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Surveying Computer Graphic Trends

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SURVEYING COMPUTER GRAPHIC TRENDS

(TITLE)

BY

Angela Bradley

THESIS

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Professors Johnson, Sorge, and Wilen

Submitted by:

Angela Bradley

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Abstract/Introduction

Computer graphics is a new tool for the visual artist. Historic and educational theories and facts outline the rapid growth of the medium and how it has become an essential tool for educators, researchers and businesses. Business applications remain at the periphery of computer graphic applications, but are included in the general trend of the new medium's development.

Visual art generated through computer graphic imaging is exemplified in the work of artists: Barbara Nessim, computer graphic student, Jim Squires, and the team of computer graphic artists, Richard Chuang and Glenn Entis. Nessim is a career graphic designer and artist, who only recently chose to explore the computer graphic medium. Jim Squires is a student of computer graphic art who generates images by writing programs for that purpose. The team of Chuang and Entis generates animated computer graphics in its own studio, Pacific Data Images, for commercial purposes. An overview of how each artist works, and what considerations must be made in generating these images, gives an understanding of the general trends prevalent in the computer graphic field.

A type of shape called a "fractal" is discussed to illustrate the importance these shapes have in computer imaging. Fractals had little importance for any discipline until they could be generated on the computer screen.

Their relevance to the analysis of chaotic shapes in nature has opened a whole new realm of study for disciplines such as mathematics, ecology and meteorology, among others.

The computer graphic field is a new and essential by-product of the computer revolution. The discipline is important for visual artists because it is a virtually unexplored medium that has great potential.

Reviewing Historic Parallels in Scientific and Artistic Achievement

Since the time of the ancient Greeks, and Pythagoras' mathematical formulations, parallels have been drawn between advancing technological knowledge and periods of extraordinary artistic achievement. The Renaissance and our own time serve as additional examples of these similarities. A summary of these periods and the parallels that exist between them will be disclosed. It is apparent that recently theorized formulas in the sciences, and their repercussions in technology, have stimulated various contemporary aesthetic developments.

The classical Greek era is considered a significant period in mankind's intellectual development for many reasons. One is the Greeks' formulation of the first scientific method, which sought absolutes through inferring possible solutions to a given problem or circumstance. M. C. Goodall, author of Science and the Politician,[1] has labeled this seminal classical Greek theory "First Science" for this reason. Practical and philosophical application of "First Science" enabled painters, sculptors, and architects to create forms never before equaled in their perfection of proportion, balance and idealization. Practical application of the Greeks' theories prescribed the innovations of the Renaissance which, in turn, prescribed the technological society as we experience it.

Goodall has named the scientific innovations of the Renaissance, "Second Science." This era inspired people with "universal" curiosities, who brought forth a need for new ways of analyzing, categorizing and utilizing knowledge. They began testing hypotheses by various physical means and measures, such as volumes, weights and tensions, then put these solutions to practical and aesthetic use. This new methodology revolutionized technology and simultaneously influenced philosophical concerns. Use of "Second Science" had, until recently, been the only means by which all architectural and aesthetic ideals were realized. "Second Science" enabled moderns to ponder the possibility of yet another reality, one in which the physical and ideological worlds were understood, and where a reality of process and interrelatedness would be included and finally utilized.

Charles Darwin and Albert Einstein had the distinction of developing the base around which the humanities and "Third Science" are now evolving. It is quite probable that the combined theories of these men have altered mankind's conception of itself and significantly revised its ideologies. Darwin's theory was being popularized around 1905, the year in which Albert Einstein postulated the Theory of Relativity. Darwin's Theory of Evolution can be defined as life's continuous processes, while Einstein's Theory of Relativity virtually redefined reality. Reality had been perceived as one consciousness universally experienced, but has become accepted as being completely conceptual and individually defined. These theories have, in science and technology, created practical advances in leaps and bounds; and in the realm of the arts, have stimulated experimentation, debate and conflict. It has been over 70 years since the popularization of Darwin's and Einstein's theories; even so, scientists claim that these theories are, as yet, nascent. Scientists are unable to define objectives, cannot apply mores to their experimentation, and cannot perceive limitations. Being as such, the scientific/technological minds are in a state of perplexity. Their world is not unlike that of the avant-garde in this respect, for after decades of experimentation and enthusiasm, artists have no single aim or set of aims, and so being, have little credibility with the world at large.

Computer graphics are a relatively recent technological advancement that is having significant impact on artists throughout the world. Whether an artist is fearful of the possibilities, indifferent, or embraces the opportunity, none is unaware of the effect this new medium will have on the artistic community and on many other fields, as well. It is relevant to show that the computer revolution is having a powerful impact; it is also necessary to show that such revolutions have had historic precedent.

History

The development of computer graphics took years of research; in fact, some of the work may be traced to the mid-19th century. However, it was in 1950 the first computer-driven display, attached to MIT's Whirlwind I computer, was used to generate simple pictures

> This display made use of a cathode ray tube (CRT) similar to the one used in television sets. Several years earlier, a CRT had been used by the late F. Williams as an information storage device; this technique was to emerge years later, in the form of the storage CRT incorporated in many low-cost interactive graphic terminals.
>
> During the 1950s interactive computer graphics made little progress because the computers of that period were so unsuited to interactive use. These computers were "number crunchers" that performed lengthy calculations for physicists and missile designers. Only toward the end of the decade, with the development of machines like MIT's TX-O and TX-2, did interactive computing become feasible, and interest in computer graphics then began to increase rapidly.
>
> The single event that did most to promote interactive computer graphics as an important new field was the publication in 1962 of a brilliant thesis by Ivan F. Sutherland, who had just received his Ph.D. from MIT. This thesis entitled Sketchpad: A Man-Machine Graphical Communication System, proved to many readers that interactive computer graphics was a viable, useful and exciting field of research. By the mid-1960s, large computer graphbic research projects were underway at MIT, General Motors, Bell Telephone Laboratories, and Lockheed Aircraft. . . .
>
> If the 1960's represent the heady years of computer graphics research, the 1970s have been the decade in which this research began to bear fruit. Interactive displays are now in use in many countries and are widely used for educational purposes, even in elementary schools.[2]

The history of computer graphics is brief; this makes the study of it exciting. The future of the discipline is unfolding before us.

In reviewing the history of computer graphics, it is apparent that MIT has been the center for research and development. One man who has contributed significantly to the direction of computer graphic research is Marvin Minsky. He and a group of artists have directed their students in the implementation of computer graphic research in fine arts.

Marvin Minsky has been a Donor Professor at MIT since 1974. His years have been spent analyzing the problem of intelligence. He has developed computer processes that parallel human decision making. He has utilized observations of child behavior in developing new methods of problem solving.

In 1970, Dr. Minsky developed a computer which had a video screen and could produce animated visual displays. He believed these displays ". . . would be an extremely valuable aid in schools."[3] Minsky explains the potential of computers in an educational setting:

> Even young children become deeply engaged with ideas about computers when they can literally see what they are doing by creating movies on the screen, enough for realistic animation effects. By comparison typical hobby computers can only draw a few thousand dots a second. Moreover, they cannot display a whole book size page of text, so Minsky included a second screen in his computer, which had room for six thousand alphabetical characters, so that children could edit their

> compositions on it. One fifth grader in Lexington, Mass. programmed a garden of flowers that appeared on the screen and grew according to laws that the child wrote into his program.[4]

Computers as teaching aids are appearing in more and more classrooms across the nation and internationally. Students using computers range from small children to post-doctoral candidates. Minsky's development of the system described was slightly ahead of its time. He attempted to market the system, and formed a company to do so, but explains, ". . . our company ran out of money because we had not realized how much time it would take for teachers to persuade school boards to plan budgets for such things. . . .[5]

Marketing of Minsky's computer occurred before the development of silicon chips. Silicon chips have made microcomputers more available to businesses and the public because they are inexpensively manufactured and enable computers to be produced in a portable size. The rapid development of computers is exemplified by the six-year time span between the concept of utilizing computers within educational systems and their actual implementation. The evolution of computers is not complete. Researchers already anticipate a new generation of computers that will enable manufacturers to produce systems that are quicker, smaller and more inexpensive.

