," Scientific American, Vol.232 (6).

20. Kapandji, I.A., (1970), The Physiology of the Joints, Vol. 1, 2, 3. E&S Livingstone, Edinburgh.

21. Klee, P. (1964), The Thinking Eye, George Wittenborn Inc., New York.

22. Kozlowski, L.T., Cutting, J.E. (1978), "Recognizing the gender of walkers from point-lights mounted on ankles: Some second thoughts," Perception & Psychophysics, Vol.23 (5).

23. Lieberman, D.E. (1977), Computer Methods, C.V. Mosby Company, Saint Louis.

24. MacKay, D.M. (1981), "What Does It Mean to Perceive?," lecture, Massachusetts Institute of Technology, Department of Psychology.

25. Mamber,S. (1974), Cinema verite in America, MIT Press, Cambridge.

26. Mann, R.W. (1974), "Technology and Human Rehabilitation Prostheses for Sensory Rehabilitation and/or Sensory Substitution," Advances in Biomedical Engineering, Vol. 4.

27. Merleau-Ponty, M. (1964), The Primacy of Perception, Northwestern University Press, Evanston.

28. Morris,D. (1977), Manwatching, Harry N. Abrams, New York.

29. Muybridge, E. (1955), The Human Figure in Motion, Dover Publications, New York.

30. Negroponte, N.P. (1980), "Media Technology: The Human Interface with Information Sciences," The Industrial Liaison Program of the Massachusetts Institute of Technology, MIT, Cambridge.

31. Negroponte, N. (1981) "Media Room," Proceedings of the SID, Vol.22 (2).

32. Piaget, J. (1948), The Child's Conception of Space, W.W. Norton & Company, New York.

33. Piaget, J. (1971), Biology and Knowledge, The University of Chicago Press,Chicago.

34. Pincus,E. (1969), Guide to Filmmaking, New American Library, New York.

35. Poizner, H., et.al (1980), "Three-Dimensional Reconstruction and Quantification Movement: Towards a Visual-'Phonetics' of A Visual-Gestural Language," MIT and University of California at La Jolla, first draft.

36. Pribram,K. (1978), "What the Fuss Is All About," Re-Vision, Summer/Fall.

37. Pudovkin, V.I. (1949), Film Technique and Film Acting, Vision Press/ Wehman Bros.,Hackensack.

38. Rasch, P.J., Burke, R.K. (1967), Kinesiology and Applied Anatomy the Science of Human Movement, 3rd. Ed., Lea & Febiger, Philadelphia.

39. Ruesch, J., Bateson, G. (1968), Communication: The Social Matrix of Psychiatry, W.W. Norton & Company, New York.

40. Rushmer,R.F. (1979), "Alternative Futures for Biomedical Research: The ALZA Distinguished Lecture," Annals of Biomedical Engineering, Vol.7 (1).

41. Schmandt,C. (1980), "Some Applications of Three-Dimensional Input," S.M. Thesis, Massachusetts Institute of Technology.

42. Scheflen, A.E. (1974), How Behavior Means, Anchor Press/Doubleday, New York.

43. Schiffman, H.R. (1976), Sensation and Perception, John Wiley & Sons, New York.

44. Schmidt, R.F., editor (1978), Fundamentals of Sensory Physiology, Springer-Verlag, New York.

45. Teuber,M.L. (1981), "Theories of Perception in the Work of Paul Klee," lecture, Massachusetts Institute of Technology, Department of Psychology.

46. Todd, M.E. (1937), The Thinking Body, Dance Horizons, Inc., New York.

47. Vaganova,A. (1946), Basic Principles of Classical Ballet, Dover Publications, New York.

48. Weiner,N. (1950), The Human Use of Human Beings - Cybernetics and Society, Houghton Mifflin, Boston.

49. Whorf, B.L, (1956), Language, Thought, and Reality, MIT Press, Cambridge.

50. Wylie, L., MacKensie,M. "Interview by MacKensie on Videotape on the subject of Wylie's teaching French language classes at Harvard University, 1981," Videotape.