Visual Music: Searching for an Aesthetic

Tom DeWitt

Abstract-If the nonverbal and emotionally evocative aesthetic of music is to be extended to visual art, we must examine the psychology of sight and the intuitive uses of this psychology by visual artists. The structure of the eye, the nerve connections between the eye and the brain, and the visual cortex can give us clues as to how human perception is uniquely sensitive. These sensitivities, amplified through the self-expression of artists, can induce emotional responses that are more related to the form of the expression than to the content of the imagery. Works by the author and by other artists who influenced him are used to illustrate these points.

I. INTRODUCTION

During the nineteenth century, Helmholtz [1] studied the relationship between musical harmony and the human perceptual apparatus. His discoveries can guide an investigation into the relationship between music and visual art, not because he uncovered a direct correlation, but because his method of analysis can be used to find one. In a key finding, Helmholtz concluded that we appreciate the geometric progression in sound frequencies because our ears seem to produce these overtones even in the absence of their physical presence. In other words, we enjoy the art born from the subtle manipulation of our aural psychology.

If we apply this methodology to sight, it is reasonable to suggest that the eye has intrinsic physical properties that point toward an aesthetic. The centric structure of the retina with its logarithmic density of sensor cells radiating from the fovia, the cone and rod retinal cells that are sensitive respectively to color and monochrome, the crossing of left/right eye neurons in the optic nerve chiasma, and the processing of the visual cortex itself are all unique psychological phenomena that must be examined.

II. VISUAL HARMONY

Interesting work has been pursued by Chaikin and Schwartz at the New York University Brain Research Lab, showing how visual processing might work [2, 3]. Noting that cells in the eye and brain are distributed in a polar coordinate system, as opposed to the Cartesian coordinates that usually are used in computational geometry, they postulated that our visual apparatus simplifies some image processing problems, particularly geometric rotation. Their model of visual perception and cognition seems to be related to an aesthetic that I developed independently in my art.

In 1974 I produced a work called *Philharmonia* [4], which was based on the logarithmic spiral. It was realized using an audio synthesizer to draw pictures. If a sine and its cosine wave form are displayed on an oscilloscope as the vertical and horizontal inputs, a circle or oval will be produced. If these wave forms are amplitude modulated by wave forms at frequencies higher than the sine wave frequency, the circle is pinched into a shape like a flower or a rose window. The petals move dynamically but are stable when the modulating frequency is at integral multiples of the sine wave frequency. The pattern in the petal leaves is determined by the timbral qualities (wave shape) of the modulating wave form. An image made by this technique is shown in Fig. 1. Since the process was realized with an audio synthesizer, I was able to record a sound track simultaneously.

My endeavors in this area were by no means the first. Probably the most impressive formal body of work of this type was realized by the Whitney brothers, James and John Sr. I had been influenced by these artists at the beginning of my filmmaking career, and in 1965 I approached John seeking an apprenticeship. He declined my request but did

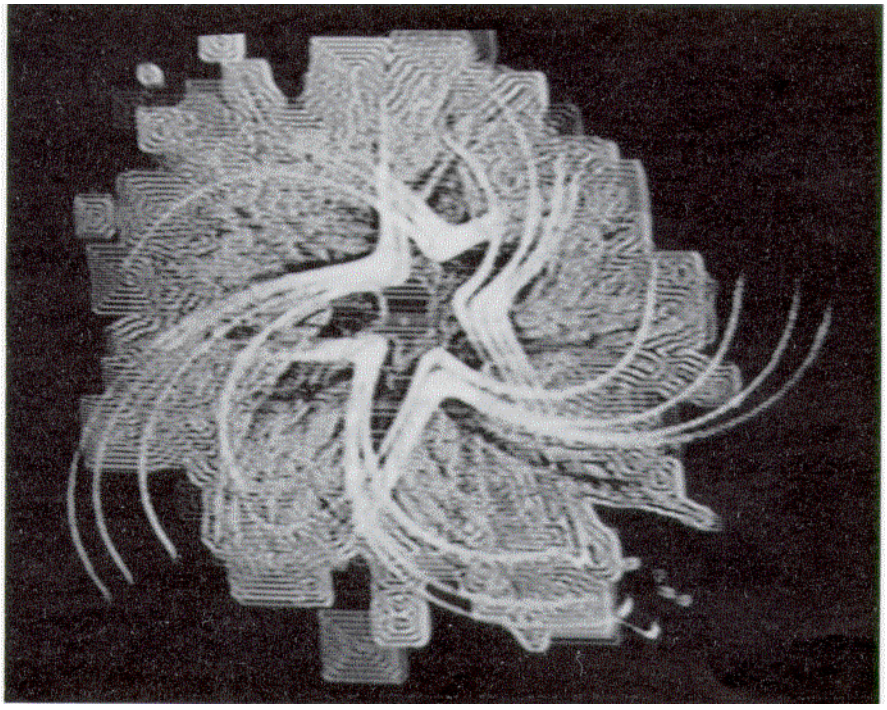

Fig. 1. Frame from *Studies for Philharmonia,* videotape, 1974 showing a pentatonic petal made using the algorithms of digital harmony. The lobes of the flower correspond to the harmony of a simultaneously created musical composition.

Tom DeWitt (multi-media artist), Image Processing Laboratory, Rensselaer Polytechnic Institute, Troy, NY 12180, U.S.A.
Received 7 July 1986.

Pergamon Journals Ltd.
Printed in Great Britain.
0024-094X/87 $3.00+0.00

share his teaching with the entire world by publishing a treatise on the subject, *Digital Harmony [5]*, in which he described his simple and effective algorithms for producing a pleasing time variant image by modulating spirals. These can be described as digital computer programs, providing a much-needed notation for the emerging visual music art form.

In my efforts to notate, I resorted to conventional musical practices, a linear strip of notes on paper. I used graph paper and a form of notation explored in this century by such artists as Villa-Lobos and Gershwin—skyline notation. The choice was premised on an automated score reader I was developing. The notated graph paper was placed on registration pins, much like those used in cell animation, and a video camera converted it to an electronic signal. An electronic circuit reduced the video image to a set of timed pulses which corresponded to the position of each note on each line, and this could be read by a small computer.

