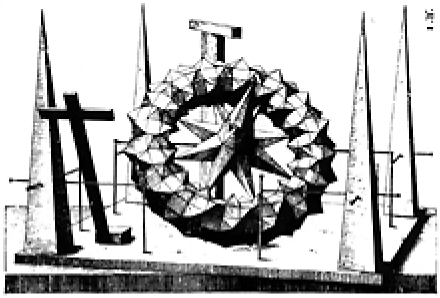
On the History and Aesthetics of the Digital Image

Peter Weibel

I.

Probably the most significant event since the very invention of the image are the changes in man's conception of the image that the advent of the digital image is entailing. However trenchant and decisive this may be, the history of the image already prepared the ground for it.

If we assume that the major distinction between the traditional image and the digital one is that the classical form of depiction is analogous, that is, it follows the principles of similarity, congruency and continuity, and that the electronic form of depiction is digital, that is, it uses the smallest, discontinuous, non-homogeneous elements, then we can depart our reflections to this topic from those movements in art which advanced the rupture in the traditional conception of the image. This extends from the insurrection of the abstract at the beginning of this century to kinetic art.



Wenzel Jamnitzer: Perspectiva Corporum Regularium, 1568

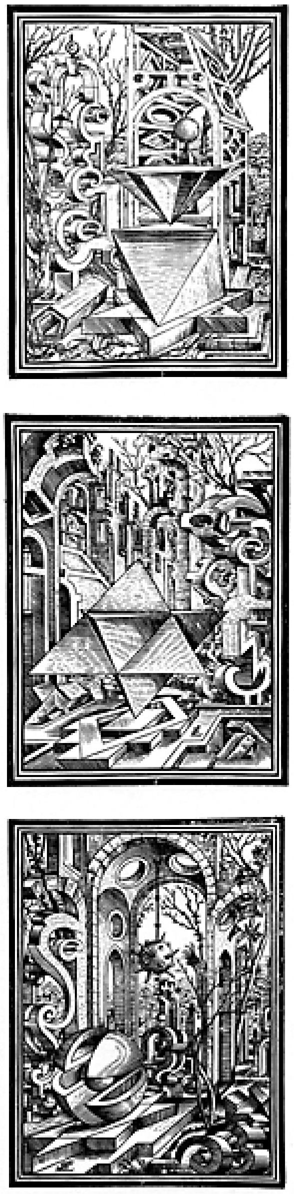
In accepting this distinction (from the concept of "digital art" evolves dialectically the concept of "analog art" which by definition signifies nothing else than classical art), we must overlook certain philosophical incongruencies. So, for instance, the fact that there are of course analogous elements in digital art and digital elements in analog art, since in the last analysis, any continuous analogous process can be reduced to small discontinuous pieces, in the same way a continuous line can be constructed from discontinuous dots. In the latter case, the distance between the adjacent dots is so small that it can no longer be discerned by the human eye. This awakens the illusion of a continuous line when in fact the distance exists numerically and can be represented. Digital art does exactly this: it allows analogous processes in nature to be represented digitally.

By means of dots that correspond to a specific number, the computer is able to generate a line on a connecting monitor. The monitor screen is a sort of number field in which each number which consists either of a digit, digit pair or a sequence of digits, (e.g. 00101) can be matched with a dot. The representation of numbers is generally performed with two digits (0/1), so-called binary digits, since this is the only way numbers can be represented electrically, that is, by means of electrical impulses for one and no impulses for 0. Thus we can say that digital representation and binary representation are linked to each other.

The computer then computes the number sequence, that is, the sequence of dots which on the connecting monitor create the impression of a line. This, of course, is only possible when the resolution capacity of the monitor screen is so great that the distances between the dots can be made so small that this distance and the size of the dots can no longer be discerned by the eye, although they actually exist numerically.

For greater clarity, I will retrace some ground and go into further detail. When a monitor screen has only a small resolution capacity, this means that it is a field of numbers comprising only few numbers. So that the small amount of numbers (= dots) can fill the field they must be large enough since of course it is only possible to fill this field with smaller number dots when there are more of them. 8

large dots, however, placed next to each other linearly over the surface of the monitor screen by no means must appear as a line. Rather, one needs a great number of dots in such quantity and so minute that they seem continuous as a line does. A display the size of a normal TV screen with about 600 rows to 800 dots is a number field consisting of 480,000 dots. It is easy to imagine how small these 480,000 dots have to be to fit in the screen and thus how easily the illusion of a line can be awakened. Since these dots can also have a different color, it is possible not only to produce forms but also color surfaces, so that the colored forms create the impression of motion and authenticity when they are changed, or rather, moved 25 times a second. The greater the resolution capacity is, the greater the number of dots or numbers available for depiction is, the greater the representation's authenticity, the better the illusion of realness and the more realistic the depiction actually appears. The efforts to obtain a greater resolution (e.g. 1000 rows) are born of the wish to achieve greater visual realism.



Lorenz Stöer: Geometria Et Perspectiva, 1567

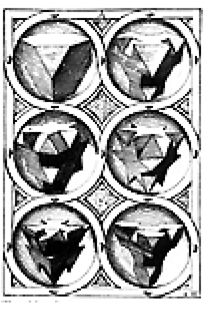
If one considers that this amount of numbers and dots is not activated by simply tracing the image input with a beam as in television but rather entering into a computer for computation, one can imagine the great number of calculating operations and algorithms (commands defining the steps) needed for creating the line of a human profile on the monitor screen. Here there are no images or a reality to serve as a model but only numbers and calculating operations which through electronic transformations create forms that then appear on the monitor screen as forms. This is called artificial image generation or synthetic imagery, the basis of which is the number. If one considers that numbers not only correspond to the dots but also to their colors and intensity, meaning that the computer monitor must deal with millions of numbers for a simple color image for which the programmer has to come up with an algorithm (a sequence of commands for the calculating steps), one can easily conceive how much calculating work is needed to make just one non-moving digital image. If these images are supposed to move in a natural way, too, needing to be changed 25 times per second, the amount of calculating operations becomes excessive, posing great demands on the rapidness and complexity of the computer's calculating power.

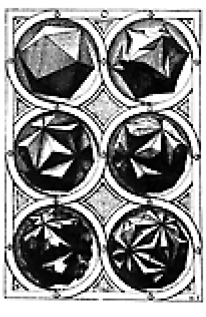
If we strain our imagination a bit more, we would expect the line drawn on a tablet with a light pen (joystick) to appear immediately and not only after lengthy calculating operations on the computer monitor screen and the movements on the tablet to be simultaneously followed by the line appearing on the monitor screen. By the same token, one would expect the sounds a pianist produces by hitting the keys to resound right away—and not later. This must take place in "real time"; thus the piano can said to be a "real-time display".

The enormous amount of calculating that the computer must surmount within a second of time can, of course, only be accomplished by super computers. For this reason, the motion and forms of figures on the screens of video games are clumsy, the low level of their motion and representation hardly awakening the illusion of realness. The calculation procedures required for higher levels implemented in microchips simply cannot be performed. The same holds true for personal computers.

In the field of digitally moved images, digital computer animation, there is not only a demand for monitors with greater resolution but also for super-computers that are increasingly rapid and large, since only these computers are able to perform the enormous amount of calculations required for the forms, colors and movements created numerically by the computer to appear on the monitor screen or (transmitted by laser) to appear on the film strip with an impression of realness. If one could buy the world's most rapid computer, one would come closer to the goal of generating, metaphorically speaking, colorful moving forms corresponding to natural objects in the real world by means of comprehensive calculating operations across the number field of the monitor screen. This means not only processing huge amounts of data regarding position, intensity, color, etc. of hundreds of thousands of dots within fractions of a second, but also computing the calculating operations needed for their control (= formation) which can only be done numerically as well. Such digitally generated images can, given the optimal resolution and calculating capacity of super-computers, produce increasingly realistic simulations of 3-D objects and events.

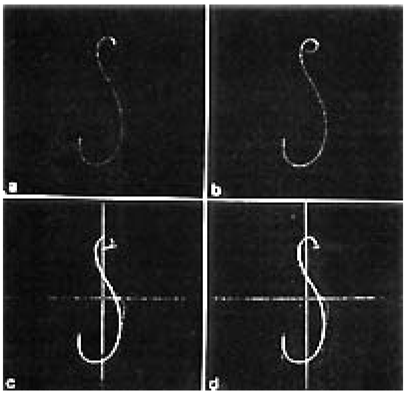
DIGITAL PRODUCTIONS in Los Angeles has the most rapid computer in the world, CRAY-1, of which only about 25 exist running 24 hours a day. The digital image is supposed to simulate 3-D objects and events realistically by means of "digital scene simulation" as the company calls this method on the basis of computer-generated moving images: "a film-design studio creates reality by computer"—this is the ultimate goal of the digital image. Is it this? The contrary, I would say, since it is the essence of the digital image rather to create more than reality by computer, but to look more real. The basic principle (in the sense of the idealistic German ontology) of the digital image is precisely to make non-reality realistic by computer. We don't need any moving photographs but rather the digital image to move beyond these, transforming the depiction (of reality) into a generation of images (of a new reality).





Wenzel Jamnitzer:Perspectiva Corporum Regularium, 1568

The digital image unites the possibilities of painting (subjectivity, freedom, non-reality) and of photography (objectivity, mechanics, reality). Reproduction and fantasy, the two estranged sisters, are reconciled in the digital image. In the future it may be possible to speak of digital film or digital video, since the digital image can be realized in any medium.



Curve fitting having nonzero curvature at an end, 1978

The digital image which allows one to intervene in each section of the picture surface as freely as the artist can in the canvas to form each portion of the picture as one wishes does not just emancipate the art apparatus from its torturous and constricting mechanics but also liberates our thinking in images par excellence from its many constraints. Thus the digital image is the first real foreboding of the "liberated image" like the digital sound of "liberated sound" the program of which was set down at the turn of the century. The art of the twentieth century has undertaken the emancipation of the image in two phases. In the first half of the century with Futurism, Cubism, Cubofuturism, Suprematism, Dadaism, Surrealism, etc. In the second phase with Action Painting, Fluxus, Happening, Pop Art, Kinetism, Op-Art, Ambiente, Arte Povera, actions, performances, etc.

Aspects of this emancipation are visible as features of the digital image. I mention only the color forms of the abstract up to the Informel, the machine iconography of Dadaism (from Hausmann to Picabia), synthetic image findings and object transformations of Surrealism (from Dali to Magritte), the interaction and participation present in Happenings, etc. In the visual music films, or videos, abstract color impressions appear once again; also Surrealist collages, since the digital image is a collage expanded in terms of time and the number of spatial layers, as well. This collage is a composition in time and, similar to music, has left the two-dimensionality of the surface for the fourth dimension. The raster-technique (Lichtenstein, Warhol, Dieter Rot, Sigmar Polke, etc.) is still another tacit characteristic of the digital image, like the participation of the audience in video art (from installations to video games).