Minsky's work has been fundamental to the development and popularization of computer graphics. He is acknowledged as an important and influential individual at MIT. At every university, certain postures and attitudes are pervasive throughout the institution. So, it is unlikely that colleagues at the same institution are unaware of developments in other departments.

Gyorgy Kepes recently resigned as Director of the Center of Advanced Visual Studies at MIT, although he still retains a teaching position there. Kepes is the founder of the Center, which originated as an outgrowth of the Schools of Architecture and of Humanities. The Center is now affiliated with only the School of Architecture.

Much of what may be considered progressive in the visual arts, architecture, and design is taking place at MIT. MIT, which is active in fields such as ecology and urban studies, is cognizant of the moral obligations facing a university that it contributes to our nation's technological and economic growth.

But Kepes is keenly aware of the lack of humanitarian concern that often comes with advanced technological and economic power. Upon his arrival at MIT, Kepes sought links to connect the visual arts with his colleagues' scientific and technological studies. His work includes paintings, photography, light works, designs and books. He may be considered successful as a teacher, and financially, but it is ". . . not agreed upon in the art world that his path is the right one."[6] Even so, it is at MIT that new technologies have influenced visual arts most.

Gyorgy Kepes was part of a group that called themselves Constructivists. The group began as painters, designers, architects and engineers. Their purpose was to apply aesthetic ideals to technological necessities. Kepes grew up in the rural country of Hungary, where he worked on the Hungarian National Folk Movement during the teens. Kepes later joined with a group in Germany called the Bauhaus. Political reasons prompted his leaving Europe. He was invited to the United States to continue work at the Bauhaus of Chicago. Eventually, he gravitated to MIT, where he was first invited as a visiting artist.

One of the books Kepes wrote is entitled The New Landscape. Walter Gropius, a colleague at the Chicago Bauhaus, contributed to the publication with a piece called "Reorientation":

> The student's mind, particularly that of the potential artist or architect, will become increasingly inventive when he is guided not only by the intellectual, but also by the practical sensory experiences, by a program of "search" rather than "research."[7]

This statement has relevance for today, because it encourages student artists to keep seeking new methods of image making. It is the teaching of these values that guides artists in image making, dispelling fear of new technologies. Prior to the current popularization of computer graphic studies, Johnathan Benthall, author of Science and Technology in Art Today, observed:

> In all the world's art capitals, the avant-garde seems half paralysed. This situation in the art world needs to be mentioned because the scientific, technological world is not alone in currently going through a period of self-questioning and perplexity.[8]

Now, however, it seems computer graphics have opened a new medium for exploration. This development and other significant developments have dispelled the stagnation scientific and art communities have been feeling for many years. The interrelatedness of the disciplines has again been realized and, again, both are initiating stimulating research.

Moholy Nagy, a colleague of Kepes since their work in Hungary, expressed a thought similar to those that have been challenging students all along:

> An optimist by nature cannot conceal his concern that artists will not be able to cope with the new problems using the traditional limited tools of the past. . . . He believes that artists exploring the potential of the tools of contemporary technology . . . could produce an art that through clarity, order and imagination, would make itself relevant for our time. . . .[9]

What is similar about teachers such as Minsky, Kepes and Nagy is their optimism regarding new technology, and the computer, in particular, as a teaching and reflective tool. The teaching, optimism, and relevancy these men personify has made an incredible impact on many students who are now involved with computers themselves. The infinite possibilities inherent in computer graphics have not yet been discussed. However, while it is essential to demonstrate an understanding of the technological aspect of computer graphics, it is also necessary to consider the larger societal implications of the medium. Minsky, Kepes and Nagy must be respected as technically able men, who place concern for and responsibility to mankind at the forefront of their research.

Changes in Education

Students and teachers internationally are experiencing the changes that the computer usage has generated. Awareness of change and the realization of computers having just recently become more common in schools, is leading to speculation on how the traditional educational process will be affected. Computer use in education was planned. Marvin Minsky supported the idea many years before computers were economically feasible. The actualization of computers in the classroom demonstrated that children were learning in ways characteristically different from the traditional educational processes. This has stimulated thought about changing the educational process.

At the MIT Division of Research and Education, a colleague of Dr. Minsky, Seymour Papert, reinforces the need for changes in the educational system:

> When each child has a personal, portable computer, parents and educators will have to think in new ways about schools and education. Schools as they are now are already obsolete.[10]

Dr. Papert is uncertain of how the computer will alter the education process. "It could make present classroom and teaching methods more rigid or it could make them more open."[11]

Experience with our current educational process shows its shortcomings. John Holt, a colleague of Dr. Papert and author of Why Children Fail, supports Dr. Papert and further explains the problems:

> In the classroom . . . children must conform to behavior patterns and engage in activities that may make little sense to them. They come away from the classroom feeling powerless and alienated.
>
> Under these circumstances chlidren do not learn. Ironically, teaching--the main activity of the classroom--"impeded learning and gets in the way of (and takes the place of) those motivations that are the root of learning,". . .[12]

The purpose of education is to ready young people for the society of which they will be a part in adulthood. Both Dr. Papert and Dr. Holt agree on the problem, and they share their concerns with other professionals.

At MIT's Technology and Policy Program, in 1979, experts posed the question and answered:

> Why has innovative technology had so little impact on these public needs? In a word: because no one knows how to supply it, . . .[13]

Innovative technology is difficult to introduce into traditional situations, and to manage. Dean Gillette, of Bell Telephone Laboratories, Inc., indicates the difficulty of the task in the following statement: ". . . think of trying to be so specific about what should be meant by 'improving education' . . ."[14]

Innovative technology is beginning to change the educational system. Computers have become affordable enough to have in classroom situations.

> Compare the computer to the pencil, . . . and its potential becomes clear. The child controls the computer just as he controls the pencil. But the pencil limits the child who, for example, is learning composition. Correcting mistakes, changing words and phrases, and moving sentences or whole paragraphs are messy and hard to do with a pencil. The computer makes things easy to do. Learning proceeds more smoothly, since the child is not so likely to become frustrated.
>
> And children's use of a computer is not limited to writing. A child can program a computer to draw, make music, and in science and history projects, and play games. "The computer expands a child's field for action."[15]

Overall, educators are pushing for the availability of computer terminals for their students. Indeed, it is expected that these children will be technically literate and a world apart from the prior generation. The fruits of computer implementation will be worth bearing witness to.

Computer-enhanced education for children will have far-reaching effects. But there are also interesting developments occurring in higher education. "All school settings are in some measure unique, . . . and even more important--all perceive themselves as unique."[16]

As economic conditions have constricted in recent history, innovative steps have been taken by many universities to maintain or elevate the quality of education.

> Each tends to embrace improvements that are self-initiated and self-directed. The result: innovative change in education has as many different meanings as there are teachers in countless different classrooms--and students.[17]

This statement relates to the situations exemplified next.

