Computer Graphics: Effects of Origins

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ABSTRACT

New forms of art and technology are frequently cast in the mode of old forms, just as other aspects of material and symbolic culture have been. Only when these new forms become available to the larger population can they affect cultural patterns of maintenance and change. The author traces the evolution from alphanumeric hardcopy, static and dynamic screen images, through objects and events that are not screen-based, to dynamic, interactive, multisensory output. The effects of origins and prior practices in both technology and art on form, content, material, technique, meaning and purpose of computer graphics are explored. Speculation regarding possible and probable futures are raised.

> *New developments in any particular field only become part of the general culture when they enter the experience of people who are not specialists in that area.*
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> —Waddington

Computer graphics, as defined by Franke and Beyer [1], has been in existence a relatively short time. Changes in the form of this medium, from static alphanumeric hardcopy to dynamic interactive multisensory output, have been dramatic and rapid. These changes are not simply technical effects. They contribute to maintenance and change of culturally conditioned conceptual patterns in the larger cultural historical context. By reviewing specific works and what appear to be underlying conditions and assumptions that shaped these works, I hope to establish the relation of specific image, object, event or environment to conceptual frames. These frames exist within art and technology and are present in other forms of symbolic and material culture.

Examples from other media illustrate cultural tendencies to cast developing forms of material and symbolic culture in previous modes. The stone columns of ancient Egyptian architecture were based on earlier bound papyrus columns. Early oil paintings were similar in technique to egg tempera paintings and did not take advantage of oil's mixing properties, slower drying and resultant appearance of softer edges. Early mass-produced furniture imitated handcrafted furniture in form and applied ornamentation. The motorized McCormick reaper had a cast-iron bull's head on the front. Many other such examples exist.

Electronic and photonic art forms have been and will continue to be influenced by their origins and practices. Two earlier papers examine computer graphics as a reflection of culturally embedded aesthetic theories based on varying views of reality [2] and developing technologies of communication as reflecting cultural maintenance and change [3]. In this paper the origins and practices of computer graphics from 1945 to the present are examined to reveal cultural patterns embedded in their material and symbolic form. Reflecting origins and prior practices, these embedded patterns may have existed in art, technology or other aspects of material and symbolic culture. It is a premise of this paper that old cultural patterns do not die. They may fade or become more evident; that is, they may be deemphasized or emphasized. Only as part of the general 'nonexpert' culture can such patterns contribute significantly to maintenance and/or change [4].

An analogy may be drawn between early views of potential uses for electricity and those of potential uses for the computer. Electricity had been considered theoretically interesting but of little or no practical value. The potential for widespread and multiple uses of microcomputers by the general public was suggested as late as 1978 at the Second West Coast Computer Faire. Several engineers and programmers were amused, because of the impossibility of there being "that many programmers". This perspective is analogous to early market predictions of the Mercedes Benz Corporation, which limited the number of potential automobile sales to the very low number of trained chauffeurs then available.

These examples express the tendency to set limits of 'the possible' based on previous experience, knowledge and conceptual frames. An increasing number of contemporary theorists are stressing the importance of origins and practices in unmasking assumptions within current forms and practices [5]. Those who originate and use new forms of art and technology embed their assumptions in the new symbolic and material forms. As time passes the original users develop familiarity and facility. New users bring additional assumptions and considerations of form, content, material, technique, meaning and purpose. However, some traces of the origins and practices remain in these forms, which consequently contribute to both cultural maintenance and change. Cultural patterns are affected in proportion to the spread in the use of these forms.

Selected examples of earlier and contemporary computer-related images, objects, events and environments are examined to show reliance on previous forms and to present evolving possibilities in harmony with larger cultural and historical patterns. A tension has existed in the development of computer graphics between the scientific and artistic views of imagery and their evaluation. Origins and evolving practices are seen both to support and to diminish this tension. These practices increasingly penetrate the population at large. An examination of the fluctuating borders between computer graphics theory and practice in scientific/technological use, in artistic use and in 'everyday' use reveals differing patterns of cultural authorization. These patterns may be said to support cultural maintenance if, for example, the same authorizing assumptions are present

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across uses. Conversely, if sufficient new and different authorizing assumptions are present, they may support cultural change.

CONCEPTUAL BACKGROUND

C. P. Snow, in *The Two Cultures and the Scientific Revolution,* discussed the growing lack of understanding between the artificially divided intellectual spheres of the arts and humanities and of the sciences. Several papers examine the potential of the computer as information processor to join divided intellectual spheres [6–8]. Computer scientists and technologists may assist individuals in the arts and humanities to understand potential uses for computers. Theorists from the arts and humanities may examine implicit assumptions in the form, function and content of developing technologies. Perhaps more important, theorists in the arts and humanities may assist scientists, engineers and technicians in directing the development of new technologies toward cultural goals before technological ones. This would entail emphasizing potential effects on the quality of human life, especially in aesthetics and ethics. These transdisciplinary objectives have been proposed for educators as well. Disciplinary divisions within the institutions of education present obstacles to planning cultural goals before technological developments [9] and encourage the prevalent reactive planning mode. Active planning requires participation of many individuals with varying perspectives and prior experiences in order to set cultural goals on which to base future technological development. This is in harmony with the position of Weizenbaum [10], who emphasizes the importance of human choice in directing the consequences of technological innovation. Rather than directing the consequences, however, I propose selecting them. In part, problems arise when we attempt to implement this mode of thinking, because educational institutions remain rooted in origins and prior practices. Among these origins and practices are the separation of intellectual disciplines, and of theory from practice within disciplines, the decontextualization of knowledge from lived experience, and heavy reliance on a model of nineteenth-century scientific knowledge as a value-free framework in which to place and communicate all knowledge.