My idea was to liberate the artist from the electronic music studio by allowing notation at the piano or simply from memory, just as composers score for orchestras. I started to develop the machine to read scores in 1976, when electronic music equipment was only slightly more accessible to composers than professional orchestras. By the time the work was published in 1981 [6], the modest price of home computer systems had provided composers with accessible tools for composition. Digital music synthesizers with piano keyboards have since become ubiquitous.

My notation for visual harmony presumed that a composition was to be constructed from a fixed vocabulary of visual notes, much like the diatonic scale. John Whitney affirms this assumption of mine. In a manner remarkably similar to aural harmony, logarithmic spirals have stable structures only at fixed intervals of frequency. If a piano keyboard is used for a musical performance, it can be used simultaneously to produce visual harmony based on Whitney's digital harmony. A demonstration of this technique came in 1974 when Laurie Spiegel, Phil Edelstein, Randy Cohen and I recorded "Studies for Philharmonia" in a live improvisational setting.

Perhaps the piano keyboard is a suitable performance tool for visual harmony; after all, it has become commonplace as an interface to sophisticated musical synthesizers. However, I have often thought that the universal use of the piano keyboard is an anachronism forced on us by the technical evolution of the piano. If chordal structures are desired during a piano performance, the physical size of two hands is imposed on the composition. I propose that we construct cluster keyboards based on that more recently evolved digital interface, the typewriter. With a two-dimensional keyboard, virtually any 10 notes could be played simultaneously.

When computers are used to make visual or aural music, they can be programmed to create a polyphony from a single command. Consider the implementation of a graphic mouse by Laurie Spiegel [7]. In her computer-based instrument, the two-dimensional position of the graphic screen cursor, as controlled by a mouse or trackball, triggers the production of chordal structures. I have proposed a similar performance controller based on my tracking system, Pantomation. In this system, the three-dimensional movement of a conductor's baton is interpreted by a music program as an interactive control for changes in the music [8].

III. COLOR

Universal agreement on a color aesthetic has not yet been reached, nor is there a set of rules correlating music tones and visual colors. This contrasts with Western music theory, which long ago settled on a set of aural frequencies, suggestively named the chromatic scale, upon which generations of composers have built aesthetic architecture. John Whitney reflects on this difficult problem of achieving a formalism for color when he writes:

> I confess my own puzzlement despite nearly forty years of color filmmaking . . . . One propounds theories for the use and effect of color; I make a new plan with each film. Rarely have the best ideas lived up to expectations [9].

However, on the simplest level, one can consider the important threshold between monochrome (black/white) and color. I found this transition to trigger a psychological release with emotional connotations. In my first film, *AtmosFear* [10], I used a time dissolve from a city skyline in color to a high-contrast monochrome image of identical composition which establishes a day-to-night feeling. This is followed by colored abstractions superimposed above the skyline, leading to jazzy city neon night scenes. The film ends with a dramatic voyage along railroad tracks, the movement of the track ties made more stark by the high-contrast, black-and-white film stock used to record the image.

The superimposition of a color pattern over a black-and-white pattern places the color pattern in sharper relief. In *Koan* [11], richly saturated flesh tones in the foreground image are juxtaposed over muted backgrounds (Color Plate No. 1). The eye sees the muted background as distant and remote. Yet the background motif was actually derived by electronically tracking the movement of the foreground subject, a couple clapping hands. Technically speaking, the background in this image is an integral part of the foreground image, but the use of a muted color scheme for the background resulted in a clear sense of separation between the hands in the foreground and the sky-like background their movement created.

Perhaps because the monochrome retinal neurons, called rods, are more sensitive to light than the color-sensitive cones are, the transition from black and white to color can produce the sensation of awakening. As our level of visual perception grows in increased amplitudes of light, visual perception changes from black and white to color. My film, *The Leap [12]*, pivots on this monochrome to color transition, in that the moment of denouement—a leap from confusion to enlightenment—is accompanied by the introduction of color into the motif. The reverse transition from color to black and white leaves a feeling of release into twilight. I suggested this to Dean Winkler when he was producing *First Experiment with Bryon's Solids* [13], and the effect can be observed in his tape's finale: intensely colored geometric objects transform to black and white before they fade out completely.

Another interesting psychological effect of black and white seems to be its association with the factual as opposed to the emotional. Our emotions are often described as colors, e.g. green with envy, blue with heartbreak, red with anger. Newspapers and journals, by way of contrast, fulfill their primary roles without the use of color. We speak of the facts in black and white. In my film, *Fall* [14], I represented the impersonal face of the machines of war in black and white. These images were then processed into colors of fire to portray their emotional connotations. In my videotape, *This Is TV— America* [15], a commentator is recorded in color in front of a sequence of television commercials shown in black and white. The black and white is a foil for the commentator's skin tones, but more importantly, the black-and-white presentation of the once-glossy color

commercials makes them easier to view with objective detachment—the goal of the spoken commentary.

IV. THE DEPTH DIMENSION

It was not long ago in musical history that the stereo revolution swept a new wave of audiophile instruments into the mass market. Visual stereo also enjoyed a moment of commercialization in the early 1950s, but public interest proved ephemeral. However, one should remember that the genre in which stereo visualizations were used during this period was almost exclusively the genre of those dark melodramas, horror films. Such a base exploitation cannot be considered a definitive test of aesthetic merit, although we can conclude that the stereo effect, which involves, in part, the joining of the optic nerves at the chiasma, has the power to excite the psyche. It is my personal contention that three-dimensional projection of moving images will return to the forefront of cinema art with the emergence of visual music.

One of the leaders in this field, Vibeke Sorensen, has been producing three-dimensional computer graphics since 1975. She has been perfecting the stereo representation of solid objects through a series of gallery installations, e.g. *Micro Fishe* [16]. I drew much inspiration from my association with Sorensen while participating in the film *Hot Wax* [17]. I converted some still frames from this piece into parallax barrier stereograms, a form of stereo-pair photograph that can be viewed without wearing special glasses [18]. Recently I demonstrated that this technique can be applied to make flat panel computer graphics displays, such as plasma panels, into goggleless three-dimensional displays. Such displays could be combined with my Pantomation system, mentioned above as a controller for music, to detect the position in three-dimensional space of a movable stylus. This allows an artist to draw in three dimensions. Further experimentation has resulted in my invention of a monocular rangefinder that can be used to acquire the surface coordinates of solid objects [19].