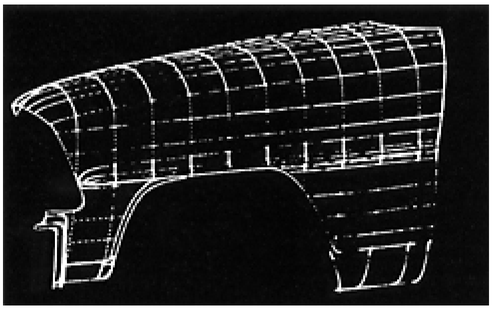
Many of the aesthetic aspects of earlier forms of art are directive for digital art, which, however, transcends these. The examples one could still name for this are too numerous. The plotted line of some drawings by Matisse up to Warhol have ended in the plotter (a drawing device of the computer). From Pointillism to Divisionism all the way up to the raster-technique, there are dot-techniques that call painting as an analog art into question. The synaesthetic concepts of the total artwork from the turn of the century already formulated the program of music videos: to make visible what is audible. The actual development of electrical and electronic art began in the mid-sixties: on the one hand, in popular music: light shows, slide projections, films, pulsing fluid elements, experiments with the electrical guitar. On the other hand, in avant-garde: video art which could reach back to the great tradition of the abstract film; neon works, installations, etc. In the media art of today, one mainly finds mixed forms, in art as well as in popular culture. Lucas' super-productions as well as Laurie Anderson's music videos use film, video techniques and digital technology to an equal extent. We are standing before the quantum leap: digital image-works are becoming independent of other artistic forms, digital art is becoming autonomous. The most noticeable transformation of the digital image with respect to the phenomenology of its aesthetics and its relation to the classical analogous image (in spite of all genealogy) is best illustrated in the transition of the monitor screen of TV to the computer screen.

To the extent that the picture surface of the TV has become a familiar source of imagery, the computer monitor screen seems alienating and disturbing.

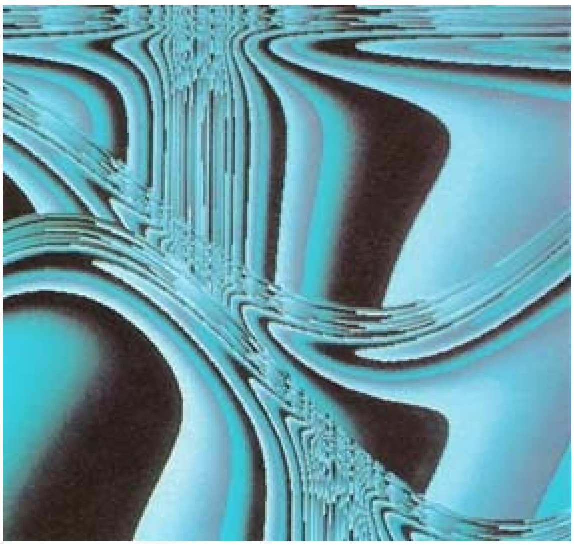
This is because the TV carries on with the passive consumption of conventional picture codes where as the computer demands an interaction with new pictorial codes. The transformation of the TV screen into a computer screen through the connecting video displays, which make a computer out of a static object, also signifies another change: the monitor suddenly assumes a new aesthetics of information and communication.

If it is the special feature and advantage of digital art that it is ideally suited for digitally depicting analogous processes in nature, if, in other words, a pictorial technique perfectly matches its object as digital scene simulation (the digital realistic simulation of 3-D objects and events in time) does, then this can only mean that the world itself is digitally organized, that everything analogous is also expressible in digital form. Thus digital art is becoming a more and more adequate expression of our world.

Alan Norton: "Fractal Domains af Attraction — 9", 1983



A CRT picture drived from an image desribed by approximately 2,500 short line segments, 1968



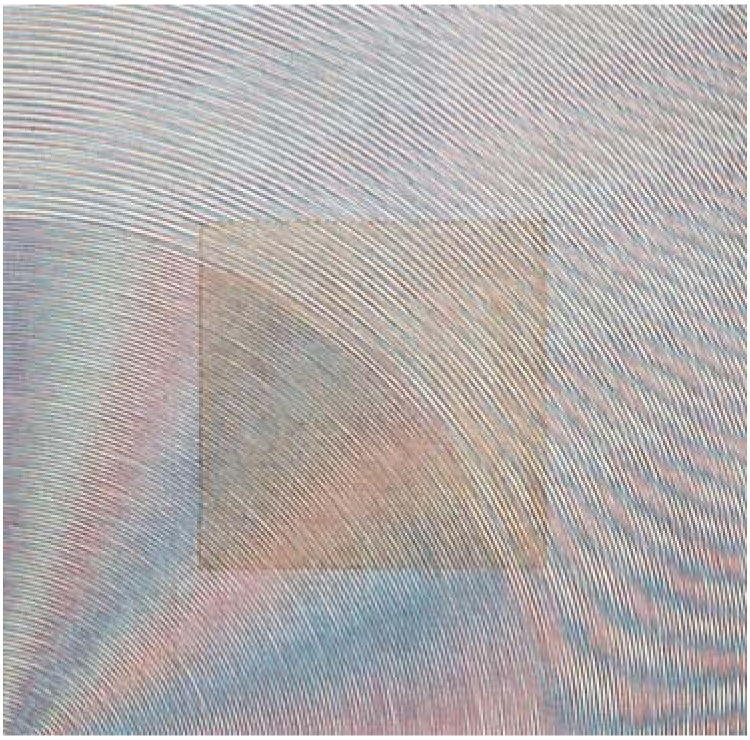
Frank Dietrich, Softy 3", 1983

II.

Computer graphics can be said to have formally begun with the work of Ivan E. Sutherland in 1963 (1). Sutherland is a disciple of the pioneers of information and image processing machines at MIT, Claude Shannon, Marvin Minsky and Steven A. Coons. Sutherland works now at the University of Utah, Salt Lake City, a center of computer animation and digital images in the United States. In his now classic thesis, he showed how a computer could be employed for interactive design of line drawings using a simple cathode-ray tube display and a few auxiliary input controls. Others had already connected CRTs to computers in the early fifties to generate simple output displays. But it was not until Sutherland developed his system for man-machine interactive picture generation that people became aware of the full potential offered by computer graphics.

The realization of this potential, however, was slow to develop. Three major barriers were encountered. The first was the then high cost of computing. It was quickly discovered that computer graphics, especially if it were to be interactive, imposed inordinate demands on the computer in terms of both processing requirements and memory size. During the sixties, the cost of meeting these demands could be justified only for research purposes in a few universities and some large industrial research laboratories.

The second barrier was a lack of understanding of the intricacies of the picture-generating software that would be needed for an effective computer graphics system. It was soon learned that one had to develop a data structure that in some sense would mirror the often barely realized but visually obvious relationships inherent in a two-dimensional picture. (In fact, the origin of much of today's data management theory can be traced to early work in computer graphics). Algorithms for hidden-line removal, shading, and scan conversion were needed and generally proved far more complex than was first anticipated. Even as ostensibly simple a task as drawing a straight line segment or arc of a circle on a digitally-oriented display turned out to require algorithms which were by no means trivial.

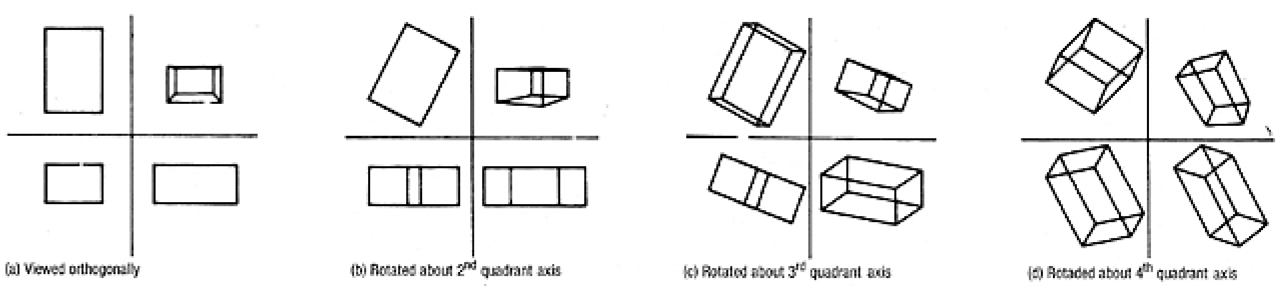


Christa Schubert: Untitled", 1983

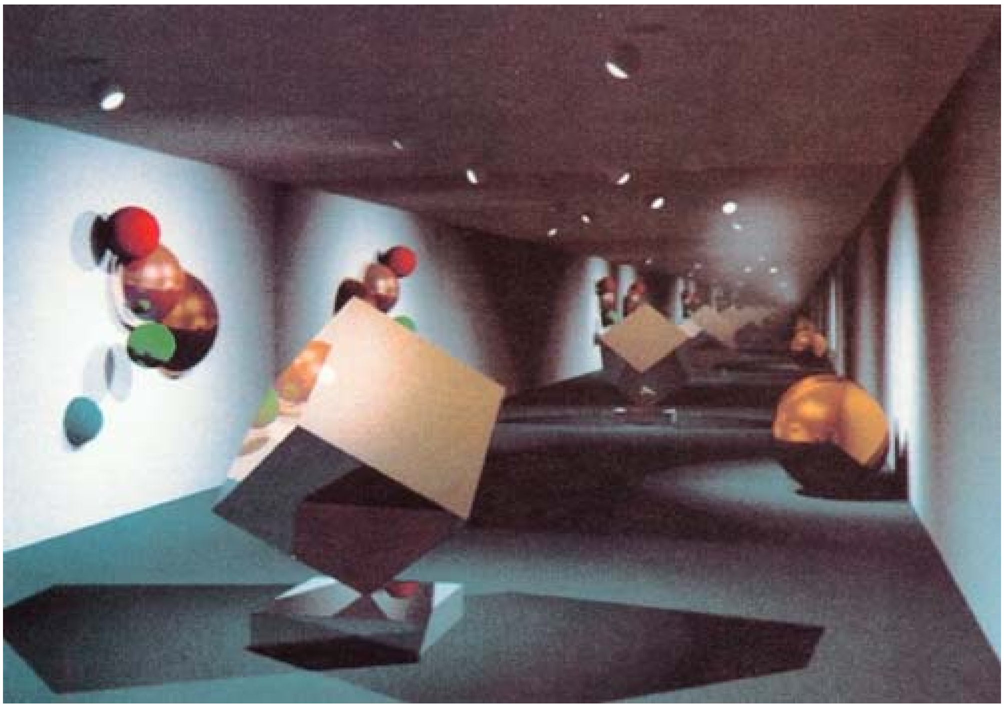
Fortunately, as it has many other technological innovations, time favored computer graphics. The cost of computer equipment kept dropping year after year, while that of labor kept increasing. Operating systems were improved, and our ability to cope with complex software became more sophisticated. Impressive progress was made in the development of algorithms for generating pictures, specially those intended to represent views of three-dimensional objects. The progress, though slow, has been sufficient enough that now, at the beginning of the eighties, computer graphics is finally becoming accepted as an effective, powerful, and economically sound tool of the engineer, scientist, designer, manager, illustrator, and artist.