Institutional enculturation within restricted disciplinary frameworks results in very different concepts of the 'limits of the possible' and the 'dimensions of the desirable' held by individuals trained in the arts and humanities from those trained in the sciences. Although most institutionalized education remains inside disciplinary boundaries, the most innovative research in many disciplines has become transdisciplinary. It is evidenced by hyphenated disciplinary names in the sciences, by cross listings of the same event in performance and gallery advertisements in the arts, and by artistic and technical scientific work sharing media such as computer graphics, holography and other photonic applications. Computer uses such as computer graphics have been adopted across disciplinary boundaries and are present in multiple disciplines. The development of the MIT Media Lab is based on the integration of three formerly separated media industries; Negroponte's design for the MIT lab's logo displayed the intersection of three areas, broadcast and motion picture industry, print and publishing industry, and the computer industry [11]. The integration of formerly separate areas in multimedia photo-optic telecommunications continues this trend [12]. The development of computer graphics clearly reflects trends diminishing the rigidity of boundaries among disciplines and applications. Contemporary work in disciplines formerly untouched by computer graphics now reveal convergence that may lead to reevaluation of structures within institutional education. Areas in which alphanumeric symbolic textual representations constituted primary analytic tools now utilize visual spatial representations. No single academic area such as computer science or graphic art 'owns' computer graphics. Rather, individuals in pure and applied science, cognitive and social science, the arts, humanities and professions use it with varying assumptions and purposes. Areas of scientific and technological inquiry such as artificial intelligence, pattern recognition, human/computer vision systems, human/computer interfaces such as iconic screen interfaces, visual programming, and scientific visualization all utilize computer graphics. Education and communication use graphics and multimedia in a hypermedia environment. Entertainment and advertising use computer graphics for special effects, camera control, storyboard construction and other applications. In short, computer graphics has escaped narrow specialization and may contribute significantly to cultural maintenance or change.

Early misunderstandings and difficulties of collaboration between computer graphic pioneers from art and computer science may be seen as resulting, in part, from different educational enculturation. Effects of these origins and practices remain, but a gradual improvement has been achieved. Individual computer graphic pioneers are merging education in art and computer science in themselves or forming a partnership with others who have complementary skills. Teams from multiple disciplines are working in academic institutions developing scientific visualization and cognitive and perceptual research; in government research for defense and other practical applications; and in advertising and entertainment. Nonspecialists use home computers for business, education and entertainment, many with iconic graphic interfaces.

These instances of transdisciplinary, multidisciplinary and cross-disciplinary research and practice are becoming more prevalent. However, educational and other cultural institutions still support separate disciplines. Until they are altered, separateness of values, attitudes and beliefs of individuals enculturated within the distinct academic disciplines will perpetuate the status quo. Recent theoretical work in cognitive science and computer science, as well as that in contemporary theory in the arts, humanities and social sciences, provides theoretical rationales for cultural change.

BACKGROUND: COMPUTER GRAPHICS HISTORY

The Early Years and Beyond

In the 1940s analogue computers were used to generate the earliest computer graphics and display them on oscilloscopes [13]. Ben F. Lapofsky and Herbert W. Franke were among the pioneers creating these images. Franke's graphics were phase forms, presented as events rather than as static imagery. Lapofsky's *Oscillon No. 4* was included in the first edition of Franke's book, *Computer Graphics—Computer Art.* His work continues to explore similar forms. An early version of a plotting device was the Henry drawing computer, a modified analog computer designed by D. P. Henry that produced drawings by a combination of pen movements and table movements.

It was not until the 1960s that digital imagery replaced the prevailing analog imagery. Examples of digitally computed imagery included alphanumeric hardcopy from teletypes, line printers and flat-bed plotters. At nearly the same time, linear, drawn hardcopy of geometric forms was produced as geometric calculations such as Lissajous figures and vector graphics. Because early computers had low capacity of speed and memory, these calculations were generated in a painfully slow display, then recorded by photographing the screen or drawn by plotters.

Usually these images were done by engineers and technicians employed by government, industry or large research institutions. The design of hardware and software reflected practical purposes, as did most of the images done in these settings. Not all images served technological research or practical purposes; some were done in 'spare time' by engineers and technicians. For example, an image called *Stained Glass Windows,* a graphic designed in the Army Ballistics Research Laboratory, reflects a desire by individuals not trained in art to produce aesthetic imagery. It received second prize in the Computer and Automation Computer Imagery Contest in 1963. Although color was not introduced for images created for practical purposes, it sometimes occurred in images created for visual aesthetic purposes. John C. Mott-Smitt produced an early scientific visualization of subatomic particles in a force field. He also varied this same program for visual aesthetic purposes; he introduced color by utilizing color filters and creating multiple exposures from his visual display screen. Nake introduced color in the plotter-drawn images of matrix multiplication. He assigned various numbers to colors and supplied the plotter with colored drawing pens.

An example of the more prevalent practical imagery done at this time is William Fetter's seven-system man. This program created the image of a man with seven movable components using data representing a fiftieth-percentile pilot of the U.S. Air Force. Its purpose was to assist in the design of an ergonomically efficient cockpit. Fetter and his technical group also attempted a computer-graphic landing simulation for the air force. These graphics are transparent wire-frame constructions; that is, they used no hidden-line algorithms.

Perhaps the most effective and most cited computer-graphic imagery of the early period is that of the Computer Technique Group of Japan. By combining photographic and geometric data, this group produced graphics that may be read as political commentary, *Kennedy in a Dog* and *Marilyn Monroe in a Net.* These transformations and their two-dimensional interpolations such as *Running Cola Becomes Africa* may be considered classics of this early period. The group also produced one of the first interactive environmental pieces, called *Automatic Painting Machine No. 1.* It consisted of a painting mechanism, control unit, paper-tape reader and a happening zone. Four types of input were used to control this device: manual, paper-tape program, light-sensor input from happening zone and sound-sensor input from this zone. The machine produced painted canvases up to 2 by 1.5 meters; the painting instrument consisted of four color sprays operated by compressed air through electromagnetic valves. All the individuals comprising the Computer Technique Group were engineers and programmers; none were professional artists.