Like Sorensen, I have produced a series of still images for viewing with stereoscopic viewers. What motivates my work is the concept of extending the colors, textures, and sensibilities of Impressionist painting into the three-dimensional realm. Although much of twentieth-century visual art has created flat representations of three-dimensional space [20], I have developed computer programs that convert two-dimensional images into stereo-pair renderings of three-dimensional images. This technique uses the grey tones of an image as a code for depth information. The concept is borrowed from topographical mapping, but it can be generalized for most surfaces. Fig. 2 shows a grey scale encoded landscape. Fig. 3 shows its stereo rendering.

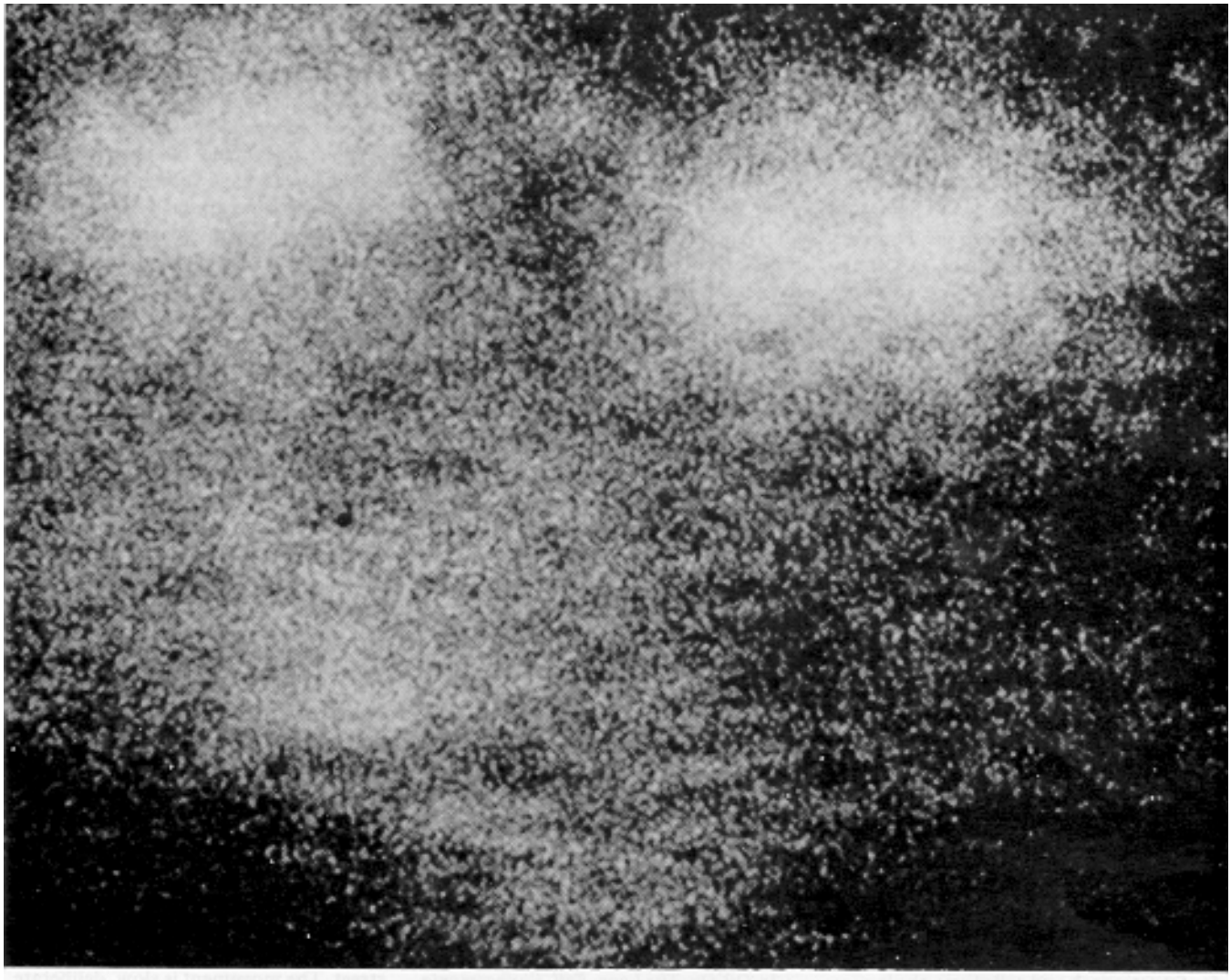

Fig. 2. A computer-generated topographical view of a synthetic landscape. The image contains enough information for three-dimensional rendering. The horizontal and vertical dimensions are the plane of the photograph, and the third dimension is encoded as levels of grey.