Computer graphics entails both hardware and software technology. As with conventional numerical computing, we may have both batch and interactive modes. In the batch (or "passive") mode, the speed with which pictures are generated is of secondary importance, and they may appear on a digitally controlled pen plotter, or a CRT. For the interactive (or "active") mode, the time of picture generation is critical, and the display must appear on a CRT, or a plasma panel.

In the early days of computer graphics, primary attention had to be given to the hardware. This is much less true today, since excellent high-performance hardware has become available from many manufacturers. Instead, the emphasis has now shifted to the algorithms for generating the various kinds of pictures that are desired (line drawings, gray scale shaded pictures, color pictures, perspective projections of three-dimensional objects, etc.) and to the software for conveniently programming (i.e. "drawing") the pictures.



Additive rotation, beginning at (a) of a "wireframe" box about axes perpendicular to the orthogonal viewing quadrants. The 1^{st} quadrant in each subfigure shows a perspective view of the 3^{rd} quadrant or front view. 1963



Roy Hall: "The Gallery", 1983

GRAPHICS SYSTEMS

Timothy' Johnson's paper (2) may be considered an extension of Sutherland's work from two to three dimensions. In a simple, straightforward manner, it guides the reader through the techniques needed to design three-dimensional, planar-faced solids using the orthographic and perspective two-dimensional projections familiar to every engineer and designer. Homogeneous coordinates are introduced to permit 3-D translation, rotation, and scaling to be accomplished with a single matrix multiplication. Johnson adopted this technique from Roberts' work (3) relating to this description of three-dimensional solids. The paper addresses many of the subtle problems encountered in trying to design a three-dimensional plane. In a real sense, this paper is as much the forerunner of 3-D graphics as Sutherland's first paper is the forerunner of computer graphics in general. Already in Sutherland's paper, the need is pointed out for structuring the image-defining data in away that will facilitate the various manipulations one needs to perform on the data in an interactive computer environment. In succeeding years, this realization was strongly reinforced as more researchers took up the challenge offered by computer graphics. Data transformations known to be conceptually simple could become horrendously costly in computer time without careful attention to data structure. Indirectly, in the progress of studying how to do graphics with a computer, much insight was gained in how we humans perceive 2-D and 3-D structures and subconsciously draw on much "world knowledge" available to us. The development of effective data structures was recognized as one of the key challenges facing computer graphics; and much attention was devoted to it.

GRAPHICS FACILITIES

Interactive computer graphics—the word "interactive" is almost always assumed when one refers to computer graphics—requires the availability of a display medium in which a picture can appear within a fraction of a second after all the necessary data for it has been generated by the computer.

The "third-generation" graphics terminals, rather than relying on software to perform the transformations of scaling, translating and rotating, are equipped with special high-speed hardware which is used to perform these transformations "on the fly"—that is, in a continuous manner as the image-describing data list is converted by the display processor to electrical analog signals which cause the desired deflections of the CRT beam. As a result, the transformations are accomplished essentially without any loss of time. Previous graphics terminals permitted the display of "moving" images by having the display processor transform (scale, translate and rotate) slightly the images from one display frame to the next. This worked well for simple images (generated by small image lists). For larger images, even the most powerful computers proved unable to compute the required transformations fast enough to permit refreshing the image at the required 30 frames per second. An unpleasant flicker of the image was the inevitable result. Also, recognizing the importance of fast transformation for 3-D graphics, Hagan and his associates (4) extended the hardware transformation capability at once to three dimensions. The ready facility for modeling 3-D objects IN MOTION represented an important advance in the field. In more recent years, high-speed digital transformation has replaced the analog circuitry. However, the general design concepts described in this paper still govern the architecture of high-performance graphics terminals.

In recent years there has been an increasing interest in raster displays over vector displays. Raster CRT displays offer the potential advantages of permitting the use of inexpensive black-and-white or color commercial television monitors, of simplifying the refresh problem, and permitting selective erasure. Their main disadvantage is the need for a relatively costly refresh memory, although with the cost of computer memory dropping steadily in recent years, this disadvantage is becoming progressively less important. A second disadvantage is that line drawing data is normally SPECIFIED in vector form, that is, as a sequence of line segments defined in a display file in terms of the coordinates of the lines' endpoints. To display a line drawing on a raster display requires an operation known as scan conversion, in which the original line-segment-defining data is converted to appropriately positioned dots in the bit patterns of sequential scan lines.

Scan conversion is important not only for CRT raster display, but also, of course, for the various raster-scan hard copy devices such as electrostatic plotters and line printers.

Although line printers were never intended to serve as graphical output devices, their ready availability makes them appealing for both line-drawing and halftone graphics.

COMPUTER GRAPHIC TERMINALS

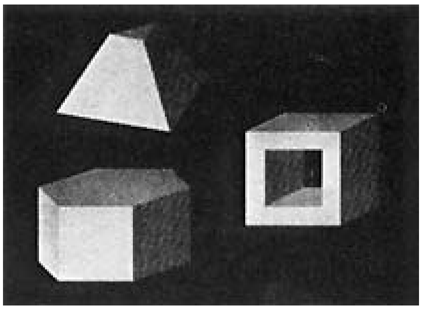
It is generally accepted that a computer graphic terminal is defined as one which contains means for graphic output (particularly in the form of a cathode-ray tube display) and means for graphic input (particularly in the form of a hand-operated electronic device for the input of pictorial information and for user interaction with the display). There are innumerable additional features normally associated with such terminals, the most common one being the inclusion of a conventional keyboard, often augmented by a set of special "function buttons", in the user's console. The more sophisticated terminal systems may also include means for quickly generating hard copies of displayed pictures, means for optically scanning hard copy input drawings, and conventional printers of various types.

Although computer-driven CRT displays were used, particularly for debugging purposes, in some of the earliest digital computer systems, widespread interest in graphic consoles is relatively recent and is due to the great emphasis presently placed on improving man-machine communication. It is clear that the present state-of-the-art in graphic terminals has been reached as a result of:

1. efforts to satisfy requirements for military terminal systems to allow machine operations to quickly comprehend and respond to real-time tactical situations;

2. recent improvements in display hardware (e.g. digital-to-analog and analog-to-digital converters, vector and character generators, etc.); and

3. the development of real-time computer systems which can efficiently handle large numbers of interrupts from peripheral devices.



A figure illustrating Shading Possibilities, 1974

Brad de Graf, Payson Stevens: "Entropy", 1983

ALGORITHMS FOR LINE AND CURVE GENERATION

A subject of considerable importance to both designers and users of computer graphics systems is the development of efficient algorithms for generating lines and curves. Since a refresh vector display image must be redrawn at least 30 times per second, the amount of picture data that can be displayed depends critically on the speed with which the data can be generated. Much effort has gone into the development of fast, hardware algorithms for generating vectors, characters, circles, and free-form curves. The problem is equally important when display output is to appear in hard copy on a digitally controlled pen plotter or a raster-line plotter.

The paper by Bresenham (5) is generally recognized as the first in which the generation of a digital line segment was methodically examined. The paper addresses the problem of finding the best digital approximation to a line segment specified by the coordinates of its endpoints. In a sense, it describes a "software vector generator" for a digital plotter.

A digital plotter consists of a pen that can be controlled to move stepwise in a unit distance forward or backward in the x direction, a unit distance (forward or backward) in the y direction, or any combination of both simultaneously. In effect, the pen is constrained to move from one node of an implicitly defined square mesh to one of the neighboring modes. It is thus not possible to draw a true straight line segment at any arbitrary angle. Instead every "straight" line segment—and, in fact, every curve—must be approximated by a chain of tiny, fixed-length line segments. The result is what is called a DIGITAL STRAIGHT LINE. Exactly the same effect is obtained if a line or curve is to be drawn with an electrostatic plotter (or simply with a line printer). However, in this case the curve is approximated by a chain of dots (characters, in the case of the line printer) located at the mesh nodes, rather than by tiny line segments connecting mesh nodes.

The problem of finding the "best" such digital approximation to a curve has interested a number of investigators. Some have concentrated on algorithms for which the approximation deviates a minimum from the true curve; others have shown a willingness to accept greater deviation in exchange for more rapid (or simpler) computation.

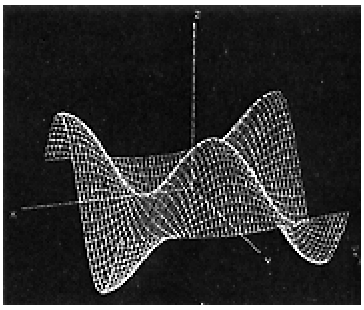
Efficient algorithms for generating good-quality digital approximations for a large class of mathematically defined curves, for the generation of digital "circles" and "free-form" curves have been developed in the seventies.

GRAPHICS LANGUAGES

The usefulness of a computer graphics system is strongly dependent on the effectiveness of the language available for creating the required abstract geometric structures and for displaying them on a CRT or plotter. Languages for computer graphics—just like computer languages in general—can be grouped into

1. low-level, assembly-type languages,
2. high-level, procedure-oriented languages, or
3. high-level, process-oriented (application-oriented) languages.

During the early and middle sixties, researchers developed a variety of graphics systems in striving to facilitate the application of computer graphics in a broad range of problems. In general, the early attempts at designing graphics languages emphasized the generation of line-drawing output and were confined to the use of graphical primitives in what were essentially assembly-type languages.



A complex figure generated using only the LINE primitive, 1974

Richard Voss: "Mount Mandelbroit", 1983

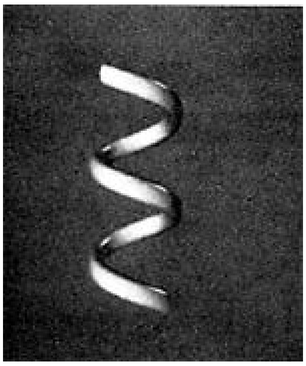
GENERATION OF HALFTONE IMAGES

Almost the early work in computer graphics was concerned with vector-type graphics—that is, output was displayed on a CRT whose beam was made to trace out the actual lines of the generated line drawing. This was fully satisfactory for all forms of engineering drawings and most architectural drawings. However, it did not readily lend itself to generating halftone images that could be used for displaying an object in terms of shaded or textured surfaces. Interest in generating halftone images finally developed in the late sixties. One of the first dealing with this topic was Bouknight (6) from the University of Illinois at Urbana. The algorithm he describes can be regarded as an extension of the Warnock (7) algorithm over which it achieved a considerable speed improvement by scanning the image in raster fashion. It thus not only generated a halftone picture but simultaneously was able to remove hidden surfaces. Its use, however, was limited to planar-faced objects.

A major advance in the rendering of halftone images was made by Gouraud (8). Gouraud approximated curved surfaces by means of small polygons so that discontinuities in shading at the boundaries would be eliminated. He was able to generate pictures of curved surfaces having remarkably smooth textures. The application of Watkins' algorithm readily permitted the elimination of hidden surfaces.