Nicholas Negroponte and the architectural machine group Seek produced experimental computer-controlled environments at MIT.

For example, they created an experimental computer-controlled habitat for gerbils in 1970. Another example of interactive environmental pieces is Bonacic's computer-controlled sculpture featured in *Leonardo* in 1974. This sculpture received environmental input from sensors.

Individuals with art backgrounds who were active in early computer graphics and continue their work include Charles Csuri, G. Nees, Robert Mallary and Duane Palyka. Csuri's static graphic, *Sine Curve Man,* and his transformations on film, *Hummingbirds* and *Aging,* were done with assistance from computer programmers. In 1970 he published "Interactive Sound and Visual Systems" based on his work at Ohio State University. Palyka's alphanumeric printer output for designing two-dimensional artworks was based on variables in the programming; these works were included in the first computer-art exhibit, "Cybernetic Serendipity". Many computer graphic artists later used this technique. Nees and Mallary created sculptures with computer-aided design and computer-controlled manufacturing techniques. In an essay, "Art, Cybernetics and the Supermarket", Moles noted the potential of introducing a variable into computer programs that control machine tools for industry, causing every item that emerged from an assembly line to vary slightly. The variability would probably be cosmetic in nature, not essentially altering the product's purpose or functional form. It could consequently be regarded as an example of marginal differentiation.

At the Second West Coast Computer Faire held in 1978, several projections were made. It was proposed that small computer systems similar to the larger systems used by Mallary for sculptures, by Laurie for weavings and by others for prints be used by individuals to create unique furniture, fabrics and prints suited to their special requirements. Applications programs with many optional branches could assist in the design process. The completed design in the form of digital data could be used to direct mechanical production of the objects. In short, computer-aided manufacturing could be customized rather than characterized by exact repetition and centralized assembly-line mass production. It was also proposed that small microprocessors be used for games and appliances. However, these applications would remain in the style of mass production, allowing the consumer little control except by veto of non-purchase. In contrast, small computer systems with suitable applications software could allow individuals to design and control essential aspects of environment. This was presented as emphasizing an appropriate role of human choice in directing the uses of technology.

These projections present a view of electronic manufacturing that is parallel to the much earlier views of Borsodi on mechanical mass production. He noted the potential for individual control of mechanical manufacture of clothing and household textile products, based on the advent of the home sewing machine. This view suffers from an optimism born of ignorance of the constraints of cultural maintenance and change, particularly the social and economic context of origins and practices. This view also ignores important differentiations between conceptual possibility and feasibility. Relationships between these are based on complex interactions of social, economic, educational and historical factors; that is, origins and prior practices must be considered. Interestingly, computers have been used to customize the tailoring of suits in West Germany and of bikinis in southern California. Measurements of the individual are taken by laser-based optical scan in the West German instance; digital photos and keyboard entry of measurements are used in southern California. Although these products are customized to a client's body, individual conceptual design differences are not employed—that is, ear lier concepts of the designer and tailor as experts remain.

During the early years of computing, other individuals and teams produced work that presaged later and current technologic/scientific and artistic work. For example, working at Bell Labs in 1966, Knowlton and Harmon produced gray-scale images from drawings, photographs and real objects by using data from a photodensitometer. This instrument presents the scanned image so prevalent in contemporary work. Later work on picture processing has been done at the Jet Propulsion Lab in Pasadena [14]. Also working at Bell Labs in 1964, E. Zajak depicted a satellite orbiting in space. In 1967, also at Bell Labs, A. Michael Noll produced a film that depicts a four-dimensional object rolling through our three-dimensional world. These examples prefigure the work of scientific visualization, in which things that have never been seen and may never be seen are presented as graphic imagery to stimulate conceptual thinking. This imagery augments thought formerly supported by alphanumeric and primitive graphic symbols [15]. Noll also produced a set of Mondrian simulations, which he presented to a group of subjects, asking, Which is the Mondrian? and Which do you prefer? [16]. This early attempt at analysis and simulation of visual forms led to generative aesthetics. Even earlier (1957), R. A. Kirsch et al. reported experiments in processing pictorial information using a digital computer [17]. The work of Noll and Kirsch presages more complex picture processing, pattern recognition and the links between computer graphics, artificial intelligence and remote sensing. The evolution of this early work can be traced in Rosenfeld's compilations [18].

The middle period of computer graphics is one of continued tension between technological/scientific and artistic realms. This tension reveals itself in choices of images, intentions and, increasingly, in conceptions of 'how the world is and ought to be'. During the middle years cost and scale of technology also became an important variable. Scientists and technologists continue to develop the most sophisticated and expensive technology. Few artists have access to this equipment. They rely on cheaper scaled-down versions of early technology; those artists who do gain access to the technical labs but lack training in science and technology encounter conceptual, technical, environmental and organizational difficulties. David Em's accounts of working in the Jet Propulsion Lab in Pasadena document these difficulties from an artist's perspective [19]. The involvement of artists with computers during the middle years is well documented in Leavitt's *Artist and Computer* and in periodicals such as *Leonardo* and *Art Forum*. ACM and IEEE publications document the development of technological and scientific imagery.