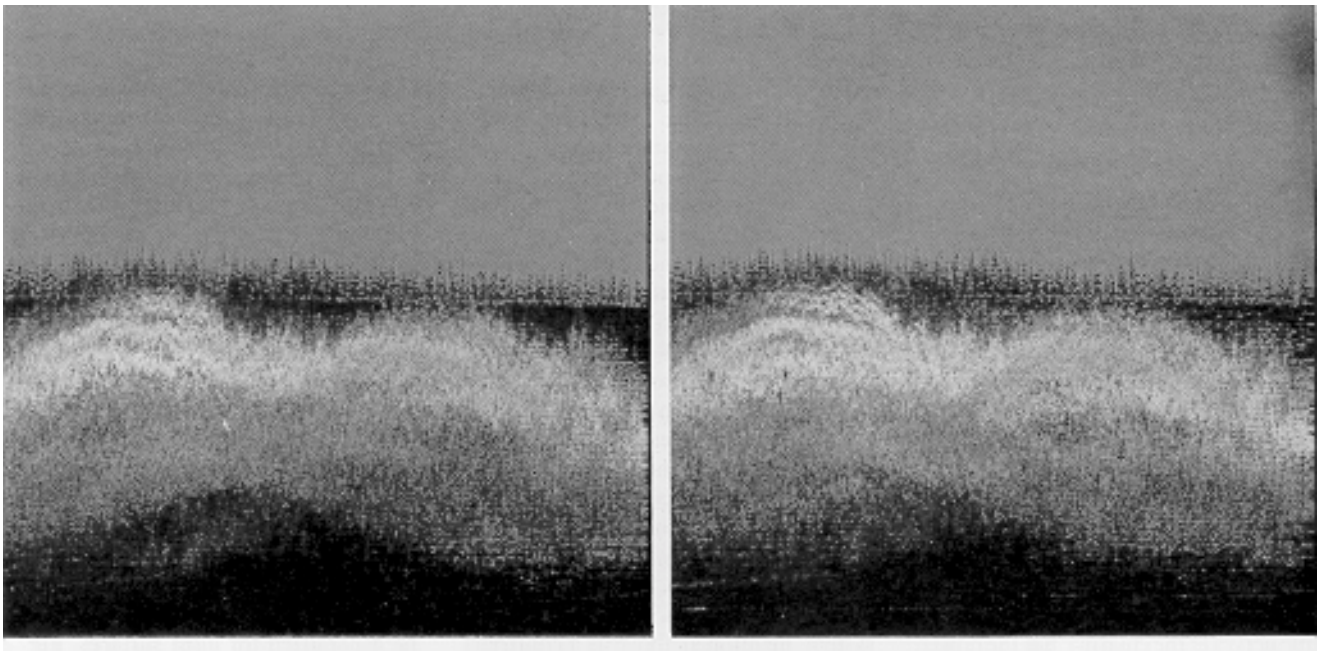

Fig. 3. Two renderings of the landscape at slight angles of rotation form a stereo pair, viewable with a stereopticon. Photograph from current work with the IBM 7350 Image Processing System at Rensselaer Polytechnic Institute, Troy, NY.

V. THE TIME DIMENSION

In discussing how the psychology of perception might imply a visual aesthetic similar to music, I began with characteristics of the eye and progressed to the stereo effect of the optic nerve linking the eye and brain. But what aesthetic grows uniquely from the processing of visual images in the brain? Clearly this question will raise many more questions, because the working of the brain is not fully understood. Consider, therefore, an entry level question: How fast do we think? Peter Mark Roget observed in the early nineteenth century that a sequence of static images appears to be joined together if presented at rates above 12 frames per second. This psychological phenomenon is the basis for motion picture techniques. With the advent of moving pictures, the time dimension was introduced into a visual art, and it was here that artists became creative in cinema, cutting the film.

The persistence of vision closely matches our aural perception, that is, discrete sound events become continuous tones at about 20 cycles per second. Like the reduction of a score into beats and measures, films are made of frames and shots. The film medium invites artists to become visual musicians, dividing up time according to a sense of change. Hence, one aesthetic that music can teach visual artists is that of tempo.

In my work with light shows in the sixties, I began to make film loops. Made for frenetic rock and roll music, the loops included a library of flicker frames, alternating clear and opaque frames at frequencies of 12 to 2 flashes per second. During performance, the rhythm loops would be bipacked in the projector with loops of motion images. This work eventuated in *Off On* [21], a film built from these loops (Fig. 4). Similarly, at the finale of *Fall,* I developed a sequence with the working title "Inevitable Rhythms" made from loops with interwoven rapid and repetitive cuts. Sometimes I have been asked to warn audiences of the danger this film could pose for epileptics, a warning based on their occasional seizures at rock concerts or in stroboscopic light. The seizures seem to be induced by stimuli occurring at a rate close to the speed of thought.

Although formalisms for tempo in musical theory have been challenged recently [22], it is instructive for visual artists to study the traditional structures upon which most music is based. I assume that moving pictures can have tempi ranging from *largo* to *presto,* just as music does. Often we see exciting scenes that are rapidly cut and lyrical scenes that are structured on shots of relatively long duration. To produce moving pictures on a par with music, it might be advisable to continue this formalism further, so that the exact duration of time between cuts would be based on a set beat frequency either subdivided by rational fractions or lengthened by integral multiples. Certainly, music has shown that this simple scheme appeals to an innate rhythmic sensibility in our psychology.

In *Off On, The Leap, Fall, Philharmonia* and *The Rhythm Machine* [23], among other pieces, rhythms were established not solely by cutting between disparate scenes but by more subtle changes within an image during a given shot. Loosely phrased, the geometry was jumpy. If one imagines the total image to be a kind of visual orchestra, the percussive beat-keeping was made by a stroboscopic emphasis of image subelements. In this way, I was able gradually to develop a visual idea, something akin to a musical melody, while sustaining immediate drama through rhythmic structure.

Rhythm can be sensed visually by discrete spatial changes in the viewing plane. Our visual perception is keyed to moving objects. They call special attention to themselves in the context of otherwise static imagery. This sensitivity to movement is another characteristic of visual psychology that has been important in developing a visual music aesthetic. Autonomous rapid eye movements, called saccades by psychologists, are an indication of mental activity. The brain is constantly commanding change in its visual sensory input. The eyes and head are repositioned to lend animation to static objects. A visual artist working in motion media such as film can provide the movement deliberately for the sake of expressing feeling. Rapid movement might provide excitement; slow movement might induce a more languid feeling.

In my films, deliberate control of movement is a primary concern. In *AtmosFear,* for example, a zoom carries the viewer through a tunnel to a dirty city street. The movement is slow, deliberate, and irresistible. The viewer is deposited in a scene by a kind of irreversible force