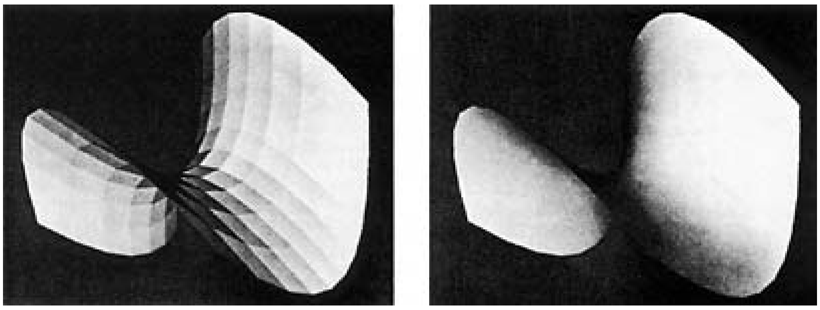
Catmull *(9)* of the New York Institute of Technology found a method for producing shaded images of curved surfaces based on the use of curved (bicubic) patches rather than polygons. The patches are as small as a raster element. Pictures of unusual realism were obtained, including pictures of "transparent" objects. The work in many ways represents the achievement of truly quality-textured pictures.

A careful study of the problem of computing the intensity for each pixel of a shaded raster-display picture was made by Blinn *(10)* of the University of Utah.

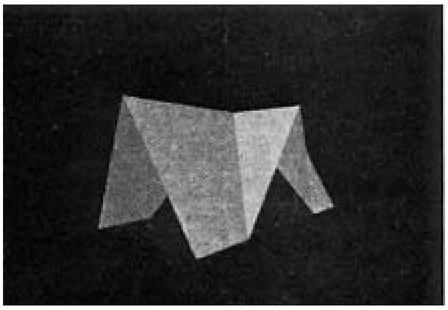
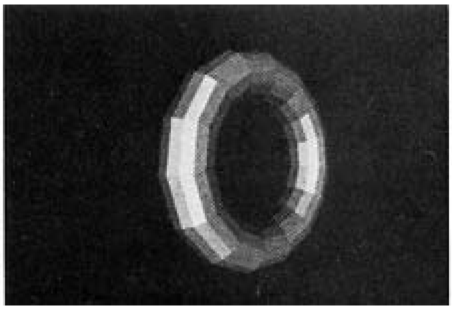
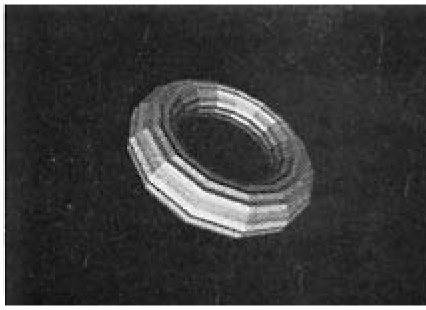


A spiral tube, 1975

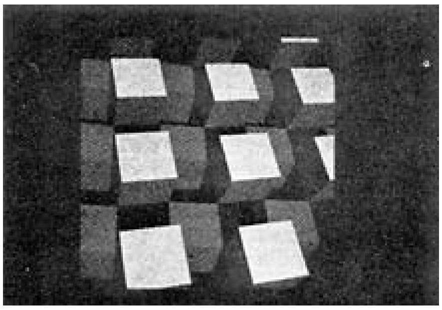
142 bottles and glasses, 1975



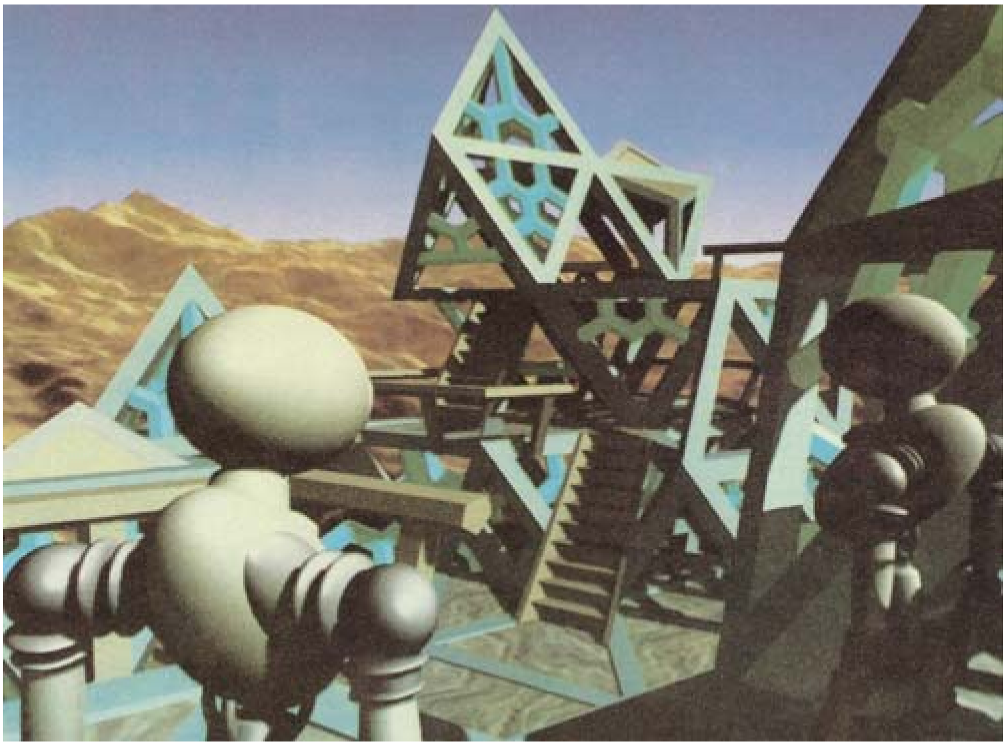
Left: Curved surface presented with Watkins algorithm. Computation time: 1 min 30 sec.
Right: Curved surface presented with author's method. Computation time: 1 min 45 sec.

Left: A-frame cottage — center: Torus — right: "Ripple" Torus



Array of cubes, 1970



Ned Greene: "Mondo Condo", 1983

COMPUTER ANIMATION

Interest in the use of computers to generate motion pictures developed almost immediately with the advent of computer graphics. As early as 1964, Knowlton (11) published a paper describing the computer production of animated movies. This began a virtual explosion of activity in this field. Initial efforts were concerned primarily with simulated motion of fairly simple objects. The images were line drawings, and the objects were limited to polygons or 2-D projections of polyhedra. In all but the most trivial cases, no provision for hidden-line elimination was included.

A major advance in computer animation occurred with the publication of Ronald M. Baecker's 1969 paper which is based on his doctorate thesis for his PhD at the Department of Electrical Engineering at MIT. Baecker carefully examines the requirements for an interactive computer animation system, and then, in a step-by-step manner, traces through the various tasks necessary to obtain a computer-generated movie. The paper provides an excellent introduction into all aspects of computer animation and should be regarded as "must" reading for anyone interested in this field.

Animation is the graphic art which occurs in time. Whereas a static image may convey complex information through a single picture, animation conveys equivalently complex information through a sequence of images seen in time. It is characteristic of this medium, as opposed to static imagery, that the actual graphical information at any given instant is relatively slight. The source of information for the viewer of animation is implicit in picture change; change in relative position, shape, and dynamics. Therefore, a computer is ideally suited to making animation "possible" through the fluid refinement of these changes.

McLaren's description of animation:
Animation is not the art of DRAWINGS-that-move but the art of MOVEMENTS-that-are-drawn.
What happens BETWEEN each frame is more important than what exists ON each frame.
Animation is therefore the art of manipulating the invisible interstices that lie between the frames. The interstices are the bones, flesh and blood of the movie; what is on each frame, merely the clothing.
Although the computer's entrance into animation has been a recent one (1964), *(11)* the growth of interest and activity has been phenomenal. Experience to date strongly suggests that the following statements are true:

1. The animated display is a natural medium for the recording and analysis of computer output from simulations and data reduction, and for the modeling, presentation, and elucidation of phenomena of physics, biology, and engineering *(12)*, *(13)*, *(14)*, *(15)*. Depiction through animation is particularly appropriate where simultaneous actions in some system must be represented. If the animation is the pictorial simulation of a complex, mathematically-expressed physical theory, then the film can only be made with the aid of a computer.

2. The computer is an ARTISTIC AND ANIMATION MEDIUM, a powerful aid in the creation of beautiful visual phenomena, and not merely a tool for the drafting of regular or repetitive pictures *(16)*, *(17)*, *(18)*, *(19)*.

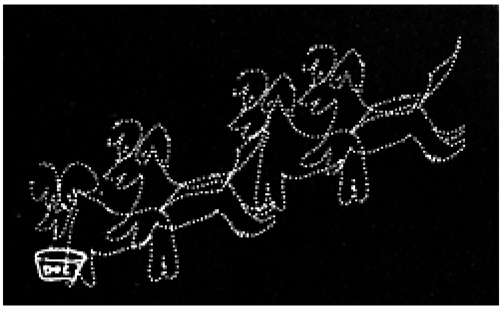
Three aspects of the role of direct graphical interaction in computer graphics are particularly relevant to computer animation:

1. The availability of immediate visual feedback of results, final or intermediate;

2. The ability to factor picture construction into stages, and to view the results after each stage; and,

3. The ability to sketch pictures directly into the computer.

The power of immediate visual feedback in animation is striking. The computer calculates, from its representation of a dynamic sequence, the individual frames of the corresponding "movie". Like a video tape recorder, it plays it back for direct evaluation. A small change may be made, the sequence recalculated, and the result viewed again. The cycle of designation of commands and sketching by the animator, followed by calculation and playback by the computer, is repeated until a suitable result is achieved. The time to go once around the feedback loop is reduced to a few seconds or minutes. In most traditional and computer animation environments, the time is a few hours or days. The difference is significant, for now the animator can see and not merely imagine the result of variation in movement and the rhythm of a dynamic display. Thus he will be led to perfect that aspect of animation that is its core: control of the changing spatial and temporal relationships of graphic information.



Jane Veeder: "Floater", 1983

Interactive computer-mediated animation is the process of constructing animated visual displays using a system containing, in one form or another, at least the following eight components:

HARDWARE:

1. A general-purpose digital computer.

2. A hierarchy of auxiliary storage. This is listed separately to emphasize the magnitude of storage required for the data structures from which an animation sequence is derived and for the visual images of which it is composed.

3. An input device such as a light pen, tablet plus stylus, or wand, which allows direct drawing to the computer in at least two spatial dimensions. The operating environment must, upon user demand, provide at least brief intervals during which the sketch may be made in real time. The animator must then be able to draw a picture without any interruption. Furthermore, the computer must record the "essential temporal information" from the act of sketching. Sampling the state of the stylus 24 times per second often suffices for our purposes.

4. An output device, such as a standard computer display scope or a suitably modified TV monitor, which allows the direct viewing of animated displays at a rate such as 24 frames per second. This is essential to enable the interactive editing of animation sub sequences. The final transmission of a "movie" to the medium of photographic film or video tape can but need not use the same mechanisms.