Higher Education

Government, business and education are beginning to work together for the advancement of high technologies. Globe economics is the basis of this partnership. Research and development are expensive in a rapidly changing socio-economic climate. Business Week's November 10, 1980 article, "Joining Hands Against Japan," begins:

> ". . .Old notions of pure competition, scholarly independence and limited government support for non-defense research are beginning to give way. Companies are almost forced to cooperate," declares William C. Norris, Chairman of Control Data Corporation.[19]

Japan has an exemplary system, which the United States admires. Many U.S. companies, universities, and our government have become less hostile toward working interdependently because of a system that is working in Japan. The system is called "Japan, Inc.," and is a triumvirate of business, government and academia "joining forces to support computer and micro-electronic research."[19]

Many U.S. firms are following Japan's lead. Examples of this concept in the United States are summarized:

> IBM is one of six companies, along with the Xerox Corporation and the Burroughs Corporation, that are currently contributing $100,000 annually--and lending a senior scientist to the California Institute of Technology to spur basic research in microelectronics. This program is similar to one underway at Stanford University, Duke University and North Carolina State University.[20]

Business, government, and education are becoming aware that

". . . there is an awful lot of knowledge that doesn't need to be proprietary."[21] It is noteworthy to consider the amount of capital the aforementioned corporations are able to manipulate. They are taking responsibility for the nation's technological growth and, consequently, her future.

The University of Minnesota is also finding support from such corporations as Control Data, Honeywell, Sperry and 3-M to help form a Microelectronics and Information Science Center (MEIS) ". . . which will be controlled jointly by corporate and university officials."[22] The government exercises control over these situations through new legislation.

> For one thing, Justice will soon issue guidelines for companies engaging in just the kind of cooperation MEIS calls for . . . . Research discoveries will be made available to any company via license.[23]

The government, business and education working toward common goals is a practical matter. "The object is to strengthen America's capacity to compete."[24]

The Massachusetts Institute of Technology has been participating in cooperative efforts for many years. However, MIT does maintain its own research facilities separate from any corporation and it does ". . . grant exclusive rights on its patents to the corporations that funded the research."[25] Two hundred sixty-five corporations support MIT. It differs from Minnesota's MEIS plan in that Minnesota's researchers and facilities will be exchanged for the corporation's facilities, funding and professional support. Roger W. Stachle, Dean of the University of Minnesota's, Institute of Technology, says, "The goal is to minimize the universities' investment in research equipment that would duplicate nearby corporate facilities."[26] The exchange is advantageous for universities. The advantage for corporations will be ". . . the inside track they will get on talent."[27]

Viable educational systems in the future most likely will have government, business, and educational systems working in tandem. Computer graphic education will need to be integrated into visual art departments. It is essential for educational institutions to enlist the financial and technological support of business and government for all to benefit. This action is not supported historically. "College researchers have traditionally guarded their independence, and looked askance at their corporate counterparts."[28] Even so, current economic pressures make the joint effort realistic and practical. Peter J. Denning, Chairman of the Computer Science Department at Purdue University, insists, "The researchers have got to have direct access to the latest equipment to learn the technology, and companies have much better facilities."[29]

Business Graphics

Many applications of computer graphics today are only marginally considered art. The applications currently applied by businesses are support for architectural renderings and proposals, topography and, using the generic term, "business graphics," meaning charts and graphs. In the case of architecture, computer graphics are used in developing an initial design, and then as a source for associates to consult when working on the functional aspect of a design.

Skidmore, Owings and Merrill, a Chicago architectural firm, has found use of computer graphics cheapest when aiding large projects. They have used the graphics system to simulate wind loading and cyclic shadows that would be cast on surrounding buildings and public areas. The physical concerns are ever-present for architectural problem solving. It is interesting to note the change Skidmore, Owings and Merrill has felt within its organization:

> Experience . . . demonstrated that for the computer to be effective it has to be integrated into the studio so that people connected with design development and evolution of the project, are involved with the ctual input of information. Not only does this put them in a better position to make decisions, but they feel they are a part of the process.[30]

This statement reinforces the positive outgrowth of the teaching of the Bauhaus, and echoes Moholy Nagy again: Artists exploring the potential of the tools of contemporary technology ". . . could produce an art that through clarity, order and imagination, would make itself relevant for our time. . . ."

Practicality is essential for any type of successful endeavor. Architecture is a soft science, and a disciplined, specialized branch of the arts. It is a discipline that comparatively early on, has considered time and money, and insightfully combined creative endeavors with modern technology. This combination has given designers more time and stimulation for creativity. ". . . If an architect can produce twice as many drawings with the computer, he can switch more of his time to design."[31]

Architecture is one of many disciplines that now uses computer graphics. Cartographers are another group that have benefited from the implementation of computer graphics systems. A simple example of their use of a system would be having to generate a map of a certain locale, and have it stored in memory to be used as a base for different topographical breakdowns at a later date.

All types of businesses are utilizing graphic systems to prepare charts and graphs, either for publication or as visual clarification of statistical data. Charts and graphs are generated, stored in memory, and manipulated as the data changes. The new technology saves time and money by having to generate the original image only once, and when minor changes are necessary, placing the changes in memory, and then regenerating the output.

The use of the computer to generate statistical data is common throughout the business world. However, the compilation and assimilation of the data into chart, graph or map form in the past had taken ". . . as long as two years to complete."[32] Robert M. Leavens, Dealer Survey Manager for General Motors' Cadillac Motor Car Division, complained, "By the time I got it done, it was obsolete."[33] Though gathering data may still take months to complete, the generating maps " . . . are produced in less than a day."[34]

Business graphics are a practical utilization of new technology. Artists are likely to tire of the simplicity and repetitive process over long periods of time. Awareness of the medium's possibilities, however, can become a catalyst for the artist to learn to manipulate images on more sophisticated systems.

Another area where computer graphics are being used is in engineering. Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) are disciplines enabling engineers to simulate, test, and refine infinite types of products from the space shuttle to contact lenses. The initial design is sketched and then programmed to display on a CRT (cathode ray tube), essentially, a television screen. The design is stored in computer memory; it can be retrieved at a later date so refinements may be made. The image may also be manipulated, enabling the artist to see it from different viewpoints.

Computer graphics have integrated technology and design. The products of this "marriage" are valuable to anyone needing to communicate. Fortune magazine cited many companies in their September 8, 1980, issue that ". . . sell sophisticated computerized substitutes for pencil and paper that allow engineers, architects and other designers to draw with exceptional speed and accuracy."[35] It is interesting to note that Fortune found Applicon, Computervision, Autotrol Technology, Gerber Scientific and United Telecommunications, among others, as companies with ". . . the highest price-earnings ratio on the New York Stock Exchange. . . ."[36] Computer graphics is a field with great potential for artists. The generated output has value for an infinite number of people who need to communicate.

Computer Graphic Artists

The term "computer graphic artist," is a fairly broad term. A computer graphic artist may be someone who has had extensive art training and experience and has only recently begun to explore computer graphic systems. Conversely, another artist may have had computer science and mathematics training only, coupled with a passive interest in the visual arts he or she is able to pursue because of the availability of computer graphic systems in technical fields. Consequently, what is occurring is an enthusiastic exchange between these traditionally polemic disciplines. The resulting images remain to be seen.

Barbara Nessim, Jim Squires, Richard Chuang and Glenn Entis are computer graphic artists. All have unique background experiences, and all are pioneering the computer graphic field. As the work of each artist is discussed, unfamiliar technical terms are likely to be encountered. Definitions for each term will be given. Though the work discussed is generated by computer systems, each artist's work relates to more traditional visual formats as well.