The primary form of computer imagery in the early years was the two-dimensional screen or plotter graphic. Three-dimensional screen imagery consisted of transparent wire-frame images. With increases in memory space and speed, and the construction of hidden line algorithms, illusory three-dimensional images began to appear on computer screens. In the mid and late 1970s further increases in speed and memory led to raster graphics and then to displays of three-dimensional colored, shaded and textured images on computer screens. Optical effects such as reflection and transparency became technically possible. Examples of these effects were developed at technological research sites such as the University of Utah. Duane Palyka worked at this site. Leavitt presents images of Palyka using some of the earliest paint programs and a digitizing tablet developed at the University of Utah. His work with this hardware and software represented a sharp departure from stereotypical geometric computer imagery. Because his imagery simulated and explored earlier artistic media, Palyka could use it to present concepts from within the mind of the artist, much as if he were drawing or painting them. He worked with Ivan Sutherland's first interactive drawing system, Sketchpad. Other interesting developments at this site include Sutherland's device that directed the display directly into the visual system of the person wearing the device, who could see a three-dimensional wire frame world suspended in space around her or him [20]. This development was an initial step toward virtual environments. Later, a report on GROPE-I by Batter and Brooks, working at another site, illustrated the development of another step toward virtual environments, tactile and kinesthetic illusion [21]. This work and that of Fetter presage the virtual environments that currently exist for defense simulations. One task that had been set for the University of Utah research group by their government funding source was not met: the generation of dynamic three-dimensional screen graphics displayed in real time. Even though the images presented color, light and shade, reflections, transparencies and opaqueness, their display took a long time to generate on the screen. The task of generating real-time graphics required a conceptual shift rather than purely technological improvement.

Graphics done by computer scientists, engineers and technicians continued to be practical and increasingly to be rooted in assumptions of objective realism. Their creators believed they could create an adequate simulation of visual and physical aspects of the world grounded in mathematical formulae and algorithmic expression. (In this, they entered the realm of visually simulating three-dimensional reality on a two-dimensional surface, the same problem that had occupied Roman artists practicing illusionism and Renaissance artists who revived visual perspective.) Scientific visualization involves expression both of physical laws and of visual/optical laws. Both artists and scientists abstract natural laws from the 'real' world to express it mathematically and to present it visually.

With the development of ray-tracing techniques, particle systems, and other techniques for depicting the three-dimensional world and dynamic systems within it, technical imagery outstripped the planar illusionism previously practiced by artists. With greater precision in reality simulation through computer graphics came the realization that the images formed were too perfect, or hyperreal. These hyperreal images failed to create the visual effect of the real world, because they did not include imperfections and irregularities characteristic of natural phenomena. Consequently, they looked 'too plastic'. They revealed the abstract nature of physical law—its abstraction and noncorrespondence to the vision of lived experience. Attempts to remedy the problem of hyperreality included applying variations in textural-pattern maps to the surface of illusory three-dimensional computed objects. Degraded versions of the hardware and the software developed during this stage are now available for use by artists. An interesting result has been work based on aesthetic modernism, which concentrates on composition with elements and principles of design but also treats the two-dimensional surface as three-dimensional. The work of M. Pruitt is characterized by this combination [22].

While computer scientists and technicians were pushing back the technical limits of computer graphics, many artists explored characteristics of earlier computer-graphic imagery. Following the first major international exhibition of computer art in London in 1968, more artists began to take an interest in the computer as an artistic medium. By the late 1970s, computers were more available to artists, although the latest and most expensive models remained in the laboratories of industry, government and research institutions. Computing power remained a scarce resource. Many artists began using the computer as a designing or executing device. A common practice, utilized by Barbadillo, Sykora, Giorgioni, Marcus and Leavitt, among others, involved generating multiple designs from a single program, choosing one and executing it in a traditional art medium. Palyka and Molnar had used this technique earlier. Most of the resulting work was visually similar to modernist art.

Modernist schools of criticism—formalism and empiricism—analyze composition in terms of elements and principles of design. Both schools of criticism can be viewed as reductive; that is, they ignore historical, social or representational references within an artwork. They decontextualize a set of abstract references, elements and principles of design in order to describe and analyze the work. The empiricist school of criticism attempts to make aesthetic and artistic critical analysis in a scientific manner. It describes artworks by reducing them to their elements, analyzes by relations among these elements, and interprets and judges based on these descriptions and formal analysis. Its method is similar to the scientific method of observation, analysis, proposal and testing of hypotheses. Both formalist and empiricist criticism claim to be universally applicable to art, whatever its context, and value-free. Consequently, this style of art, whether associated with computer graphics or not, may be said to confirm cultural assumptions similar to those of scientific research and practices of scientific visualization using computers.

Other artists were interested in taking advantage of computer control of external devices for creating artifacts or for creating interactive, responsive sculptures or environments, some of which cross disciplines within the arts as well as across the arts and sciences to incorporate sound and human movement received from sensors and keyboards. Ihnatowicz and Cohen join art and artificial intelligence in their sculpture and drawing. Their works attempt to assimilate scientific, psychological and philosophical discourse. Ihnatowicz's sculpture *Senster* presents motions that may be interpreted as emotional behaviors such as distress and fear in reaction to large crowds and noisy environments. Jasia Reichardt commented, "It is as if behavior were more important than appearance in making us feel that something is alive," and "Confronted by this artificial device, it is clear that people have no difficulty in organizing their psychological responses as if The Senster were alive—an animal or another human being" [23].

Cohen has constructed a series of computer programs that direct the activities of a drawing turtle. He attempts to describe the process by which human beings read symbols and images. His programs imitate experts who know aspects of picture making, such as shading, spatial distribution and determination of inside and outside of forms. He regards the computer as an intelligent assistant, analogous to a human assistant to an artist such as Rubens. This work recalls the Turing Test. Can we mistake the drawn expression of a machine for that of a human artist? These artworks reveal their relations to movements in the art world such as happenings and participatory theatre. In them, the division between artist, participant and artwork diminishes in importance.