SOFTWARE:

1. A "language" for the construction and manipulation of static pictures.

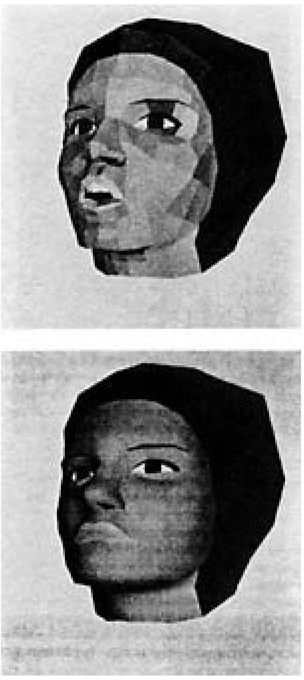
2. A "language" for the representation and specification of picture change and the dynamics of picture change. We shall introduce in this paper methods of specifying dynamics not possible with traditional animation media and not yet attempted in the brief history of computer animation.

3. A set of programs that transforms the specifications of picture structure and picture dynamics into a sequence of visual images.

4. A set of programs that stores into and retrieves from auxiliary memory this sequence of visual images, and facilitates both its real time playback for immediate viewing and its transmission to and from permanent recording media.

With the development of raster graphics in the early seventies, efforts were soon made to generate moving raster images. The work of Wylie, et. al. (1967), Gouraud (1971), Warnock (1969), and Watkins (1970) provided an excellent background for the human-face animation developed by Parke (20) of the University of Utah, Computer Division (1972).

Parke's paper describes the representation, animation and data collection techniques that have been used to produce "realistic" computer generated half-tone animated sequences of a human face changing expression. It was determined that approximating the surface of a face with a polygonal skin containing approximately 250 polygons defined by about 400 vertices is sufficient to achieve a realistic face. Animation was accomplished using a cosine interpolation scheme to fill in the intermediate frames between expressions. This approach is good enough to produce realistic facial motion. The three-dimensional data used to describe the expressions of the face was obtained photogrammetrically using pairs of photographs.



Two expressions of the same face. The top one was rendered using polygonal shading. The bottom one was rendered using Gouraud's smooth shading algorithm. 1972

The human face is a challenge for computer animation for at least two reasons. First the face is not a rigid structure but is a complex flexible surface. How is the motion of such a surface specified? Secondly faces are very familiar to us, we have a well developed sense of what expressions and motions are natural for a face, and notice small deviations from our concept of how a face should appear.

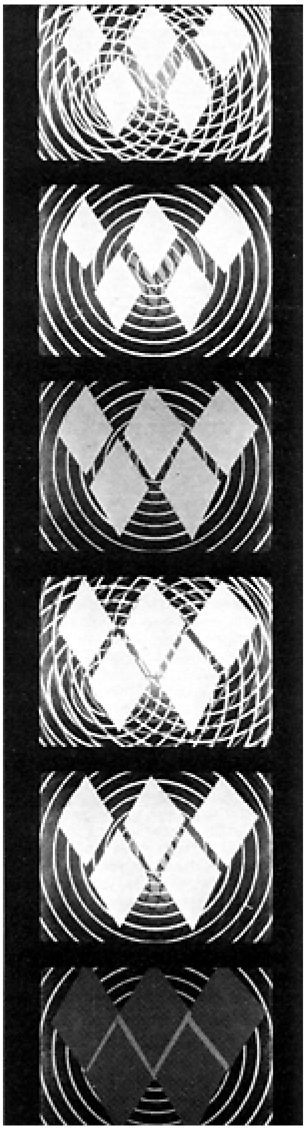
Activities in computer animation have become so vast and widespread that it is impossible even to summarize them. A large collection of computer-generated films some of outstanding quality—exists, and representative samples can usually be seen at the various annual computer conferences. Of particular interest to a reader seeking insight into this early stage should be the works of Whitney (1968), Max (1975), Csuri (1975) and others still to be named.

The refinement of computer animation systems to permit persons with minimal computer know-how to generate animated films is described in the paper by Hackathorn *(21)* of the Computer Graphics Research Group at the Ohio State University under the direction of Charles Csuri. A powerful, full-color 3-D animation system is described. The system utilizes a sophisticated animation language. The entire system was implemented on a relatively modest-size minicomputer.

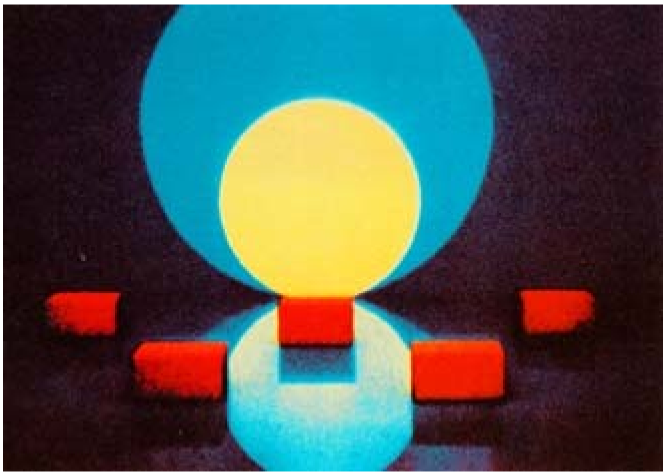
An animation software system has been developed at the The Computer Graphics Research Group which allows a person with no computer background to develop an animation idea into a finished color video product which may be seen and recorded in real time. The animation may include complex polyhedra forming words, sentences, plants, animals, and other creatures. The animation system, called Anima II, has as its three basic parts: a data generation routine used to make colored, three-dimensional objects, an animation language with a simple script-like syntax used to describe parallel motion and display transformations in a flexible, scheduled environment, the Myers' algorithm used in the visible surface, and raster scan calculations for the color display.

The development of computer generated "solid" object animation is changing the way an animator approaches the documentation of an idea. Conversational animation involves drawing and redrawing planar images on each frame throughout the entire sequence. Image creation and image animation are very often the same process. But in a 3-D computer animation environment, the user first builds a colored object then animates it and these processes are separate. The approach of 3-D color animation is similar to that found in other disciplines such as cinematography, theatre and choreography.

In the mid seventies a trend began in which computer animation began moving away from the domain of the computer engineer and entering that of the professionals filmmaker, a sign that the field had truly matured. By the second half of the seventies, extensive use of computer animation was being made to create the educational and entertainment films of commercial quality for both the movie and television industries.



Oskar Fischinger: "Allegretto"



Oskar Fischinger: "Composition in Blue", 1935

III. DIGITAL IMAGES AND THE COMPUTER COMMUNITY

The use of computers is proliferating in the arts of film and video. Computers are used for all aspects of the production process. In the form of microprocessors they are internal to virtually every device, and in the area of machine control, computers are fundamental to every procedure. Computers are integral to the very language and notation of these kinetic art forms which deal with the concepts of light, color and motion in time and space.

The advent of computer graphics in popular culture, such as special effects for film and commercial advertising, has resulted in the emergence of facilities where artists have helped to direct the focus of research and exploration in image generation and synthesis. Their input has also affected the development of hardware and software systems.

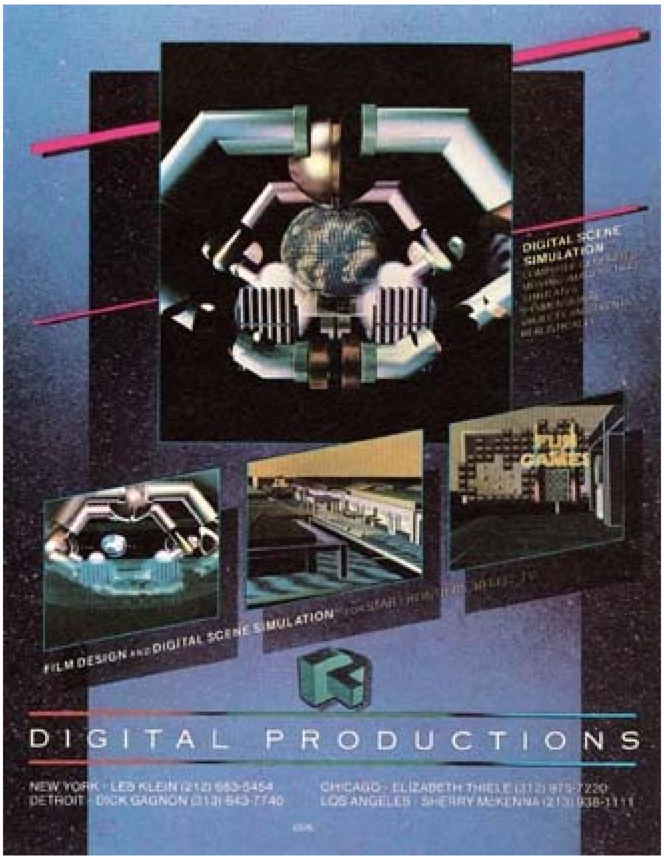
Concurrently, the tremendous effect of personal computers and video game technology on the creative process and art is just beginning to be ascertained and acknowledged. While practitioners of more traditional art forms such as painting, sculpture and printmaking are now questioning the validity of the computer in their media, film and video artists have always struggled with such concepts as the human/machine interface and the collaboration of the artist/technologist. These artists' achievements, and the resounding acceptance of their art form in major museums and art institutions around the world (as evidenced by this festival), has served to free these artists from questioning the validity of technological art.

It is therefore not surprising that these artists are responsible for some of the most remarkable achievements in the field of computer art. They are artists who have embraced computers as tools of artistic expression to either modify imagery or create entirely new visual realities.

The digital image, computer animation and graphics are the most significant technological advances in the moving image since the very invention of film. At present, advances in computer animation (cartoon trick films produced by computers) are being made in the following areas: universities, industry and art. A particularly interesting aspect of this development is the cross-connections between these three areas which are representative of individual work as well as of the whole state-of-the-art.

Researchers are leaving the university for industry, artists are moving into the university and commercial areas, engineers are switching over to art. In the process, encounters occur between the three, involving joint work.

The following universities are leading in the theoretical research basic for both hardware and software in computer culture and technology as well as in the practical implementation of this: New York Institute of Technology, the Harvard Computation Laboratory of Harvard University, Carnegie-Mellon University, the University of Utah in Salt Lake City, the Massachusetts Institute of Technology, the Berkeley Computer Graphics Lab of the Computer Graphics Lab of the Computer Science Division, the Xerox Palo Alto Research Center, the University of Illinois in Chicago, the California Institute of Technology, etc.