Barbara Nessim

Barbara Nessim was graduated from Pratt Institute over 20 years ago. Her work prior to its metamorphosis into computer form had "ethereal, fantasy-laden"[37] qualities. (Images 1, 2 and 3) In September of 1980, Ms. Nessim was

Image 1

Image 2

Image 3

invited by the head of the Council for the Arts at the Massachusetts Institute of Technology to participate in an exploration of "the great unknown, . . . computer graphics."[38] Ms. Nessim had to decline the offer; the timing was inconvenient, nevertheless the offer was tempting.

She began exploring the medium on her own. "The possibilities of creating art on a computer was an irresistible challenge."[39]

> A third fact about Barbara Nessim which made her confrontation with the computer inevitable is her curiosity and exuberance about all things graphic. When she's not working on commissioned projects, she is painting . . . or flooding her sketchbooks with intimate little drawings . . . or lecturing, . . . or judging work for exhibitions . . . or teaching. . . . She has exhibited her paintings in 28 group shows, 5 one-woman shows, has been the subject of 22 magazine articles. . . . Her work has appeared countless times on the covers and in the pages of such major magazines as Esquire, Harper's, New York Magazine, The New York Times Magazine, Time, Psychology Today, and Ms; also on posters, in books, and in a theatrical production. She is a frequent lecturer and is currently teaching courses in painting, drawing and concepts at the School of Visual Arts, The Fashion Institute of Technology and Pratt Institute, all in New York.[40]

In short, Ms. Nessim is an accomplished, established artist with a "resounding reputation."[41] While being quite successful, the need to explore new media consumed her and so, ". . . she scouted out programmers, talked to them, asked questions and read, read, read."[42] Prior to the contacts she has recently made, she had no scientific or mechanical background at all. It is fascinating to view Ms. Nessim's pen-and-ink drawings, and her watercolor sketches, and then compare them with the work she has done on a computer system. (Images 4-14)

> She has absorbed the aesthetics of art nouveau, art deco; of Richard Lindner, her teacher; of Henri Matisse, a favorite painter. There is something of Saul Steinberg's whimsy and wit and generous doses of surrealism in her work.[43]

Even so, she has "readily made the transition to the cool mechanics of electronic art."[44]

As her computer images show, use of the computer has not changed her subject matter, but her expression of it.

> In reply to the inevitable question: "Is it difficult to make the transition from traditional graphics to the computer?" She replies, "No, but you must think 'machines'."[45]

Access to a computer graphic system came through her involvement with Time, Inc. An explanation of the hardware involved and the steps taken in generating images provides a general understanding of the process.

The computer images were generated on a Teletex-Telidon IPS 2 computer at Time Video Information Services.

> The IPS 2, like most computer systems, has two monitors, a drawing tablet, a stylus and a keyboard. One monitor displays the "menu" or list of computer options. The second monitor displays the work in progress. The electronic stylus is used for drawing or making marks on the drawing tablet. All the marks made on the tablet and all commands issued through the keyboard are viewed on the viewing monitor. Among the options the computer offers are six drawing modes: a dot, a line, an arc, a rectangle, a polygon and a circle. To create a rectangle . . . all you need do is indicate the two end points of its diagonal.