Cohen's work extends early attempts to produce computer simulation of the style of artists such as Klee, Hartung and Mondrian. Cohen also attempted stylistic simulations of Bach's musical style. Kirsch and Kirsch have continued this type of analysis and simulation in a symbiotic expression of human skills and machine capabilities. In this wife-husband team, the wife is an art historian and the husband a programmer who did early research in pattern recognition. They combine an art historian's understanding of style and a programmer's technical skills to define that tentative style in the parameters of a computer program. The computer produces multiple images based upon their analyses; they test the 'goodness of fit' of these images to the art historian's sense of style and revise the program accordingly. These activities are a symbiotic interplay between human/human and human/machine [24]. Trying to determine what is viewed as an aesthetic object, others have attempted to define and program parameters of aesthetic value. The algorithmic aesthetics studies of Stiny and Gips are an example of this [25].

Gradually computing power has become accessible: hardware and software developed in the laboratories of government, industry and research institutions are available for mini- and microcomputers and economically feasible for small institutions and individuals. Based on more complex hardware and software, these are labeled 'degraded forms', simpler and more economical; among them are draw-and-paint programs, similar to those developed at the University of Utah, and scanned imagery, such as that developed at Bell Labs. Discussions on the appropriate form for computer graphics as art have followed these developments. Are there forms unique to computer graphics? Should computer graphics be used as an adjunct to other media, to emulate other media, or should it be used as a unique medium in itself? Does the work of art reside in the concept, in the computer program, in the process of performing or running this program, or in some phase of the output? If the program contains randomization, stochasticism, variables derived from environmental sensors or other interactive data, how does this affect its status as art? What of its status as original or reproduction? These are among the many questions that computer artists began to raise and have not yet fully addressed. An examination of aesthetic theories embedded in scientific/technical and artistic computer-graphic imagery, theory and practice, begins to reveal the extent of embedded cultural origins and practices in this medium. Embedded assumptions from science, technology, and the context in which these forms were originated also influence computer graphics. Form, content, meaning and purpose of contemporary computer graphics show these origins and practices.

RECENT AND CONTEMPORARY COMPUTER GRAPHICS

Artistic Uses

An examination of the computer graphics selected by recent SIGGRAPH jurors displays the continued split between the scientific/technical and the artistic. Artistic uses of computer graphics imitate the appearance, message and techniques of other contemporary art forms. For example, note the artistic theoretical emphasis on pastiche and text reflected in the supplemental issue of *Leonardo* titled *Computer Art in Context* [26]. In the face of emphasis on context by some contemporary art theorists, most artistic uses of the computer remain separate from practical, scientific or technical uses. Theorists such as Sekula in photography, Rossler in video and this author in computer graphics have urged simultaneous consideration of the multiple uses of computer graphics—artistic, technical, scientific, commercial and practical—within a single social and historical context influenced by overlapping origins and practices. It is in this vein that computer graphics for advertising, entertainment and other practical purposes may be examined.

Context of Daily Life

Contemporary uses of computer graphics retain traces of their origins and earlier practices. Although Licklider and Taylor insisted on the potentially widespread effects of computers [27], others viewed the computer world as an island economy. Now daily life is affected by computing. Even Licklider may have been surprised at the ubiquity of computer graphics. Practical and professional communities of advertising, entertainment, publishing, telecommunications, business, finance, education and medicine have joined the academic, scientific and artistic communities in using this medium.

Viewing the realm of everyday life as separate from the theory and practice of intellectual disciplines—or decontextualizing knowledge—often precludes an examination of practical uses. The origins and early practices of computer graphics shape the form and content of video games, technical effects in movies and advertisements, use of home computers for educational programming, desktop publishing and other practical applications. These relatively recent phenomena bring computer graphics from the lab to the home, business and community. The work of John O'Niell offers an interesting example of the interaction of theory and practice from the art world with the origins and practices of early technical/scientific graphics. Most video games clearly show their origins in military simulation. John O'Niell retired from the official art world (the institutional art world that sees art as separate from daily life, or decontextualized; this modernist view of art has interesting parallels to the modernist separation of scientific theory from practical effects) because he believed that art was important not in itself but only as it affected people. He believed that it had to reach people in a medium they could relate to, in a language they could understand and at a price they could afford. He believed that "material is 'art' if it can excite and stimulate observers or users to a new perception, or throw them out of an established mode of perception" [28]. He began to work in visual board games, then in video games. He produced the graphics for Atari's game *ET*. Working under the signature of Admacadiam, he produced a series of games. His *Flytes of Fancie* are game simulations of aspects of living (dreaming, loving, traveling and so on), expressed in graphics and sound. Intended as fantasy entertainment at one level, at more complex levels they may move the player toward new or renewed levels of awareness. They manifest contemporary art theory that regards art and life as integrally related and opposes modernist decontextualization of art. O'Niell's work forms an interesting parallel to a more recent publication by Berman. Berman's work reflects a trend in the history of science similar to that in contemporary art theory that stresses the contextual and value-laden aspects of theory and practice. In evaluating computer technology in terms of human value, Berman states,

> The thing to ask of any new philosophical statement, any extension of computer hardware into schools, universities, or therapists' offices, and of any new toys such as Pac-Man or Apple II is only this, Does it take me into the things I fear most and wish to avoid, or does it make it easy for me to hide, to run away from them? Does it enable me to shut out my environment, ignore politics, remain unaware of my dream life, my sexuality, and my relations with other people, or does it shove these into my face and teach me how to live with them and through them? If the answer is the latter, then I suggest to you that we are on the right track. If the former then it is my guess, as Merleau-Ponty says, that we are sinking into a sleep from which, in the name of enlightenment itself, there will be no easy awakening [29].

The form of O'Niell's game has not become popular, however, in any way comparable to military or sports simulations or to adventure games. An extensive study of the creators, participants, and form and content of video games may shed light on how the origins and practices of early computer graphics relate to current design of video games. The addiction to video games treated by such organizations as Vidanon may connect with Berman's questions about encountering and jousting with personal reality or escaping it through one addiction or another.