Influential in computer industry are not only military institutions such as NASA which receive exorbitant sums and have thus been able to make great advances, in computer animation, but also film and commercial firms such as George Lucas Ltd., Robert Abel Associates, Cranston-Csuri, Digital Effects, Digital Production. These firms produce special effects with computer graphics for movies and commercials, etc. Also firms such as Atari, Apple etc., which manufacture personal computers and video games, as well as Bell Telephone Laboratories, IBM, etc. deserve mention when one speaks of the computer communication revolution. Third, there exists a group of artists who in part depend on institutions and industry for support. Before I proceed to describe some of the most important examples of the cooperation between computer and art, I would first like to deal with some of the cross-connections existing between research, industry and art which are typical of the advent of computer culture. Additional useful information on this topic can also be found in the bibliography. Tom A. DeFanti is professor at the Department of Electrical Engineering & Computer Science of the University of Illinois in Chicago. He is a computer specialist and computer artist and is presently serving as chair of the SIGGRAPH group. Together with Dan Sandin, Bob Snyder and Jane Veeder (on whom Gene Youngblood has written an article, so that it isn't necessary to go into detail here) and others, he belongs to the Chicago Circle of Computer Art. His computer graphics language ZGRASS, designed for real-time interaction has been used by both Jane Veeder and Larry Cuba (Santa Cruz). Dan Sandin's Digital Image Processor as well as Woody Vasulka's Digital Image Articulator are among the best tools for the further processing of images. Ed Emshwiller can be named along with Veeder and Cuba as one of the leading computer artists. His famous production SUNSTONE (1979)—3 minutes produced in 3 months at the New York Institute of Technology directed by Alexander Schure—was programmed by Lance Williams and Alvy Ray Smith who works today for Lucas Film. Frederic I. Parke (see his article on the computer animation of faces, 1972) did his doctoral work at the University of Utah. He now works as professor of computer science at the New York Institute of Technology and runs its Computer Graphics Laboratory where also Paul S. Heckbert works on the subject of "Beam Tracing Polygonal Objects".

George Lucas Film Ltd. in San Rafael, California appears to be the major center of advanced computer graphics, digital image synthesis and computer animation. Ed Catmull, who was formerly at the University of Utah and has written important articles on computer graphics, also works for Lucas Film. There, he is developing "an analytical visible surface algorithm for independent pixel processing" which is so important for Pixar. Loren Carpenter, whose film VOL LIBRE (2 min.), a computer-simulated trip through a mountain landscape, is a classic of visual work, is now working at

Lucas Film on the development of algorithms for hidden surfaces (the A-Buffer, an Anti-aliased Hidden Surface Method). Adam Levinthal is working at Lucas Film on a "Chap—a SMID Processor"; Rob Cook is concentrating on "distributed ray tracing", one of the newest techniques with which realistic images can be generated on the basis of reflections and shadows. Curtis Abbott, also at Lucas Film, is working with digital sound. Others working at Lucas Film are Rodney Stock, Thomas Porter, Tom Smith, and William Reeves. Stock is the Graphics Engineering Manager and together with the above-named, participated in the project PIXAR. Apart from his film productions (eg STAR WARS), George Lucas' major concern is developing a special technique for digital film printing and for the synthetic generation of images for film, which allow an interactive playing with the monitor producing the imagery that I want to see, such as pictures from the air. These pictures obey my input and control mechanisms (for example a flight around a rock in a canyon).

Stock used to work as graphics designer at Adage Inc., which developed a graphics terminal (Stock did the vector generation). He went on to work for Evans & Sutherland Corporation, where he did hardware for flight simulation and contributed to the development of hardware for the Ampex Video Art Paint System (6). As you see, also the pioneer of computer graphics, I. E. Sutherland of University of Utah (see his work from 1963) runs his own computer firm where also Robert Schumacker, Michael Cosman and, of course, David Evans work. Like Atari, Real Time Design in Chicago, etc. it develops interactive computer graphics systems. James T. Kajiya did his doctorate work at the University of Utah, then worked for Evans & Sutherland Computer Corporation and today is professor at the California Institute of Technology.

In the late seventies, important articles on computer graphics were written by James F. Blinn who is also a graduate of the University of Utah and is now working at the Jet Propulsion Laboratory of the California Institute of Technology which has produced computer-generated animations for NASA and the famous TV-series COSMOS. Thomas Spencer and Richard R. Riesenfeld are also from the University of Utah. Riesenfeld has written important articles and is head of the Computer Science and Computer-Aided Geometric Design Group. The University of Utah, the New York Institute of Technology and Lucas Film Ltd. seem to be the strongholds in the development of the digital image and interactive computer graphics systems.

Computer commercials or High Tech commercials are commercials that are actually produced with computers or have a neon-like computer look. Such high technology commercials and special effects for movies are produced by firms such as Robert Abel Associates, Hollywood or Digital Effects Inc., New York or Cranston-Csuri Productions in Columbus, Ohio or the Entertainment Effects Group from Douglas Trumball, Adrian Malone Production or Digital Productions, both in Los Angeles. Judson Rosebush who has written much on this topic is the founder and president of Digital Effects Inc. Jeffrey Kleiser and Donald Leich work there in the computer animation division. Donald L. Stredney and Wayne Carlson are computer animators at Canston-Csuri. Charles A. Csuri not only produced a famous computer film in 1967, but also wrote important articles on computer animation during the seventies. Robert Abel studied under John Whitney Sr., the pioneer of the digital image and computer film and visual music at the University of California, Los Angeles. His best co-worker is Bill Kovacs. Pat O'Neill, the famous avantgarde film maker on the west coast in the sixties, has worked sporadically for Robert Abel as well as for Larry Cuba, in addition to his production of abstract psychedelic films in the seventies.

High Tech Videos for the general public, such as rock videos, are made by Todd Rundgren (UTOPIA VIDEO, WOODSTOCK IN NEW YORK)—see his project WILL POWERS produced in 1983 with Lynn Goldsmith for Island Rec.—or Michael Nesmith, Bill Etra (DIGITAL IMAGE), Steve Rutt (LASER TV) etc. Artistic laser TV, laser disc programs, satellite TV projects are produced by Mobile Image (Kit Galloway/Sherry Rabinowitz). The most interesting example of the interrelationships between art and High Tech business is Digital Productions in Los Angeles, which was founded by John Whitney Jr., the son and former co-worker of John Whitney Sr., the artistic pioneer of computer film, and Gary Demos.

Two further co-workers under 60 are Craig Upson who worked together with the computer pioneer, Nelson Max on developing cloud movements in computer animation, and Sherry McKenna who worked with Robert Abel on his famous "7-Up Bubble Commercial". Gary Demos, 32, worked as assistant for Whitney Sr., who produced his first computer film CATALOG in 1962. Larry Cuba

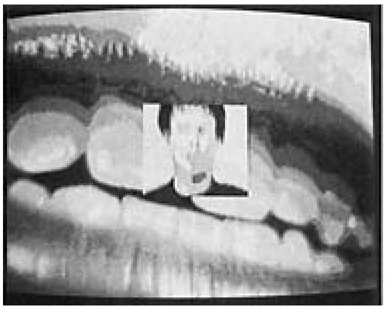
contributed to the programming of ARABESQUE (1975), 6 min.
The technique was developed by Information International Inc. (Triple) in 1974, the forerunner of Digital Productions. Digital Productions specializes in digital scene simulation, that is, computer-generated images that realistically simulate 3-D objects and events. With the help of the super computer Cray-1 and other new techniques Gary Demos developed the sophisticated software program at Digital Productions.

John Whitney, Jr., 37, the son of John Whitney Sr., produced TERMINAL SELF in 1971. In this project he departed from the geometrically rigid computer films and achieved a spatial effect with figurative means. He has also sporadically worked together with the concept artist Michael Asher in a film by the latter. Whitney Jr. has worked together with his father since he was 15, produced his own abstract film and designed a number of computer systems such as the Hybrid Optical Printer. In 1973 he was nominated for an Oscar for his contribution to WESTWORLD. Presently, the firm is working on a 20–30 minute long digital scene simulation for the movie THE LAST STARFIGHTER. Also in preparation are digital scene simulations for the film 2010, the follow-up of 2001. The sensational thing about digital scene simulation is that it aims at creating computer scenes that are indistinguishable from nature as well as realistic scenes non-existent in nature. For this purpose, the firm owns the world's most rapid super-computer CRAY 1 (costs 12 million dollars), a number of VAX and IBM small computers, 4 machines for transforming video into 35 mm film, 2 film scanners, 3 Evans & Sutherland image systems and 3 IMI motion systems for attuning the interactions with the objects. This is ushering in the future of electronic film: a movie simulated 100% with scenes that are still photographically so realistic that the audience is not able to distinguish real live action from the simulated one. Digital scene simulation is the future of the digital image, of digital art. The example of Digital Productions and the relationship of father to son shows how a formerly marginalized form of art as the abstract graphic film can become the centerpoint of a new industry. Also, it becomes clear that the experience and efforts over many years in avantgarde-film, in particular, in abstract film (from V. Eggeling and C. Fischinger in the twenties to the Whitney brothers, James and John, in the forties) pointed to the future and laid the foundations for a technological revolution of industry. From abstract film to simulation computer film, a new form of film is evolving, a new form of visions and unlimited manipulation of visual data. Since the computer-generated imagery can be stored on both video and film and can also be mixed with real scenes, computer animation incorporates the future; the future can be named digital image.

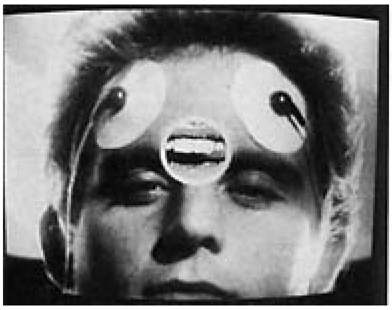
DIGITAL VIDEO

A preliminary stage of this development is the integration of video and computer technology: the digital video. This amalgam is inherent to video itself. In film the picture frame remains untouched; only from the collision of two frames, from the interval of two frames was it possible to construct meaning, motion, action. By contrast, in video, it is possible through computer technology to manipulate each single pixel's color and form by means of a computer. The access to each of the 1000 pixels of 1000 video lines by means of the computer and the possibility to change each single pixel as one pleases, allow for individual, subjective manipulation of the image as in painting and an authentic representation as in photography. After fire and electricity, the digital image stands for the third prometheic instrument of artistic representation, that is, simulation. The highly advanced technology of the digital image and its potential for simulation through computer technology, give the individual unlimited access, unlimited possibilities to construct a new visual culture, a new democratic Renaissance.

Max Almy, "Perfect Leader", 1983



Max Almy, "Dead Line", 1980



Max Almy, "Leaving the Twentieth Century", 1982

SOME ARTISTS AND THE COMPUTER

LARRY CUBA

Larry Cuba
When Luke Skywalker in George Lucas' STAR WARS flew with his warplane across the canyon of DEATH STAR to attack the thermic target of annihilation, it was not force that was guiding him, but rather Larry Cuba, the young computer animator who was showing him the way. The digital animation developed by Cuba showed diagrams on the screen: mathematical models of the canyon's forms, computer diagrams of the canyon's forms, computer diagrams of the canyon's physical structure. The computer then drew a series of perspective projections of the canyon as seen through the eyes of the pilot flying through it.