Image 4

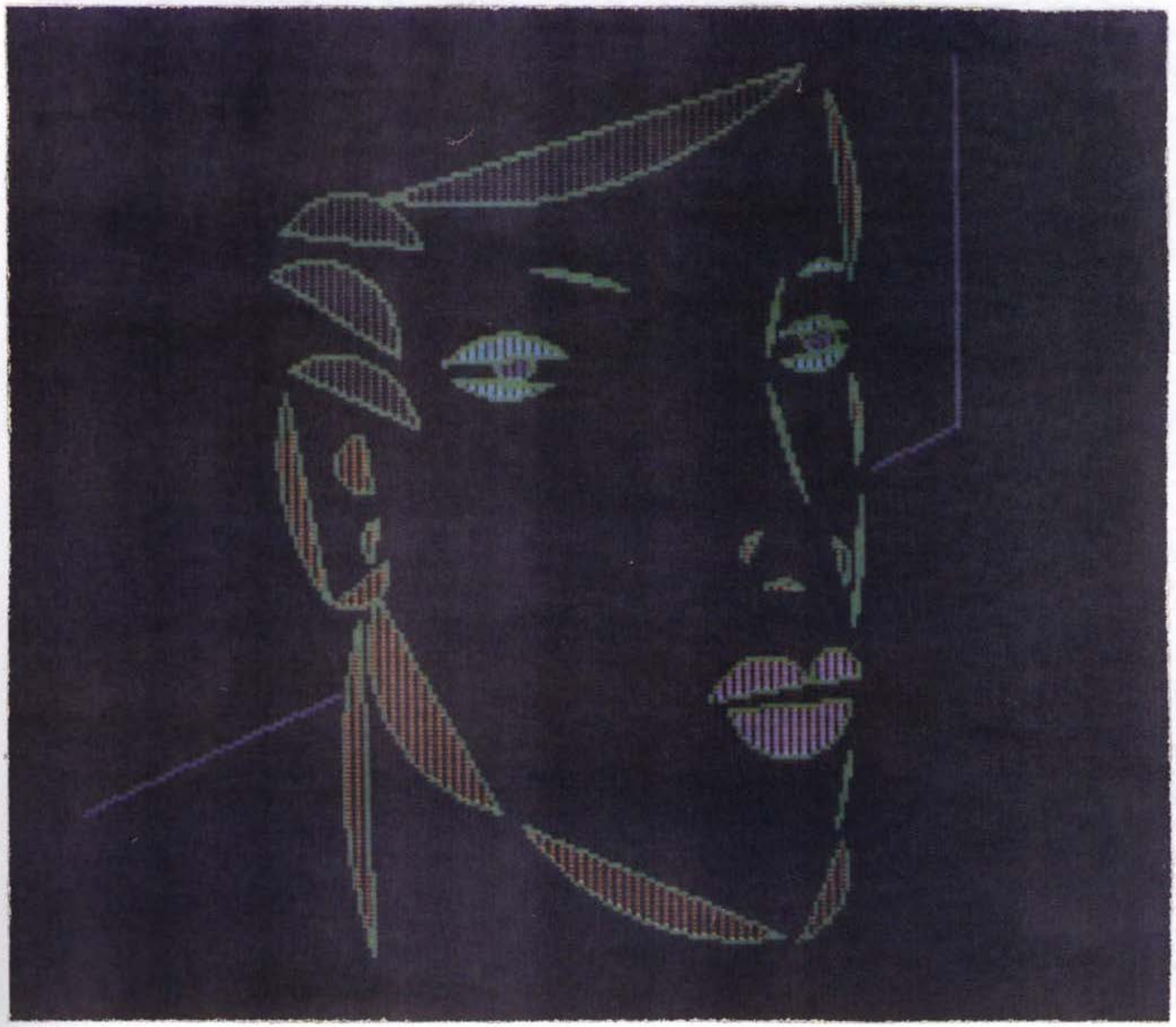


Image 5

Image 6

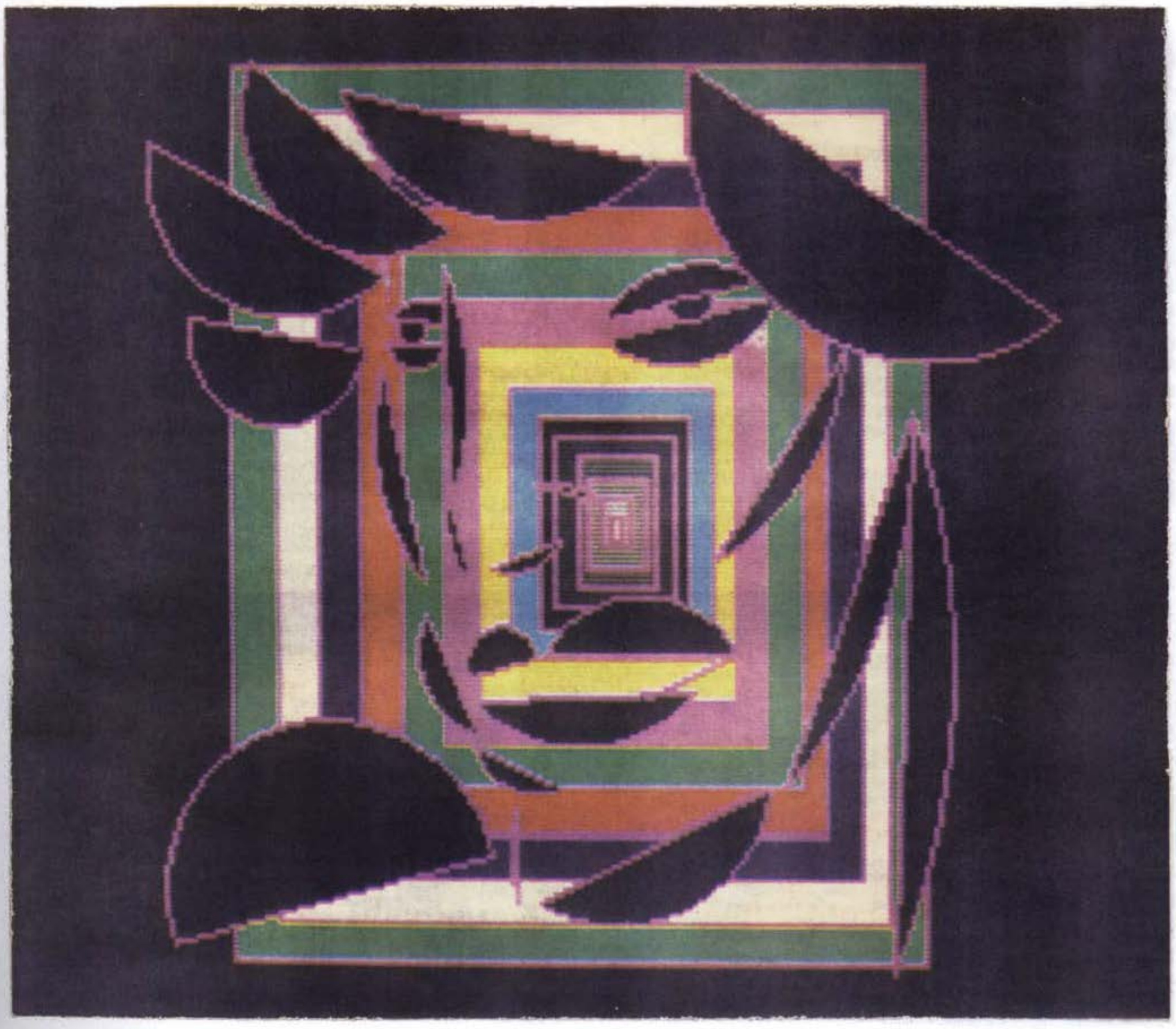


Image 7

Image 8

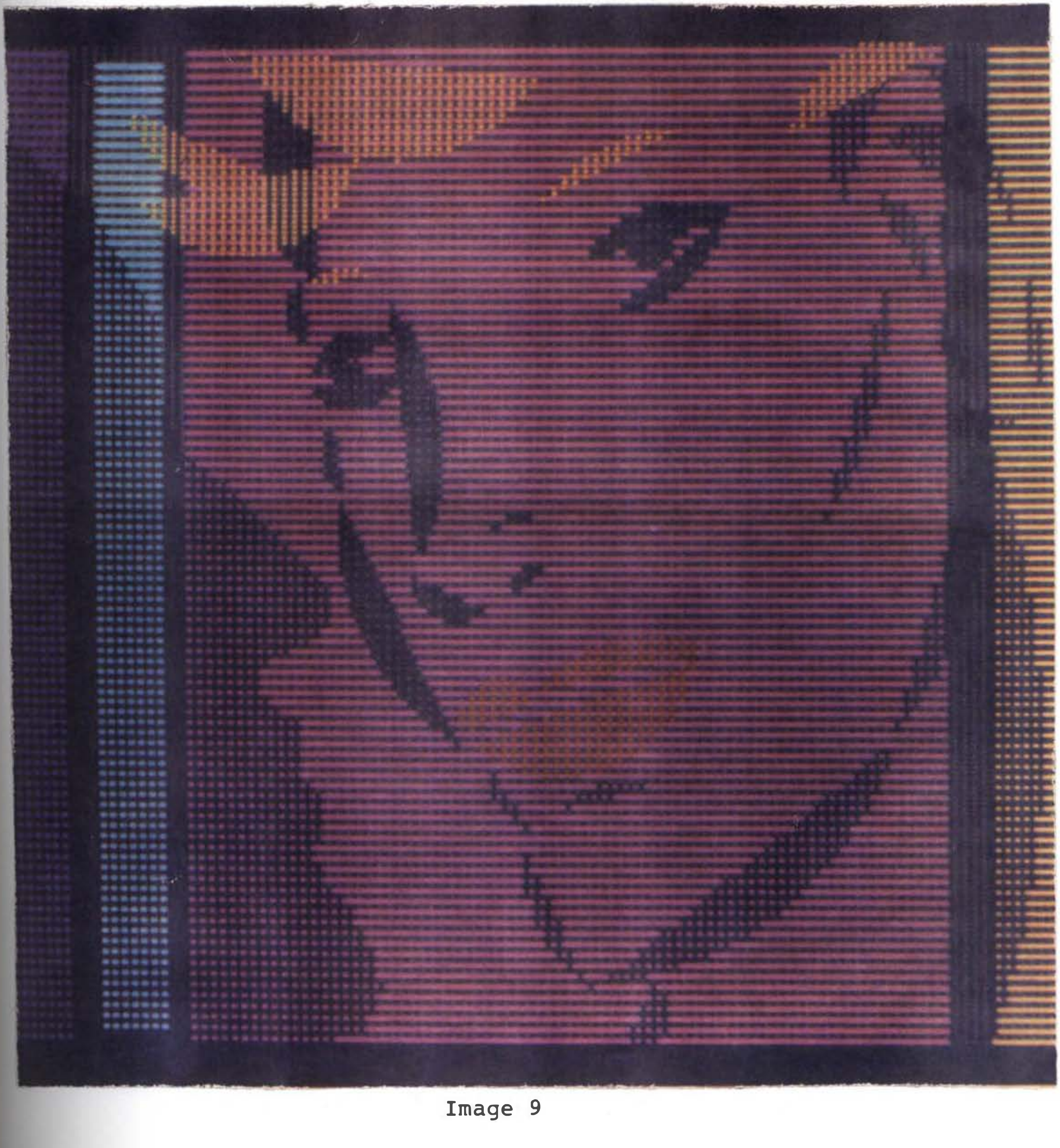


Image 9

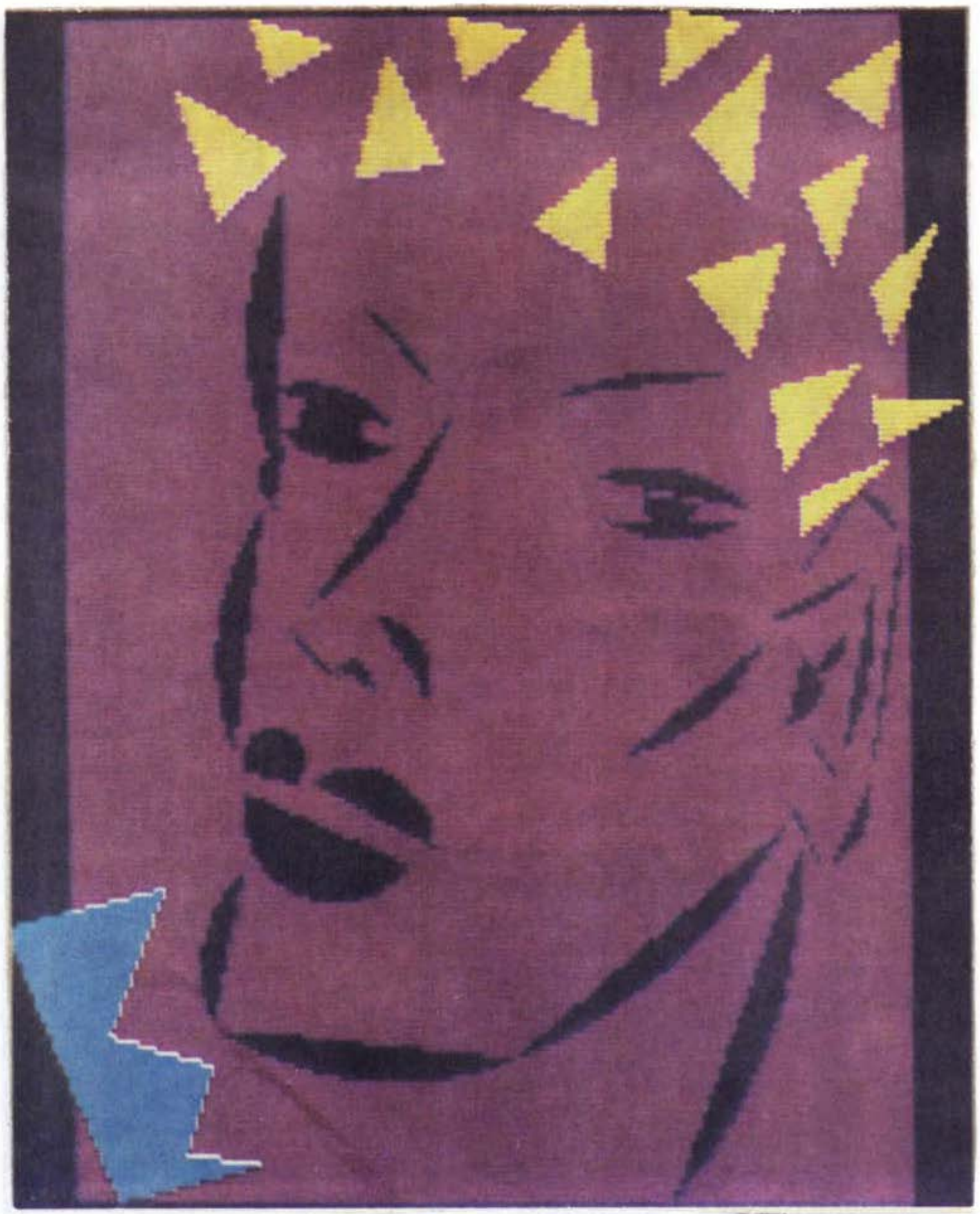


Image 10

Image 12

Image 13

Image 14

> From that information, the computer constructs the rectangle of the desired dimensions. To draw a circle, only two points indicating the length of the diameter are needed; the computer completes the cirlce. To create an arc, just three points--to indicate beginning, mid-point and end--are enough information to enable the computer to complete the figure. Triangles, zigzags and other free-form straight-sided shapes are drawn in the polygon mode. The artist indicates crucial points using the electronic stylus on the drawing tablet or by manipulating directional buttons on the keyboard, which can move a cursor up, down or diagonally.[46]

The system on which Ms. Nessim produced her latest images is not as highly developed as some. The system is exemplary of basic procedural methods and, consequently, helps show what considerations must be made when confronting a blank screen. Aside from the basic shapes utilized on the IPS 2 system, colors are an additional option.

The colors used in Ms. Nessim's computer images are certainly a far cry from her pen-and-inks and watercolors. She has altered her palette from pastel tones to the bold, saturated color available on the IPS 2 system. The colors offered on the system are: black and white, red, yellow, blue, green, magenta, cyan (a turquoise-blue), and six levels of grey tones. The list of colors at first appears very constricting; however, the system offers options that extend this palette greatly. The following is an explanation of how color may be manipulated:

> The entire form can be flooded with a desired hue, or an area can be colored pixel by pixel. You can choose to fill each pixel, every other one, every third one, etc., etc., in a choice of color and in a choice of direction, vertically, horizontally, or diagonally. The

> decision is plotted, the command fed into the computer, and it does the rest, creating striped, checkered, benday and plaid effects in a dizzying choice of patterns.[47]

A pixel is short for the term "picture element." A pixel is a bit of information; its size varies with the resolution of the screen; high resolution screens are made up of millions of pixels. Low resolution screens have fewer pixels, and the pixels in this case are of a larger size.

Bits make up bytes of memory. Consequently, when a manufacturer mentions bytes and bits, computer memory is what is being discussed. Accessing color in computers uses a lot of memory and, hence, is feasible only on larger, more expensive units.