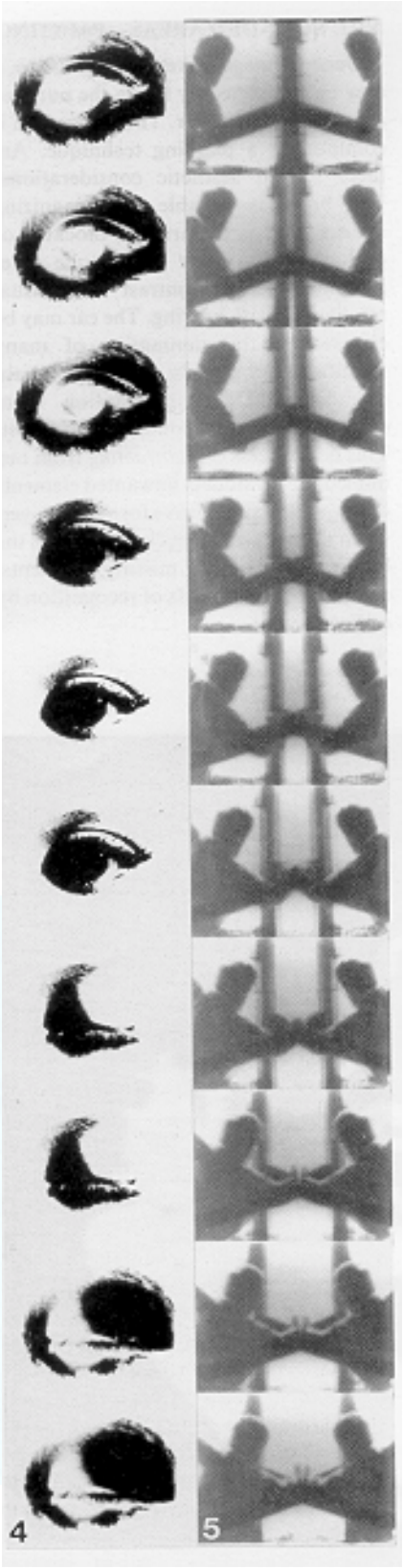

Fig. 4. Frame from *Off On*, film, 1967. A sequence of 10 frames indicating a rhythmic structure of 3 x 3, 2 x 2. This rhythm is accentuated by alternating negative and positive polarities.

Fig. 5. Frame from *The Leap*, film, 1969. The bilateral symmetry of a dancer and his environment force the eye to the image center, reinforcing a thematic motif, imprisonment. The sequence of images gives some impression of the movement.

This contrasts with the light headed circular pans of the Brooklyn Bridge which might have been inspired by a view of the world from a child's swing. At the conclusion of the film, the eye is taken on a rapid course along elevated subway tracks. The intention was to end on a note of visual excitement.

This is not to say that the mind always focuses on a moving object. If a background shifts rapidly while a foreground remains static, the mind tends to cling to the static foreground image. We can establish the feeling of rising or falling by showing an object in a fixed position against a background that moves down or up. Such feelings are akin to musical sensations; they have a universal nonverbal meaning. Much of the second half of *Fall* shows a skydiver descending against synthetic patterns that move upwards. Being the focus of the imagery, the parachutist never leaves the frame. However, the ascending patterns emphasize the sense of descent. Our brains have an instinctive emotional response to the visualization of falling, which was suitable for my composition devoted to the fall of Icarus.

VI. SYMMETRY

One of the most common intellectual constructs is polar duality, the symmetry of opposites. In living nature, bilateral symmetry is found everywhere, from mirror image sub-microscopic molecules to the macro-structures of organisms. The eyes, the optic nerves and the brain itself are structured according to bilateral symmetry. Following the logic of this investigation, the aesthetics of symmetry are suggested by these biological systems. Mirror-image symmetry, that is, symmetry along a vertical axis, is uniquely visual, because it is the most prevalent. We see it in our bodies, and we may well feel it in our brains.

The hypnotic effect of symmetrical images was introduced to me by Scott Bartlett, who developed the second half of *Off On* by using symmetrical image printing techniques. The section was very successful aesthetically and left a deep impression on me [24]. However, I felt that the quadrilateral symmetry used in some shots was less striking, more mechanical and compulsive in feeling than the technically less complex bilateral mirror image symmetries in other sequences.

I first used symmetry in my project, *The Leap* (1969). A dancer moves in front of a barrier. As originally filmed, the dancer moved constantly to the left, tracked by a camera pan. When the image was printed superimposed over its mirror symmetry, a tension was created, focused on the middle of the frame (Fig. 5). To my eye, the dancer could not 'escape' the image frame, but each movement tightened the focus on a visual enclosure. In the symmetrical image, the dancer was always reaching toward the center of the frame, counterposed against himself. The image worked well in a visual poem that dealt with the dilemma of being trapped in an externally imposed definition of one's own personality.

In *The Leap I* used symmetry thematically, but symmetry also has a purely decorative effect, most clearly seen in another collaborative venture, *Calypso Cameo* [25], which was based on a process called 'dynamarhythmic symmetry' [26]. Rather than strictly bilateral, these symmetries are created by rotating geometric primitives around a center axis. The effect is similar to Whitney's visual harmonies, but the technical description is quite different. These symmetries are formed by the relationship of the ratios between the sides of a two-dimensional geometric object and the angle of rotation. In the case of the perfect rectangle, the rotation describes a series of rectangles of decreasing size, each with the same ratio between the sides. In fact, it was this relationship that the Pythagoreans used to describe the square root of the number 2.

At the time of this writing I am using bilateral symmetry in visual music performance. The Pantomation system, described above, is used to control a laser projector. The movement of the artist is projected in bilateral symmetry, so each movement appears as a symmetrical pattern. I have used the effect both for abstract sequences and to draw representational images such as faces, birds, and butterflies.

VII. THRESHOLD BORDERS-DRAWING

Artists often begin a painting by drawing outlines of areas they plan to fill in later with detailed brushwork. In keeping with the methodology of this inquiry into the development of a visual aesthetic, we must make special note of how artists pursue the development of their arts. If visual artists use outline drawing as a method of organizing images, we must consider the aesthetic implied by such draughtsmanship. Additionally, we note recent studies in psychology which have indicated that the brain processes visual imagery by perceiving thresholds of change in image intensity [27]. These thresholds are the

outline edges of solid image areas. Outline information can be extracted from photographs by electronic or photographic processes. We can express what we see by extracting outline information from scenes of complex shading.

My first use of outlines came in *AtmosFear,* where I used both the Sabatier solarization effect [28] and off-register printing of negative and positive images. Almost a decade after this work, I was using an electronic outline generator, particularly for my pantomime piece, *War Mime* [29], in which an image is echoed for many iterations, each echo represented by an additional outline. The effect is related to that achieved by McLaren in *Pas de Deux* [30], although his outlines were achieved simply through lighting. In *Just a Day in the Life of* ...[31], 1 used the outline generator to show an out-of-body experience, as the reclining figure falls through its outline (Fig. 6). One can see literally from this image how an outline 'falls' out from an image with solid shading.

I appreciate the efficiency of outlines, because in computer graphics the amount of memory required to store an image is often a limiting factor. My Pantomation system reduces complex scenes to a few key points forming an outline in space. One can draw with it as one would with a pencil. The efficiency of outline generation permitted me to store images in a microcomputer without taxing either its memory or processing power [32, 33]. Some of my work today is focused on algorithms for converting raster-scanned images such as television into a simplified vector format for display with a laser projector. The type of laser projector I use is capable only of making outline drawings [34].