In Cuba's own films, the synthesis of art and technology results in visually surprising and convincing forms. Cuba's forms and rhythms, his exploration of the perception of motion, and the metamorphosis of forms are based on mathematical formulas. He uses computer programs (an ordered series of commands for a data processing machine) as an "ELECTRIC PAINTBRUSH". "THE PROGRAM ITSELF IS THE TOOL FOR GENERATION IMAGES. It is more a linguistic tool than a physical one. I concentrate more on how to create programs than on using old technical instruments as for instance the optical printer. It is not the individual frame, the single image that interests me as much as the motion, the rhythms, the timing which are the basis of a film, of form in motion."

Larry Cuba became interested in computer graphics as a student of architecture at the Washington University in St. Louis. From 1972 on, he studied at the California Institute of the Arts (Cal Arts). It was here that he created his first computer-animated film, FIRST FIG (1974). He also worked together with John Whitney Sr., the pioneer of computer animation. For Whitney, he did the programming for the film, ARABESQUE (1975). The program for FIRST FIG was in Fortran, a computer language not exactly suitable for computer graphics. But at the time, it was the only one that he could have access to on weekends at a firm. Through this experience, however, he gained the computer and mathematics background that he needed for his further artwork. In this system of programming he never could see the graphic results right away but always had to wait several days. This might be compared to a composer who hits a key on the piano and has to wait a week until he actually hears a sound. Cuba then moved to Chicago where he worked in the art department at the University of Illinois, the home-base of THE CHICAGO CIRCLE OF COMPUTER ART (Jane Veeder, Tom DeFanti, etc.) Here he began experimenting with Tom DeFanti's computer language, GRASS (Graphic Symbiosis System). New in this system was that the computer draws the results of the programming commands in real-time. Cuba went onto work for the renowned high technology commercial company, ABEL AND ASSOCIATES in Los Angeles. He programmed the brilliant zooms which can be seen nowadays in many TV commercials. At the end of 1975 he was asked to make a short computer animation sequence for the movie STAR WARS by George Lucas. In 1976 Cuba returned to Chicago for this purpose to work with the GRASS system again. It took him 3 months to make the two minute sequence, only the second computer animation to appear in a movie. Cuba could have made a much more accomplished computer graphics, one looking more like photography than diagrams, but Lucas wanted the simulation to have a computerish look. Thus the viewer sees the simulation of a computer diagram of Death Star on Artoo Detoo's Memory Bank in the rebel's information room.

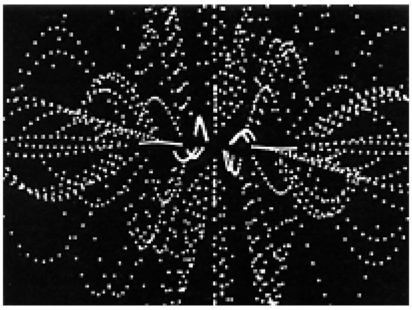
Back in Los Angeles in 1977, Cuba worked with the programming language, RAP at Information International Inc., which later became John Whitney Jr.'s DIGITAL PRODUCTION. He used RAP to create the picture material for TWO SPACE. After he no longer had access to RAP Cuba became a research associate at the University of Illinois' art department in 1977. Once the language GRASS had been refined and modified to meet the demands of STAR WARS, Cuba used it to make the film "3/78".

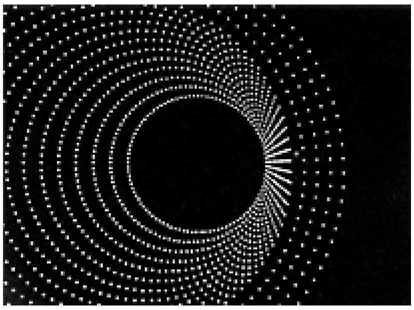
GRASS was created for artists who are not familiar with programming, since the designers of computer languages generally have little confidence in the mathematical background of the users. Cuba believes this to be a misconception. He himself prefers computer languages with implemented mathematical models, since he wants to be able to control the image through the programs.

On the move between LA and Chicago, Cuba returned to California in 1978 and resumed work on TWO SPACE, an abbreviation for two-dimensional space, which actually signifies surface, since a surface is characterized by both length and width, that is, two dimensions. TWO SPACE is built on the basis of the symmetric properties; of a surface, as specified in mathematical terms in group theory. 17 different kinds of patterns can be constructed out of one single figure, something already discovered by Islamic artists. Cuba believes that the mathematical transformation of patterns in Islamic ornamentalism is an indication that "in the Arabic civilization, THE ARTIST AND THE MATHEMATICIAN WERE ONE" (J. Bronowski, The Ascent of Man).

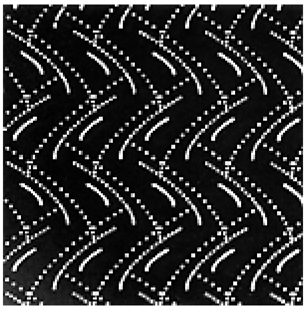
After he completed TWO SPACE in 1979, Cuba worked as a computer graphics consultant for Rand Corporation and began developing his own more flexible programming language with which he could work frame by frame. Each of Cuba's films is made with a different programming language allowing him to express some ideas and at the same time limiting the expression of other ideas. The tactile interaction with the computer by means of keys, joy sticks and light pens is unsatisfying for him, since his work also involves the exploration of mathematical and theoretical ideas. He views his films as a sort of discovery. He doesn't use the computer to perform a ready-made storyboard, but rather seeks to find pictures with the computer that transcend his visual capabilities. "I enjoy not knowing what the final images will look like. The whole purpose is to discover something that you normally don't get a chance to see!"
Cuba's DIGITAL COMPUTER ANIMATION which constructs images using mathematical structures and programs them by means of computer languages is a legitimate legacy of the great tradition of the abstract film (from Viking Eggeling to John Whitney Sr.). His computer animation creates an analogy

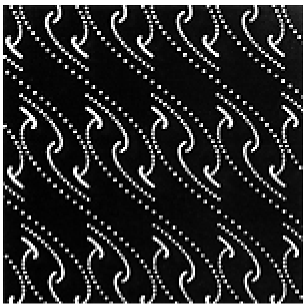
between visual perception and the structure of a linguistic or mathematical system. This is a new field for organizing aesthetic material.





"3/78", 1978





"Two Space", 1979

Cuba is especially enthusiastic about THE FUTURE OF COMPUTER ART which, as he believes, lies in the personal computer. As the personal computer becomes cheaper, easier accessible and more popular all the time, computer animation will become accepted as a standard form of communication: PICTORIAL CONVERSATION. Through the personal computer, computer graphics will become a popular means of expression and no longer be limited to artists, as photography also once was. At its beginning in the 19th century, photography was also a very complicated, expensive, semi-scientific medium only accessible to a few artists, professionals and rich amateurs. Nowadays everyone photographs and the exchange of photographs is a normal form of communication. Photography has become a sort of universal picture language. Something similar will take place in computer animation. Home computers will become as familiar to us as cars, telephones and cameras, which may sometimes be frustrating for us when they don't function the way we want them to, but are basically nothing to be opposed to.

Ed Emshwiller

Ed Emshwiller began his artistic career as a painter and science fiction illustrator. After a decade of experimental filmmaking, he began working on video in the early seventies. In his first videotapes he explored synthesized imagery combining fantasy and dance. Computer animation, in which he "paints with a digital palette", is culmination of his experience as a painter and filmmaker, and is the ideal medium for his fantastic and surreal imagery. The most recent and technically advanced of his animated films is SUNSTONE, which was made over a period of eight months at the New York Institute of Technology (NYIT), where one of the world's most advanced computer-animation systems is housed. SUNSTONE is a pivotal work in computer-generated video and a highly sophisticated exploration of the three-dimensionality possible on the video screen. The tape begins with a gray, rocklike surface on which a round sun face emerges. It opens very realistic eyes, and smiles. The suns facade cracks, and brilliant colors radiate from its head with extraordinary intensity. In a surrealistically stunning display of high technology, this face then appears on one side of a rotating cube whose other surfaces feature moving or still video images. Zooming in on one of the stills, Emshwiller presents an electronic landscape in which a walking figure becomes a rainbow-colored series of outlines.

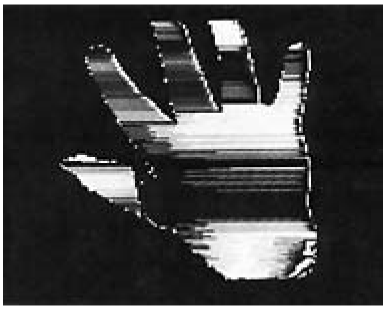
SUNSTONE, however goes beyond technology as an end in itself. Emshwiller's imagery evokes Marshall McLuhan's theory of "cool" (the cool gray rock surface) and "hot" media (the bright, pulsing orb). By using the universal image of the sun, initially etched in stone and then a cube-like satellite revolving in space, he recapitulates a variety of artistic mediums. Emshwiller's walking figure, frozen in a series of stills, is subtly reminiscent of Eadward Muybridge's photographic motion studies, and by extension, Marcel Duchamp's painting NUDE DESCENDING A STAIRCASE. SUNSTONE'S multidimensional palette fondly refers to earlier art and celebrates the future of electronic art. SCAPEMATES is a unique video—a choreography of images in which electronic forms dance with live figures. A rich imagery in an electronic framework is produced by means of computer graphics and a video synthesizer.

"Sunstone", 1979

Steina and Woody Vasulka

These two artists are pioneers of computer-generated video art. Steina, who is from Iceland, trained to be a violinist; Czechoslovakian-born Woody studied engineering and worked in film. In 1971 the Vasulkas founded the Kitchen, a small electronic-media theater in New York that has since become a major avant-garde center for video, performance, music, and dance. Several years later they developed the Digital Image Articulator, a complex digital computer that is central to the production of their work. The primary aspect of the Vasulka's work is its technical innovation. Many of their tapes serve as explanations of their pioneering techniques. While they have created many works together, they also work on their own separate productions. (Steina produces individual works under her first name). CANTALOUP is Steina's document/essay about the design, construction, and use of the Digital Image Articulator. The tape was made when the Vasulkas and Schier were eighteen months into the design of this device. Like the image processor designed by Dan Sandin (see SPIRAL PTL, 1981) the Digital

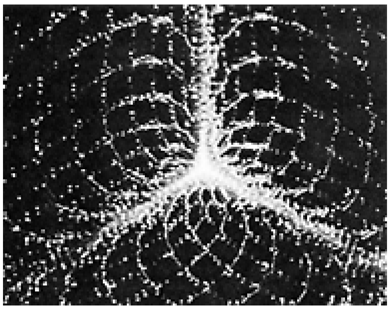
Image Articulator was designed specifically for the purpose of studying "real-time" video image performance. Steina's explanations of the machine are heard as we see the digital effects she creates using the spherical shape of a cantaloup as an image source. She describes the varying sizes of pixels (picture elements), the possibilities of multiplying the images, and the layers (slices) of color and tone which can be derived from one image. ARTIFACTS, by Woody, continues defining the potential of the Imager. "Artifacts" refers to those images produced specifically by Woody, and those arrived at by chance through experimentation, establishing a collaboration between man and machine. He manipulates an image of a sphere into myriad colors, pixels, and grids, and transforms the image of his own hand until it takes on a magical, surreal quality.