High resolution capabilities give images truer to actual paintings, photographs and real life situations. The system used by Ms. Nessim is fairly low resolution (having larger, but fewer pixels) and, consequently, her work has a computer-generated look about it.

There are certainly parameters that must be considered when working on computer graphic systems. But there are many areas where visual artists have never had as much choice, nor as much opportunity for experimentation as now.

> So, contrary to the notion that the computer <u>inhibits</u> creativity, in actual experience artists find that it <u>expands</u> their horizons. The variations and manipulations are so infinite, artists' sensibilities must be more finely tuned, and they must make more precise aesthetic judgments than in traditional drawing and painting.[48]

The altering of some methods of working is inevitable when exploring a new medium; it is the same with the computer. However, there are some methods that remain essential in any medium.

Ms. Nessim has found that the method of working from the background plane, up, is the most satisfactory way of realizing her images. This method is similar to many media--charcoal, watercolor, acrylic, pastel, oil painting--just to name a handful.

> . . . she means you must be constantly thinking ahead about what you wish to accomplish and how to command the machine to execute your plan. You must plan your image from the last plane to the first, or from background to the next level up, to the next, and so on. In a way, you are working with a graphic in motion--not in the sense of animation--but in the sense of growth. You start with the background color, add forms, color and texture, level by level. Each level of work overlays the preceding one; each new colored form opaques out the space beneath it. However, if you have a change of heart about any element, it can be readily corrected. As each level of work is completed, it can be stored in the computer memory, so that there is a complete history of the work as it evolves. Any one of the levels or sequences can be called up from the memory for reconsideration and revision. In this way, it is possible to make changes in forms, colors, sizes and positions of the elements--or the whole unit may be scrapped and recreated without disturbing other levels of the artwork.[49]

Storing previous levels of a piece of work is probably one of the more valuable features of computer graphic systems. This capability makes a series of studies easier than ever before. It also releases inhibitions when confronted with a color choice, for instance, enabling the artist to change the color of an area with a touch of a key (knowing the final result will be of highest quality, and not likely to alter the critical space around the area being changed) done heretofore by physical alteration.