Image-processed digital photography occurs in mass media publishing, television news, and as photographic evidence in court cases; its use has raised legal and ethical questions. Computer-generated characters, sets, and environments for television and the motion picture industry are being explored. *Tron* was the first movie to include a large segment of computer-generated imagery. Particle systems for simulating fire and explosions and fractals for mountains and planet surfaces have been used. *The Last Star Fighter* used live actors intercut with computer-graphic imagery. Early technical attempts to simulate human motion and human facial expression were quite disappointing. Using the fifty-first percentile to find an average human form and motion is time consuming [30]; the resulting images are boring because the movements are smooth and lack variety. Unique and dramatic variety in human motion have traditionally held the attention of the entertainment industry. Consider for example, John Wayne's walk and Marilyn Monroe's.

By 'faking it', by adding visual, dramatic and artistic content to the calculated content, David Zeltzer created several moments of computer-generated animation of a human skeleton [31]. Later at the same lab (Cranston-Csuri at Ohio State) a computer-generated animation, *Snootley and Muttley*, by Susan Van Baerle and Douglas Kingsbury, brought drama and story to computer animation of nonhuman three-dimensional cartoon characters.

In 1985 *Tony de Peltrie,* a film of a computer-generated three-dimensional human cartoon character who expressed emotion through facial and bodily motion, was presented at SIGGRAPH by Lachapelle, Bergeron, Robidoux and Langlois from the Centre de Calcul of the University of Montreal [32]. However, the expenses of resources and time make widespread use of computers to generate usual film content impractical at present. The 7-min-50-sec film *Tony de Peltrie* does not present the illusion of human drama but a caricature of it. It cost $1.5 million and took 3 years to produce. A more recent example of computer-generated special effects in the film *Abyss* is the pseudopod, a tentacle of water that takes on the facial features of film characters in an effort to communicate with them. To create the pseudopod took 6 months; this included creating multiple tapes and sending them to the director, Jim Cameron, receiving his instructions, comments and changes by fax and sending him a new tape the same day or the next day. The supervisor of computer graphics, Jay Riddle, and designers Lincoln Hu, Mark Dippé, Scott Anderson, John Knoll and Steve Williams created the effect at ILM (Industrial Light & Magic, a division of LucasFilm). Riddle states,

> He [Jim Cameron] was able to essentially direct the action of the pseudopod rather than just hand us a set of storyboards and tell us to come back to him with something in six months. It also made for a quick turnaround process, which was very important to us if we were going to prove that computer graphics could be commercially viable [33]

This same production that used sophisticated hardware and software to produce the pseudopod used low-end computers, Macintosh II, to augment the traditional film production processes. For example, storyboards drawn by an artist were scanned, manipulated and printed using the Mac. Images were resized and enhanced to select the best camera angle. A low-end software package, Super3D, was used to build computer models from drawings for set designs and props. The models could be rotated to show how they would look in perspective when they were built and "flown on and off the screen" via computerized animation so the director could approve or modify designs. The *Abyss* creative team also employed the first real-time camera simulator developed by David A. Smith (author of the Macintosh game *Colony*), to guide the filming of the underwater base. This enabled the design team to 'walk' around a wire-frame image of the underwater base displayed on the monitor. It allowed them to preview, albeit in simple detail, how the set would look before the studio spent tens of thousands of dollars building it. It also showed the best camera angles from which to shoot the film. Smith built the simulator on the Mac by encoding blueprints of the base in the three-dimensional authoring system he used to create *Colony*.

Computer graphics in advertising and entertainment rely heavily on the appeal of technical special effects made possible by earlier scientific/technical developments. In *American Cinematographer,* Lee cites Platerick, president of Computer Opticals, as stating, "Dialogue is dialogue. Sex is sex. What the audience wants is special effects." In the same article she quotes Tony Valdez describing typical graphics techniques. For the future, he predicts that "a moviegoer will walk into a screenless theatre, put on a headset and become part of the visual experience—possibly adding his own interpretations" [34]. Interestingly enough, such screenless environments exist not in theatres but in virtual environments created in defense labs for practical defense simulations, as earlier computer graphics were. These environments are also being 'played with' in artistic ways by individuals in the labs. They present remarkable visual and tactile realities [35]. Each user is clothed in a suit that transmits computer-generated visual and tactile data. Through input devices users may create and share new elements in their virtual reality. An interviewer talking with Jaron Lanier expressed concern for the addictive properties of the experience by analogy to earlier reality-transcending experiments with psychedelic drugs. Several statements by Lanier reflect art as reality shaping or transcending. Many of his views on virtual environments are similar to those expressed earlier by O'Neill about his games. Virtual reality uses computerized goggles, gloves and body suits to synthesize shared reality, which surrounds the participant; it appears to remain stable and to present different views as the participant moves head and body, as a normal room would. The gloves allow participants to feel the synthesized reality. Unlike in the real world, however, participants may design and take the form of another animate or inanimate object. Participants dressed in virtual-reality gear may see one another in the designed forms and interact with one another. As Lanier describes the potential of his virtual reality device—the "Home Reality Engine"—users can create and share a virtual world of their own design. The creation and sharing of tools, environments, creatures and experiences complete with sight, sound and touch are technically possible. Of its transcendent nature Lanier states,

> Idealistically, I might hope that Virtual Reality will provide an experience of comfort with multiple realities for a lot of people in western civilization, an experience which is otherwise rejected. . . . It will bring back a sense of the shared mystical altered sense of reality that is so important in basically every other civilization and culture prior to big patriarchal power. . . . If the technology. . . has a tendency to increase human communication, human sharing, then I think it's a good one overall, . . . the television is bad but the telephone is good. . . . I do hope that Virtual Reality will provide more meeting between people. It has a tendency to bring up empathy and reduce violence [36].