"Artifacts", 1980

Outside of the studio, their imagery takes on a startling dimension. IN SEARCH OF THE CASTLE is an essay on exploration that combines Steina's abstraction of real images and Woody's digital effects. The imagery was taped from a car reflected in a sphere—a recurring theme of her recent work--that provides a distorted, circular image. As they drive through the flat landscape, we see the Vasulkas in combination with their environment. Encapsulated in this computer globe, the Vasulka's imagery is revealed to us as an electronic journey. THE CONNECTION, their last, well-known piece, is about transaction between Paganini and Berlioz. Paganini and E. Gusella and Berlioz are played by Ashley.

Tom Defanti and Dan Sandin
Dan Sandin and Tom DeFanti have played a major role in the development of image processing and computer graphics in Chicago ever since the early 1970's. Sandin, who came to video and computers from nuclear physics in 1972, built his own image processor. DeFanti designed a computer graphics language, the Graphics Symbiosis System (GRASS), which he combined with Sandin's image processor. He then created ZGRASS (see MONTANA, 1982), a computer language designed to allow artists direct access to complex computer graphics. Both Sandin and DeFanti teach at the University of Illinois at Chicago, and designed these systems as teaching tools. Sandin's image processor was designed to teach students about color. ZGRASS was designed to teach computer graphics to engineers and artists. Here an alliance between art and technology can be recognized as well as the importance of direct access to complex technology for artists and of "real-time" systems. The instant feedback of imagery and information encourages spontaneity. SPIRAL PTL is the fifth of a series of "real-time" performances in which Sandin and DeFanti along with other artists produced video synthesis. The "PTIL" of the title refers to "probably the last" of the series. The spiral image has been central to their work for many years. Some performances were structured with music being added after the imagery was made and others in which sound dictated the images. SPIRAL PTL is tightly structured with Mimi Shevitz's audio, which varies from electronic buzzes and space-age voices to quieter sounds evocative of running water. Using the image processor like a musical instrument to perform variations on a linear spiral made of dots, DeFanti and Sandin transform this basic shape into an evermoving gyre. SPIRAL PTL is representative of the possibilities, of aligning art and technology and of the strong collaboration between audio and video.



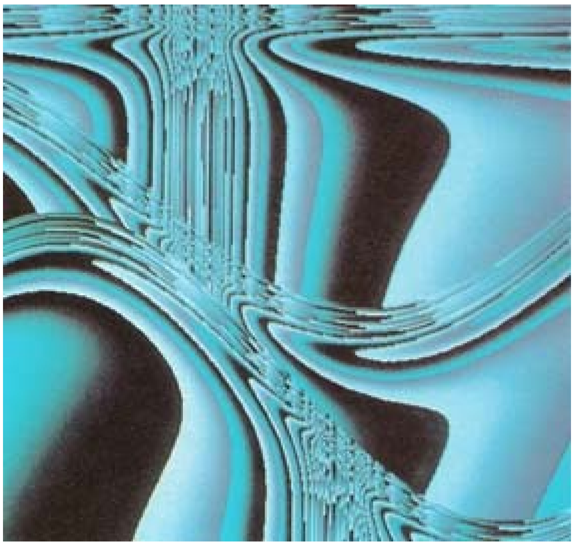
"Spiral PTL", 1981

Richard Taylor
is creative director at Magi West Coast, LA. He used to work for Information International, the company which later became Digital Productions. He is a specialist for Digital Scene Simulation, also a member of VMA. He worked as special effects-designer for "Tron".

The Jimi Hendrix Videogram
The Jimi Hendrix home cassette was produced from the VIDEO ARTIST SERIES which was presented by the cable TV program, NIGHTLIGHT. This program included SIGNOFF, a piece by Shalom Gorewitz in which Jimi Hendrix performs 'The Star-Spangled Banner'. The music of the Jimi Hendrix videogram is also available as a new LP that appeared in June of 1982 under the label 'The Jimi Hendrix Concerts Album'. This LP features titles which until now could not be heard on record, such as FIRE, I DON'T LIVE TODAY, RED HOUSE, STONE FREE, HEARTS, HEY JOE, WILD THING, VOODOO, BLEEDING HEARTS, ARE YOU EXPERIENCED, LITTLE WING, HEAR MY TRAIN. The artists who participated in this video project were selected by EAI and VideoGram International under the criterion of their ability to work with imagery and sound. The artists had the possibility to choose the music pieces themselves.

Stephen Beck
began working with light as an artistic medium while a student at the University of Chicago. He worked several years as light technician at the University's studio for experimental music 1971. As artist-in-residence at the San Francisco National Center for Experiments in Television, he designed the direct video synthesizer, an electronic device for generating images without a camera. At present, he is developing electronic systems in which he likes to include the video games and videos he has designed. He runs his own computer firm, Beck-Tech.

Frank Dietrich
received his MA in media studies from the Technische Universitaet Berlin, Germany and graduated with a MFA from the Electronic Visualization Program at the University of Illinois at Chicago. He has collaborated on large scale video-computer installations and has exhibited and published his work throughout the United States, Japan and Germany. Dietrich has been teaching computer art at the School of the Art Institute of Chicago, West Coast University and Coast Orange College in California.



Frank Dietrich, Softy 3", 1983

VISUAL MUSIC ALLIANCE (VMA)
unites those artists who are creating the future of the audiovisual media with electronic means. They work for industry (big film productions), for advertising, for record firms and for pure art. The three-year old organization has its own newspaper THE RELAY.

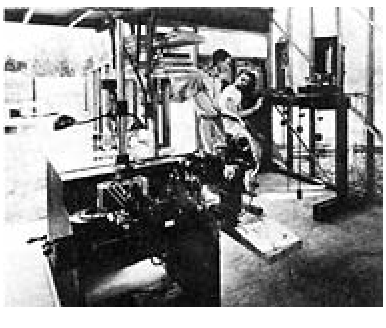
It organizes exhibitions, meetings and conferences. Its members are a unique mixture of art and business: Jo Bergmann used to work together with D. Bowie and is now video director for Warner Bros. Rec.. Robert Margouleff did productions for Stevie Wonder and Devo. John Allison, an Emmy award winner for special effects, works at "Cosmos". Gene Youngblood is the author of "Expanded Cinema", etc.

Dream Quest. Inc.,
is the name of a company that does special effects: "Blue Thunder" (directed by J. Badham with Roy Scheider), "The Outsiders" by F. F. Coppola. Scott Squires also did the special effects for "Close Encounters of the Third Kind" (S. Spielberg). Belongs to VMA.

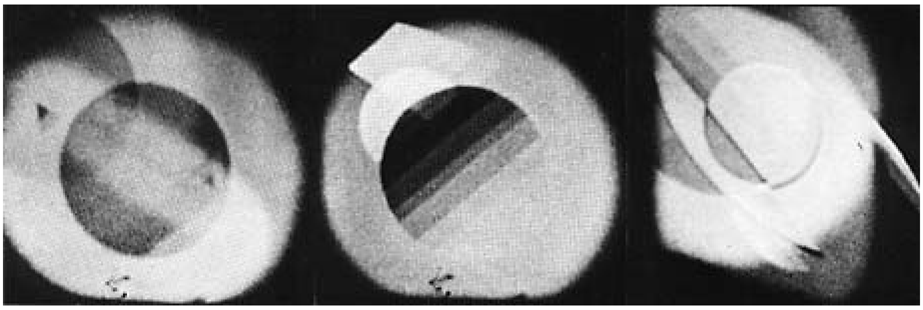
Homer & Associates
is a firm specializing in computer graphics and animation. It uses the computer language FORTH (programmed by Paul Rother) for computer-generated graphic effects and digital painting. The owner of Homer & Associates is Peter Conn, a member of the Visual Music Alliance, who has done a number of music videos; the famous "Abracadabra" (1982) by Steve Miller, among others. He represents a combination of avantgarde (Visual Music Alliance) and industry (rock videos).

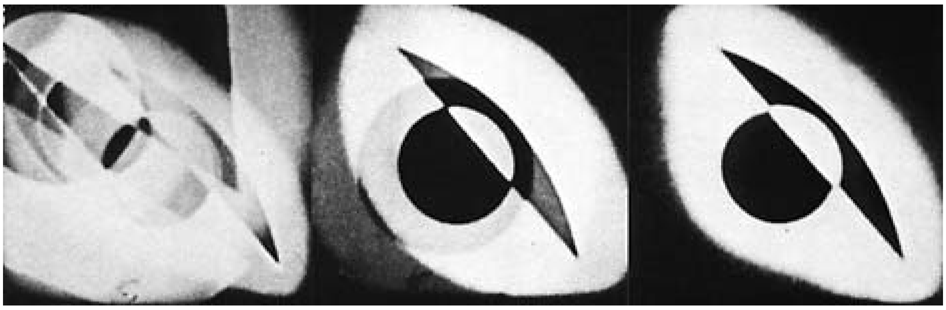
Bill Sebastian
"the color and color genius of the 20th century" (Heavy Metal) developed a system of electronic finger painting, the Outerspace Visual Communicator, a visual synthesizer, in 1978. The artist's hand glides over 400 printing keys which in turn trigger color symmetries and movements. Through rotations, compression, zoom, etc., the video image can be manipulated any time.

John Whitney, Sr.
1917: born in Altadena, California
Studied at Pomona College in California.
1939: studied music composition and photography in Europe and began his experiments with 8 mm film in Paris. During this period he was strongly influenced by Schoenberg, as he himself admits.
1941–45: worked with his brother, James, on abstract films. Developed a machine for producing synthetic light sounds for these films. Since 1966 work on the development of computer graphics sponsored by IBM. Apart from his other artistic activities he has produced a number of short films for CBS Television as well as title sequences for commercial films.
Lives today in Pacific Palisades.
1982: published a collection of essays on the subject of computer animation and visual music: "Digital Harmony".
For more information see the filmography in the German part of the catalogue.



James & John Whitneys' studio, ca. 1938





James & John Whitney: from "Five Film Exercise", 1943—44

SIGGRAPH
The organization: SIGGRAPH is the association for computing machinery's special interest group on computer graphics. Its 11,000 plus members share an interest in the theory, design, implementation and application of computer-generated graphics and interactive techniques to facilitate man/machine communication and understanding. SIGGRAPH publications, slide sets, videotapes and catalogs are a forum for the promotion and dissemination of current computer graphics research, technologies and applications. Its annual conference, complete with courses, technical presentations, exhibits, art show and film video showings, has established itself as the premier industry event.

Local groups of SIGGRAPH currently exist in eight United States areas: Washington, DC, Princeton, San Francisco, Delaware Valley, New England, Los Angeles, Chicago and Chapel Hill, NC.

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1. Star Trek II Genesis-Paramount/Lucas-Film
2. Non-Edge CIG-Grumman
3. Digital Effects Demo Rolle
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