The reproduction of computer-generated images may be achieved by many photographic processes. For some sophisticated systems, it is possible to reproduce images directly onto video tape, film or paper. On the Video Image Recorder, the system used to reproduce Ms. Nessim's work, available output options are black and white video, Polaroids and 35 mm. Ms. Nessim used the Polaroid option for quick checks on the images and the 35 mm. for hard copy.

> To make a slide, the desired image is brought up from the computer memory onto the video screen in the Video Image Recorder. The camera, which has a predetermined fixed lens setting, and comes equipped with red, green, blue and clear filters, is electronically activated. With the lens open, each of the filters automatically passes over the lens in sequence, recording the full color image on film, which is then developed in the usual commercial laboratory. From film to hard copy should take no more than three hours.[50]

So, essentially, the image on the video screen is where all the work is done. The actual piece is generated from the video screen, recorded either on video tape, in slide form, or as a photographic print. The resulting artwork will be different from much of the two-dimensional visual art historically appreciated.

Barbara Nessim is one of the artists who is pioneering the field of computer graphics. It takes a certain amount of courage to abandon art forms that have been successful in the past, as well as a good deal of curiosity. The steps being taken in computer graphics by artists like Barbara Nessim lead to discoveries that will be applicable to artists working in the computer graphic medium, and in other media.

Jim Squires

Jim Squires has been a student at UCLA since 1978. He is studying computer art under John Whitney, Sr. Unlike Barbara Nessim, Mr. Squires has had extensive training in the technological aspects of computer graphics. He is in a special situation--being able to write programs for his specific uses, and also being part of a network, whereby he is able to have his programs interface with those of other computer graphic artists.

Mr. Squires has written a program he calls "Distraction," ". . . which received its name from Squires' discovery that 'every implementation of an idea led me [him] to three new ones'."[51] The images shown here (Images 15-17) are examples of what this program can do. He developed this program in Assembly language.

Machine language is the most efficient computer language to use. The reason for this is that it is made up of zeroes and ones, or on and off switches that, when used in certain sequences, prompt the computer into certain actions

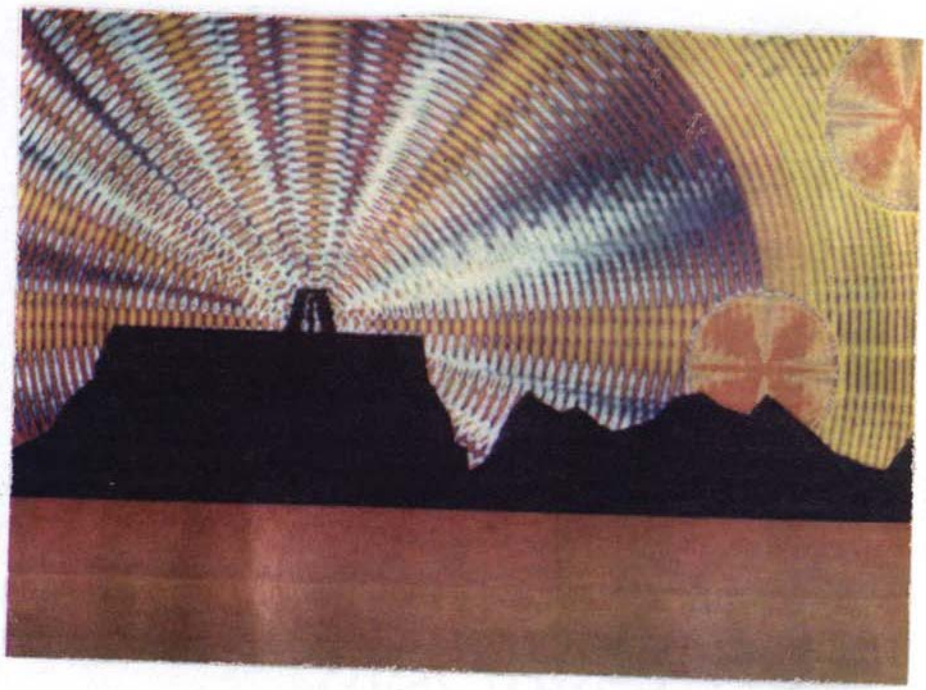


Image 15

Image 16

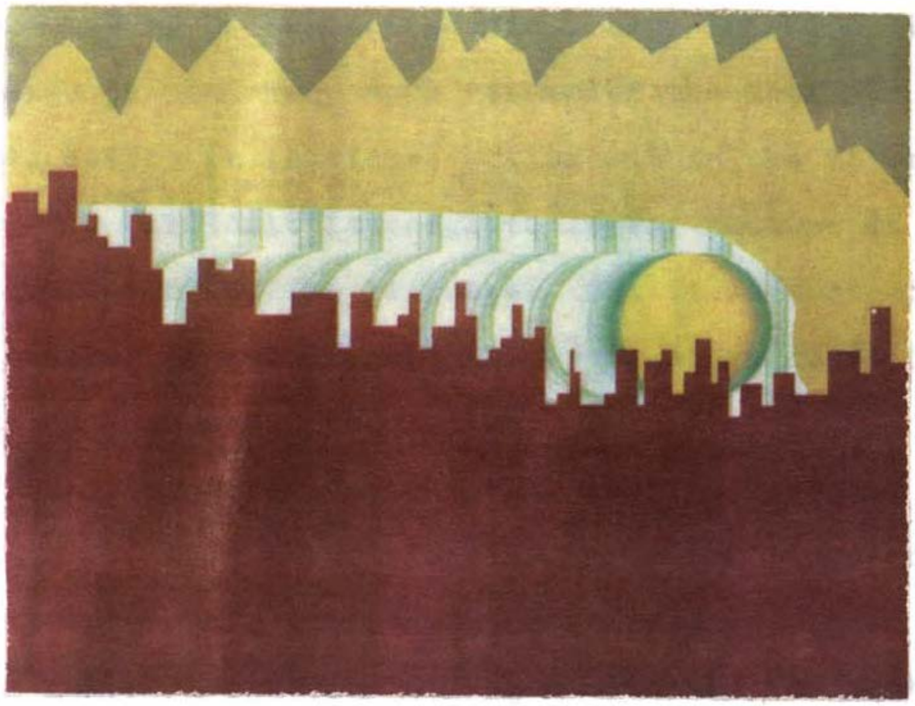


Image 17

using little memory space. It is called a low-level language, because it mostly closely resembles processes that occur directly within computer memory. In other words, it does not have to be translated from, say, BASIC, a high-level language that very much resembles the English language, before it initiates action within the memory. It is a very difficult language to learn, because it does not resemble the English language. But it is most efficient to use because it uses little memory to store codes for translation from BASIC to machine.

Mr. Squires developed the "Distraction" program on a Chromatics CGC 7900 color graphics computer. Commands to build images on this system may be entered by use of a joystick (which looks like a length of dowel rod that swivels on a base, and has a button at the top that activates and cuts off action when pressed), or through a digitizing tablet (essentially, a drawing pad, used with a light pen stylus). The pad has a mesh of wires that are sensitive to the light pen, and as an x-y coordinate of the mesh is activated by the pen, the coordinate appears on the display screen. If a rough sketch were drawn on the tablet with the stylus, the rough, organically sketched form would be what appeared on the display screen. The light pen stylus was an option available to Barbara Nessim. Instead of using hers with a digitizing tablet, the IPS 2 system required the light pen be used directly on the display screen in conjunction with commands entered in on the keyboard.

The Chromatics CGC 7900, used by Mr. Squires, is a much more sophisticated system than the IPS 2 used by Ms. Nessim. Unlike the IPS 2, which displays a total of about 15 colors, including black, white and six shades of grey, the CGC 7900 system is capable of supporting color selection from 16 million colors (256 are simultaneously displayable)--very impressive for even the most color-conscious artist. Access for artists to systems such as this one is certainly more to the point than the IPS 2.