This view assumes that the participatory and creative potential of this technology will be emphasized. Valdez predicts a less active moviegoer. Two science fiction works written many years apart have discussed similar technologies: Aldous Huxley's *Brave New World* in which people went to the Feelies, a multisensory movie environment, and William Gibson's *Count Zero* and *Mona Lisa Overdrive,* in which people plugged into a simulated stimulus deck, a multisensory simulator more like a television with a headset, providing private rather than shared experience. Both of these technologies were created by experts, not by participants; based on existing technologies, these marked the limits of the possible. Television is not necessarily a technology of centralized control and expert production. That is, however, the primary way in which it has been implemented. These examples raise questions about the potential implementation of virtual reality for advertising, entertainment, education and business, as well as questions about relationships between possible and the probable form, content and implementation of a new form.

Lanier expanded his beliefs regarding the transcendent character of this technology:

> Virtual Reality starts out as a medium just like television or computers or

> written language, but once it gets to be used to a certain degree, it ceases to be a medium and simply becomes another reality that we can inhabit. When it crosses over that boundary it becomesanother reality. I think of it as acting like a sponge where it absorbs human activity from the physical reality plane into the Virtual Reality planes. To the degree that that happens there is a very beneficial asymmetry that comes into play. When Virtual Reality sponges up good energy from the physical plane, then what you get in Virtual Reality is beautiful Art, beautiful dance, beautiful creativity, beautiful dreams to share, beautiful adventures. When Virtual Reality soaks up bad energy from the physical plane, what we get is some decrease, however small in violence and hurt on the physical plane in exchange for events on the Virtual plane which while they might be uglier, are of no consequence whatsoever because they are virtual [37].

In some ways similar to Aristotle's theory of catharsis as related to drama, Lanier's theory appears unsupported by research on effects of violence in television. In discussing the most vivid experience of virtual reality, Lanier statesthat it is the experience of leaving it:

> Because after having been in the reality that is manmade, with all the limitations and relative lack of mystery in that, to behold nature is directly beholding Aphrodite; it's directly beholding a beauty that's intense in a way that just could never have been perceived before we had something to compare physical reality to [38].

Lanier believesthat humanly created artifacts pale beside the reality they imitate. Berman argues that the same effect occurs at the theoretical, professional and practical levels of computer usage: "a formal, disembodied and abstract reality is informing the mode of perception and cognition held by those engaged in that activity" [39]. The tendency toward abstracted experience and away from richly lived experience permeates technological encounters. This abstracted experience may heighten some sensations and sedate others and for this reason may be examined as a potential addiction. I believe the concern for addiction to virtual reality might be viewed in light of addiction to television, video games and home computers. As symptoms of larger societal problems, they figure in a plethora of literature, including Schaef's *When Society Becomes an Addict* [40]. Embedment of abstracted forms of reality based on origins and prior practices appears strong. Reality transcendence may also be seen as a form of reality emphasizing selected components. Consequently, whether the form, content and use are based in prior practice or theories of reality construction or in theories of reality transcendence, they are impoverished in light of natural, lived experience. This condition applies quite well to two examples, video games and virtual reality, and causes me to temper the visionary prediction of conceptual possibilities with probabilities based on origins and practices. As these current and developing uses of computer graphics evolve, what is going on in the academic and technical world of computer graphics?

CONTEMPORARY TECHNICAL AND SCIENTIFIC RESEARCH

Contemporary research continues to be viewed as separate from daily life, although its economic and conceptual ties to industry, government and research institutions remain. More research appears transdisciplinary, however. Researchers in cognitive science are part of a recognized multidisciplinary complex that relies on neurophysiologists, psychologists, anthropologists and sociologists to inform computer scientists interested in artificial intelligence and human/computer interaction. They all use computer graphics to a greater extent than could have been previously imagined.

Some of the research questions concern the role that imagery plays in cognition [41], how graphic interfaces, graphic- and object-oriented and iconic programming languages [42] and pictorial information retrieval figure in computer science [43]. Others investigate how we understand, simulate and best utilize the varying characteristics of human and machine vision [44], the visual and conceptual relationships between animation, simulation and visualization [45], and the value of graphic representations of mathematical, scientific and logical conceptual constructs as opposed to alphanumeric representations [46].

CONCLUSIONS

Cultural valuing patterns embedded in early computer usage include validation of alphanumeric representation over graphic, tactile or kinesthetic representation. Separation of disciplines and decontextualization of knowledge are still institutionally maintained but are changing in the practices of theory and research.

Culturally accepted concepts embedded in technical/scientific imagery remain in hardware and software used later for artistic and entertainment purposes, among them techniques for the display of three-dimensional visual form. When scientists take these techniques to their logical limits in the technical/scientific realm, they find that they need to borrow the concepts and methods of artistic practice in order to create graphic images that look more real than images based solely on algorithms. Scientists label this practice with terms such as 'faking it', revealing continued ambivalence about the relative value of visual reality (as presented by artists to make it 'look real') compared to scientific reality (based on physical laws, optics, etc.). The legitimation of the scientific as a value-free representation of reality provides a basis for its own deconstruction. This occurs when viewed through the eyes of artists from the same culture as the scientist, engineer or technician but with a different educational enculturation. This also occurs if we examine this reality through historical imagery or cross-cultural imagery and through what has been written or recorded about these images. That is, the relative status of scientific reality is revealed.