VIII. BOUNDED AREAS-PAINTING

Once an image is sketched in outline, it may be completed by filling the outlined areas with solid color. This procedure is common as a painting technique. Are there related aesthetic considerations? The brain is capable of recognizing images that are partially blocked or occluded from view by opaque foreground objects. Contrast this visual mechanism with hearing. The ear may be exposed to the summation of many simultaneous sounds, but the brain extracts coherent information from subsets of the total sound environment. This is a process of *subtracting* from our immediate awareness unwanted elements of a complex audio wave form. However, when the eye sees an occluded object, the brain fills in the missing elements, completing the process of recognition by *adding* pieces.

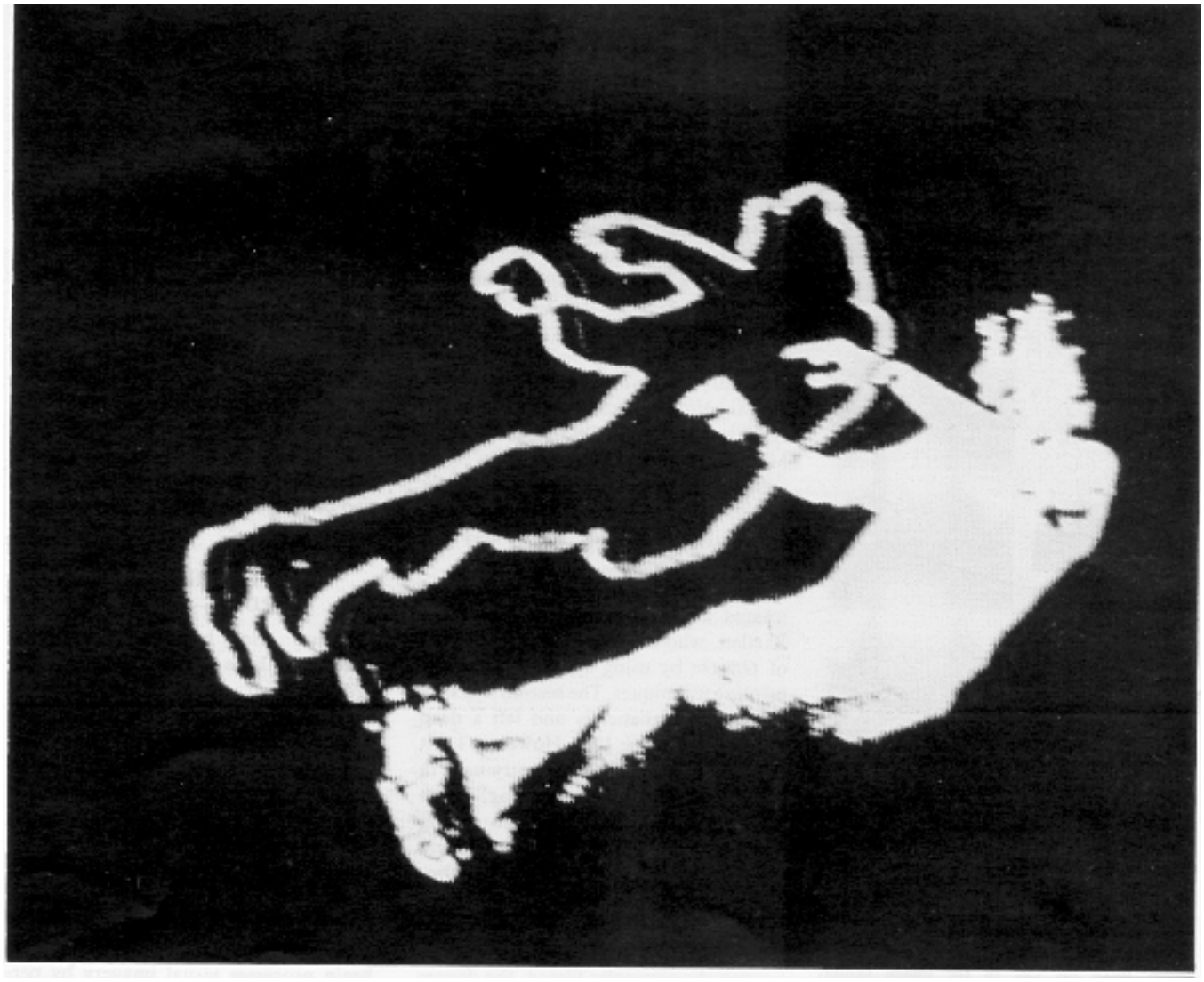

Fig. 6. Frame from *Just a Day in the Life of...*, videotape, 1975. The outline of a mime literally shows how edge information 'falls out' from shaded solid fields. The simplified outline, like the clown-white face of the mime, is elegant in its simplicity.

Such a powerful mental mechanism is surely a springboard for aesthetic discovery. The process bears a similarity to painting, that is, filling in contiguously bounded areas with solid imagery. The painter decides what portion of an occluded image to reveal. The decision may be made to facilitate the viewer's mental reconstruction of a blocked object or to tease the viewer with a hint of something missing.

The simplest form of creative judgement in creating bounded areas is the cropping or framing of an image. Here the artist imposes a limit on the field of view within the artwork. For the filmmaker or video artist, this frame is fixed by convention. However, the motion media such as film and video offer the artist a new horizon, the ability to change the parameters of interior occlusions as a function of time.

The creative team of WTV (Dean Winkler, Tom DeWitt and Vibeke Sorensen) explored the aesthetics of motion painting by investigating techniques that reproduce the aesthetics of two types of painting: watercolors and matte knife oil painting. In *Aquarelles* [35], bounded areas were sortened electronically and the colors within the bounded areas were allowed to flow into nearby spaces (Fig. 7). Moreover, the colors within a bounded area were dynamically mixed over time by recursive feedback through a digital frame buffer. The effect made the colors run together, as if in a water medium. The videotape *Koan* followed a different procedure. Here bounded areas were sharply divided, as if cut by a matte knife (Color Plate No. 1). The most recently created image appears in the foreground and occludes the remnants of previous frames which have been accumulated in a digital frame buffer.