Simultaneous examination of scientific/technological and artistic uses of computers reveals aspects that show they share authorizing assumptions. This may be compared to the use of spatio-graphic juxtaposition of texts by Genet and Hegel by Derrida in his work *Glas* [47]. Although Genet and Hegel may appear as opposites, they may also be seen to share assumptions of materiality of language and authorization of gender politics. Science and art may be shown to share embedded patterns. Scientific realism assumes that immutable natural laws may be represented symbolically as one-to-one correspondence with reality, expressed, for example, in the illusion of three-dimensional space on a two-dimensional surface in art and in illusory three-dimensional computer graphics. Abstraction of concepts or theories about natural law may also be represented as scientific visualization—for example, in a construct such as a model of the functional architecture of the visual cortex [48]. Through this abstracted representation, its reductionist nature emphasizes some aspects and deemphasizes others. There is a correspondence to abstraction in the visual arts. In these representations, aspects of form and/or meaning are emphasized or deemphasized. Even the methods employed in modernist criticism show correspondence to the scientific method. Consequently, both scientific and artistic sources rely on culturally embedded patterns of reality represented by varying degrees of abstraction in symbolic and material culture. Their shared assumptions about the value of abstract representations of reality have contributed to the practice of decontextualization, to cultural maintenance of that larger embedded pattern.

In *Arts and Ideas* [49], Fleming has labeled the twentieth century a century of relativity. In mathematics, Gödel showed the contextual nature of mathematical proofs. Einstein's theory of relativity, Heisenberg's uncertainty principle, and quantum theory brought relativity and contextuality to the physical sciences. Contemporary theorists in cognitive psychology, anthropology and philosophy also call our attention to the relative nature of human knowledge and values. Many stress individual, cultural and historical differences rather than panhuman universals. Attention to detail and context are in conflict with the valuing of abstraction and decontextualization. Consequently this may contribute to cultural change. Artists, scientists or technicians may accept these trends, reject them or operate in a culture influenced by them without awareness of their influence. In any case, their work reflects this influence. As these aspects permeate the larger culture and the experience of nonspecialists, cultural change may occur.

In examining possible and the probable trends in computer graphics, cultural maintenance and change must be considered. The gradual shift from decontextualization inherited from the past to our contemporary emphasis on context is reflected in historical and contemporary computer graphics imagery and purposes. Divisions of knowledge, separation of the practical from the theoretical and other assumptions about knowledge formerly taken for granted have been challenged in this entury. As this shift continues into the next century, it may generate new conepts of what knowledge involves. These concepts may be based not only n alphanumeric print media but on xperience and expression through data obtained and expressed in graph-, sound, touch and movement.

Telecommunications using photonic transmission, fiber optics, promises delivery of multiple services and multimedia to the home over one vehicle. This may include telephone, fax, television, computer data, database queries and telemetry. The development of technology, theory and practical applications join to amplify some conceptual structures and decrease emphasis on others. As these changes occur we need increasingly to provide citizens a broad education that includes technology and its relation to human values. Technological development brings unexpected results. In constructing scenarios for the future, writers may be optimistically visionary, pessimistically visionary or unable to envision future effects. In any case, the visions remain rooted in their experience and understanding of the status quo. From this stance, will the future resemble the pessimism of Huxley's *Brave New World* or Gibson's cyber-punk science fiction? Or will it bring a new positive reality rooted in the present but not yet imagined? Will it extend the present with unexpected cultural constructs emphasized and deemphasized? These views exhibit limits of the possible and the relationship of new technology to origins and prior practices. In the two fictional cases we see the delivery of canned realities made in centralized settings by experts, for delivery in public and private settings. In Gibson's reality only the experts can experience the true euphoria of completely disembodied experience. It consists of death in the natural world and living on in a humanly constructed cyberspace. These two authors' science-fiction accounts reflect experience with movies in theatres and television as alienated private viewing: separate from 'real life', with no effects accruing to lived experience. Their views contrast as markedly from Lanier's vision for virtual reality as early visionary predictions for television contrast with its current uses. Lanier proposes the creation and sharing of virtual realities by individuals for purposes of transcendence. Both science-fiction accounts see virtual realities as constructed by experts in centralized production settings for purposes of sensual stimulation with no acknowledgment of causal or logical connection to the practical world. They are decontextualized fictive experiences. Contemporary psychological research regarding effects of violence in television on attitudes and actions conflicts with this view. In light of this discussion, I leave the reader to consider the relationship of possible and probable uses of computer graphic applications, including virtual reality, in terms of origins and practices.

References and Notes

1. H. Franke, *Computer Graphics—Computer Art* (London: Phaidon, 1971) p. 7. Franke's definition of computer art is "any aesthetic formation which has arisen on the basis of the logical or numerical transposition of given data with the aid of electronic mechanisms." According to Beyer (unpublished lecture, 1976), "computer graphics centers about visual output and uses other media/techniques in auxiliary methods."

2. B. J. Jones, "Computer Imagery: Imitation and Representations of Reality", *Leonardo* Supplemental Issue *Computer Art in Context* (1989) pp. 31–38.

3. B. J. Jones, "Cultural Implications of Integrated Media" (1989 unpublished manuscript).

4. The research reported in this paper reflects my work since 1973, when I began to collect images and essays on the computer in the arts and humanities. In 1976 I compiled an educational slide set, a history of computer graphics (funded by the National Science Foundation and the Oregon Mathematics Education Council). At the 1978 Conference for Computer Assisted Learning I drew an analogy between early uses of electricity and computers and in 1978 at the Second West Coast Computer Faire suggested the potential widespread and multiple uses for microcomputers. B. J. Jones, "Computer Art and Art-Related Applications in Computer Graphics: A Historical Perspective and Projected Possibilities", *Proceedings of the Second West Coast Computer Faire*, J. C. Warren, ed. (San Jose, CA: 1978).

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13. This section relies heavily on H. Franke (see [1]) and Franke's *Computer Art—Computer Graphics*, 2nd Ed. (New York: SpringerVerlag, 1985); J. Reichardt, *Computer Serendipity* (New York: Praeger, 1969), *Computer Art and Ideas* (Greenwich, CT: New York Graphic Society, 1971), and *The Computer and Art* (New York: Van Nostrand Reinhold, 1971); R. Leavitt *Artist and Computer* (New York: Harmony, 1976); and selected periodic literature from *Leonardo* and *Art Forum*.

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