The key to much of this work is called exactly that: keying. The term is used in video to describe a process by which images are electronically combined. In graphic art and modern pictures, the term commonly used for this technique is matting. The artist creates a composite image by overlaying discrete images. The sensibility of the artist determines where to place images so that occluded background objects will be sensed in their entirety. The matte or key determines where these occlusions will occur and the transparency of the foreground image.

As my work progressed into threedimensional representation of solid objects, I encountered a related graphic device, hidden line removal. In threedimensional space, occlusions are implied by the distance of an object from the viewer. Objects closest to the eye occlude all others further back along each line of sight. Although this may seem intuitively obvious, the computer programming required to achieve the effect is not. A substantial effort is now underway to achieve efficient methods for hidden line

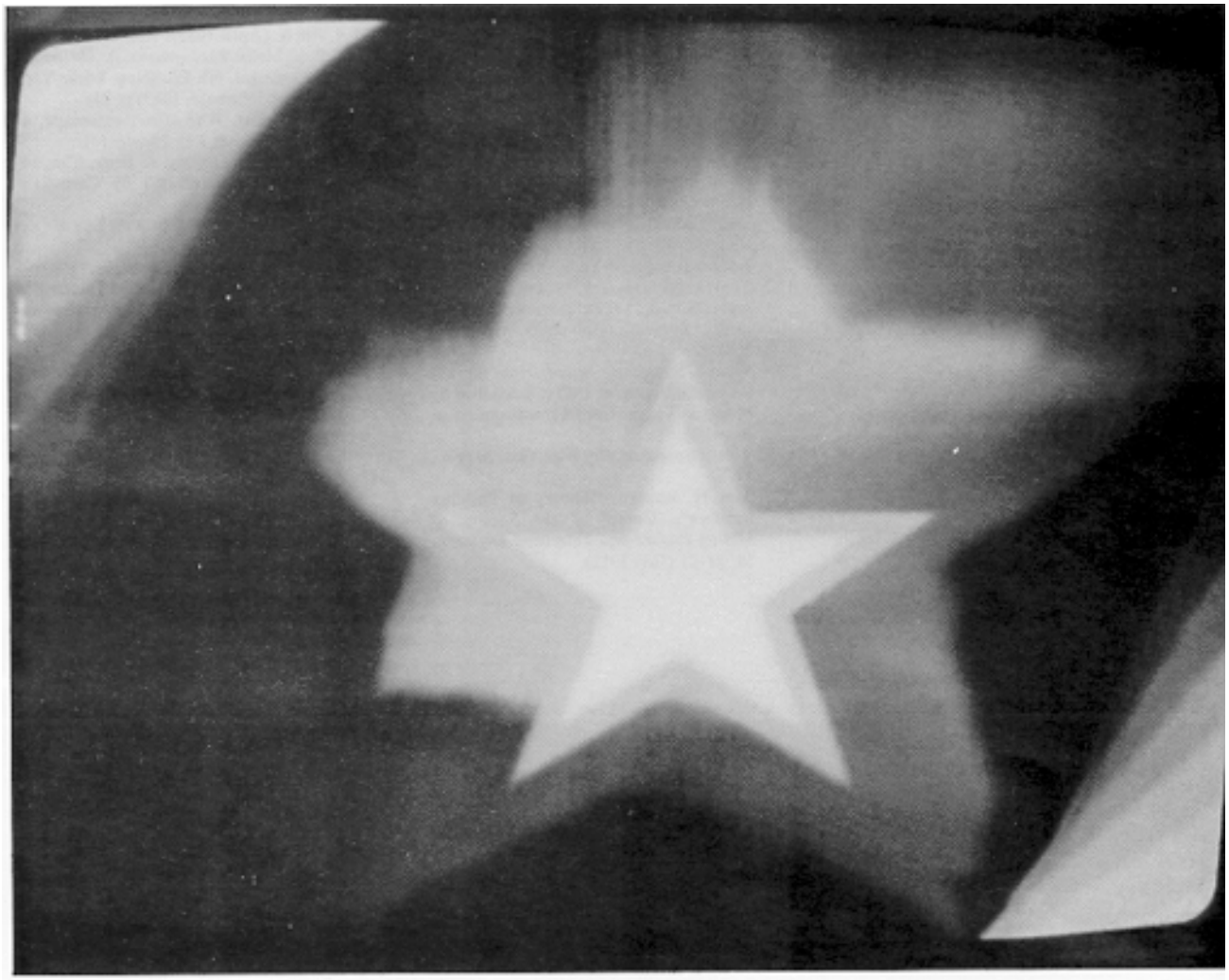

Fig. 7. Frame from Aquarel%s, videotape, 1980. A sharply edged five-pointed star oozes into a watery surrounding, much as watercolors spread on a wet substrate. This electronic technique helps build a bridge from motion graphics to a traditional painting medium.

removal in computer-generated graphics. Perhaps such research can be said to confirm that the development of the visual arts is motivated by the unique characteristics of the psychology of perception.

IX. CONCLUSION

A new art form, visual music, is emerging. Its aesthetic can be deduced partially by examining key features of human visual perception: the structure of the eye, the nerve pathways from the eye to the visual cortex, and functional characteristics of the brain. The precursors to visual music are traditional music and visual art, and their aesthetics are quite relevant in instructing the infant art form. The artists working in visual music are guided by an intuitive grasp of how certain images can directly induce emotional responses. The natural genius of such creators must be respected as an indicator for directions to be taken by the art. This is an exciting era, for we are witnessing the birth of a branch in the cultural tree. If the importance of aural music is any indication, visual music may become a major vehicle for artistic self-expression.

Acknowledgements-The author would like to thank Jim Modestino, Director of the RPI Image Processing Laboratory, for providing acess to photographic and computing facilities. Madlyn DeWitt, the author's mother, has helped in many ways, and he particularly would like to thank her for her editorial assistance in preparing this manuscript.

REFERENCES AND NOTES

1. H.L. Helmholtz, *On the Sensations of Tone as a Psychological Basis for the Theory of Music* (New York: Dover, 1954).
2. George Chaikin and Carl Wieman, "Logarithmic Spiral Grids for Image Processing and Display", *Computer Graphics and Image Processing* **11**, 197-226 (1979).
3. E.L. Schwartz, "Spatial Mapping in the Primate Sensory Projection: Analytic Structure and Relevance in Perception", *Biological Cybernetics* **25**, 181-194 (1977). Tom DeWitt, *Philharmonia*, videotape, 10 min., 1974, in *Cathode Ray Theater* (Distributed by Electronic Arts Intermix, New York).
5. John Whitney, *Digital Harmony* (New York: Byte Books, McGraw Hill, 1980). The title is somewhat misleading. Much of the Whitneys' work and much of my work were realized with analog devices.
6. Tom DeWitt, *Pantomation*, videotape, 10 min., 1980, in *SIGGRAPH Video Review*, No. 2, Section 9 (1981).
7. Peter Wetzler, "Music Mouse by Laurie Spiegel", *Ear Magazine of New Music* **10**, No. 5, 6 (New York: New Wilderness Foundation).
8. Tom DeWitt, "Pantomation-Scoring and Performance Interface", *Ear Magazine of New Music* **9**, No. 5, 68 (New York: New Wilderness Foundation, Fall 1985).
9. John Whitney [5] p. 90.
10. Tom DeWitt, *AtmosFear*, film, 6 min., 1966 (Distributed by Museum of Modern Art, New York).
11. *WTV, Koan*, videotape, 3 min., 1981, in *TeleVisions* (Distributed by Electronic Arts Intermix, New York).
12. Tom DeWitt, *TheLeap*, film, 8 min., 1969 (Distributed by Canyon Cinema, San Francisco).
13. Dean Winkler, *First Experiment with Bryon's Solids*, videotape, 5 min., 1980 (Distributed by Electronic Arts Intermix, New York).
14. Tom DeWitt, *Fall*, film, 16 min., 1971 (Distributed by New York Filmmakers Cooperative, New York).
15. Tom De Witt, This Is *TV-America*, videotape, 28 min., 1979 (Distributed by Art Dept., Syracuse University, Syracuse, NY).
16. Vibeke Sorensen, *Micro Fishe* et al., stereo photographs,1985 (Distributed by Modern Visual Communications, Los Angeles).
17. Vibeke Sorensen, *Hot Wax*, film, 30 min., 1978.
18. Sam H. Kaplan, "Theory of Parallax Barriers", *Journal of the Society of Motion Picture and Television Engineers* 59, 11-21 (July 1952).
19. Tom DeWitt, "Rangefinding by Diffraction", U.S. Patent.
20. Robert Hughes, *The Shock of the New*, (New York: Knopf, 1981). Hughes is hardly the first critic to observe how twentieth-century art flattened the image, but he eloquently presents this observation in both a book and a companion television series.
21. Scott Bartlett, Tom DeWitt et al., *Off On*, film, 10 min., 1967 (Distributed by Museum of Modern Art, New York).
22. John Cage, *Silence*, lectures and writings, 1961 (Middletown, CT: Wesleyan Univ. Press, 1961). John Whitney takes exception to Cage's views on music and makes an argument advocating a return to harmony. Cage's rejection of traditional rhythmic structures calls for a similar rebuttal.
23. Tom DeWitt, Joel Chadabe, George Kindler, Vibeke Sorensen, *The Rhythm Machine*, videotape, 10 min., 1979.
24. Tom DeWitt, "*Off On*, The Binary Hangup", *Film Magazine* (San Francisco State College), **1**, No. 1, 17 (1968).
25. Tom DeWitt and Vibeke Sorensen, *Calypso Cameo*, videotape, 2 min., 1983.
26. Edward B. Edwards, *Dynamarhythmic Design* (New York: The Century Co., 1932).
27. Tomaso Poggio, "Vision by Man and Machine", *Scientific American* **250**, No. 4, 106 ff. (April 1985).
28. C.B. Neblette, *Photography, ItsMaterials and Processes*, 6th Ed. (New York: Van Nostrand Reinhold, 1963) p. 218.
29. Tom DeWitt, *War Mime*, videotape, 4 min., in *Cathode Ray Theater* [4].
30. Normal McLaren, *Pas de Deux*, film, 14 min., 1969 (Distributed by Canadian Film Board).
31. Tom *DeWitt,Just a Day in the Life of...*,videotape, 20 min., 1975.
32. Tom DeWitt and Phil Edelstein, "Pantomation-A System for Position Tracking", *Proceedings of the Second Symposium on Small Computers in the Arts*, No. 455 (IEEE Computer Society, 1982) p. 61.
33. Tom DeWitt, "A Pantomation Interface for the Apple II", *Proceedings of the Third Symposium on Small Computers in the Arts*, No. 499 (IEEE Computer Society, 1983) p. 25.
34. Alan Jackson, "Laser Shows-The Use of Computers", in *Proceedings . . . [33]* p. 115.
35. WTV, *Aquarelles*, videotape, 7 min., 1980, in *TeleVisions* [11].

No. 1. Upper right. WTV (Dean Winkler, Tom DeWitt and Vibeke Sorensen), frame from Koan, videotape, 1981. This electronically processed image emulates matte knife painting in oil. Boundaries are sharply defined or are marked by straight line strokes. The color scheme deliberately mutes the saturation of the background, although electronically the 'sky' was formed by tracking the movement of the hands in the foreground. (See Artist's Article by Tom DeWitt).

No. 2. Center. Liliane Lijn, A Ritual Dialogue: Woman of War and Lady of the Wild Things (Woman of War, painted steel, aluminium, synthetic fibres, glass tank prism, aluminium mesh, glass beads, piano wire, audio system, 5 milliwatt helium-neon laser, smoke machine and computer, 8'9" high, 1986; Lady of the Wild Things, painted steel, synthetic fibres, optical glass prism, aluminium mesh, light emitting diodes and a sound-to-light microprocessing system, 8' high with an 8'wing spread, 1983). These sculptures are female archetypes performing a ritual dialogue. One is aggressively active, whereas the other is reflectively passive. Together they form a communicative whole

No. 3. Lower right. Hand-blown cups for the modern glass harmonica, made of resilient semi-conductor-grade fused quartz glass. Each cup is shaped, then tuned either by grinding or by etching and, finally, flamed. Liquid gold bands are painted and then baked onto the sharps and flats to mark them. Each cup sits on its own cork, which is slid onto the central steel shaft. (See Document by Finkenbeiner and Meyer.)