The Chromatics CGC 7900 and the IPS 2 are similar in the type of reproduction processes compatible with each. Like the IPS 2, the CGC 7900 images are reproduced by a camera outside the hardware system itself. "Hard copy in the form of 35 mm. Kodak Ektachrome slides was produced from the CGC 7900's screen on a Matrix 3000 color camera."[52] As mentioned earlier, another form of reproduction, one which more complex systems utilize, is generated within the hardware itself and hard copy takes the form of video film, slide film or paper.

The "Distraction" program is considered a first generation version; Squires would like to ". . . eventually create key frames of an animation sequence. His anticipated second version will take two key frames and interpolate the image, thus 'animating' a sequence from one key frame to the next."[53] Interpolation is a process that begins with one image and generates the intermediate steps between it, and a second image. An example might be accessing two images, one of a man standing with his right arm extended to the side and bent at the elbow. The second image is of the man with his right arm extended straight out at his side, at a 90-degree angle to his body. The computer program would interpolate, or generate, the intermediate images, between the first image and the second, thus, when shown in sequence, the image is animated. It is obvious how much time will be saved in animation by this process. Squires has developed a prototype for the second generation of "Distraction" and has used it ". . . to generate color background for the video visual music of Bradley Friedman's videotape, Hot Splice."[54]

An explanation is given about the generating of "Desert Discovery," in order to see the similarities and differences in the working processes of Squires and of Barbara Nessim.

> To create an image, the user can specify areas of color and fill them. He or she can also create curves and shaded groupings of polygons, filtering and smearing areas under precise control . . . to create the radiating "sky" in "Desert Discovery," Squires started with several superimposed circles; this resulted in a moire pattern that was then smoothed by a programming routine.
>
> The "mesa" in the image is an outlined black polygon, and the "desert floor" consists of color strips that are linerally shaded in value.
>
> In Squires' opinion, the most important computer technique he has access to, the one that helps him the most in the creation of his artwork,

> is the ability to test and evaluate tens of thousands of colors for a given image in a matter of minutes. This is particularly important in a potential animation program because, depending on how certain images are shaded, they can appear to be either approaching or receding from a viewer. But this ability to test the effects of color on an image also gives Squires occasional moments of discomfort. "I can't help feeling guilty at times," he admitted. "No artist has ever had tools like this before. It would take hours or days of painstaking work for many conventional artists to change the colors on one of their images even once.[55]

The system Squires uses has a larger memory, he knows how to program in Assembly language and, consequently, he is able to use his system's memory for the special effects he desires. As visual art, his images seem illustrative at one extreme--his "Desert Discovery" and "The Last Survivor" are exemplary of this--and concerned with pattern at the other, as in "Revenge of the MCP." Most of the interest in the pieces lies in the new technique, the wonder of how it was done. The compositions themselves are simple, the two "landscapes" work well enough, but the third, patterned, "The Revenge of the MCP," lacks compositional strength. While Squires is certainly capable technically, his training in aesthetics appears wanting.

Barbara Nessim could be considered the Ying, and Jim Squires the Yang in computer graphic development. Her strength is unquestionably visual presentation. Her work lacks the sophisticated techniques of Squires, but, nonetheless, her images have a wonderful, lyrical sense of composition; and while her palette is limited, she is able to convey excitement, daring and boldness.

Their works' strengths and weaknesses are complementary. There is room for the visually strong to learn from the technically able, and the technically able has need to learn from the visually strong. These artists exemplify the necessary and stimulating exchanges computer graphic artists are experiencing.

Richard Chuang and Glenn Entis

Richard Chuang and Glenn Entis are Vice Presidents of Pacific Data Images, a three-person group that produces computer-generated animation for broadcast television and film. The company was formed in 1982. Richard Chuang is Vice President of Hardware Engineering and Technical Director at PDI. He is one of the original designers of the company's animation system. He holds a B.S. degree in electrical engineering from the University of California, Davis. Glenn Entis, also at PDI, is Vice President of Software and Technical Director. He, too, was one of the developers of PDI's animation system. He holds a B.A. degree in philosophy and a B.F.A. in fine arts from Ohio Wesleyan University. He has also done graduate work in computer science at the Polytechnic Institute of New York.

The work Chuang and Entis are producing will need much more explanation, technically, than did either Nessim's or Squires'. Their work is at the cutting edge of what is developing in computer graphics, and essential to the understanding of the medium's potential. It is also apparent from the reproduction of some of their stills (Images 18 and 19), that the quality of their compositions and sense of design is highly developed.

In an article in Computer Graphics and Applications, Chuang and Entis give a step-by-step explanation of their animation production methods. They utilize technical skills, practical methods and aesthetics to produce pioneering prototypes. Their narration illustrates the processes involved in computer-generated video:

> The animation of computer generated images has made a number of contributions to the entertainment industry, and the future of these images in film and television looks promising. Although many computer animation techniques have been widely researched and published, their actual commercial use in production studios is still in its relative infancy.
>
> The creation of animation for the entertainment field requires a combination of technical capability, design sense, and practical production skills . . . we describe the use of computer graphics techniques in a production environment; in doing so, we stress the practice, rather than theory, of computer graphics.
>
> Pacific Data Images produces commercial computer generated animation for broadcast television. What follows is a step-by-step explanation of how commercial animation is produced at our facility. In the course of this explanation, we will discuss several tools we've built to support the animation process. In particular, we emphasize software at PDI, since software continues to be the key technical animation component that cannot be bought "off-the-shelf."
>
> The techniques covered . . . provide an example of how a typical piece is produced in our studio, so we make no claim to universality. Nonetheless, this walk through our production process should impart a sense of what producing computer animation is like.

Image 18

Image 19

> System Overview. The PDI animation system was developed specifically for the production of commercial animation. It produces smooth animation of 3-D shaded raster images and features an animation language, a modeling tool kit, real time animation design, and several viewing options. Output is to 16 mm. or 35 mm. film, or to one inch video tap.[56]

In reviewing statements made about PDI's animation system thus far, it is wise to define some of the terminology being used. First, Chuang and Entis mention "software" being a key component in technical animation, and that it cannot be bought "off-the-shelf." Software, in this use, is different programs written by computer programmers to produce various results. There are software programs written for all sorts of uses--for bookkeeping, publishing and teaching--to name a few. The software programs are stored on floppy disks and are written in various computer languages; a few software languages that have been mentioned before are BASIC and Assembly. In the paragraph subheaded System Overview, there are a few terms worth defining in order to make further reading comprehensible.

The phrase, "3-D shaded raster images" may be explained as any image on the screen appearing to be three-dimensional. It is shaded, or modelled, so as to give an illusion of three dimensions, and which is recorded onto film, for example, by the raster scanning technique. The raster scanning technique records the 3-D shaded images through a light-sensitive component that scans back and forth across an image, one row of pixels at a time, recording the color of each pixel onto the receiving film. When the complete image is scanned, as just described, the product is a still reproduction of one frame in a video sequence.

Another phrase that may need clarification is "animation language." This is simply explained as a programming language written with the specific end result of animating images. However simply the phrase may be explained, the actual development of a new animation language may take months of tedious writing, rewriting and debugging.

A "modelling tool kit" is a program that enables the artist to do exactly as the phrase indicates, and that is to model, or shade, and reshape various images. It is most likely written in an animation language. In animation, the light source is likely to change the way objects appear because of the movement of the objects, or because the light source itself is moving.

The combined capability of animation and modelling is the basis of computer graphic imaging.

"Real time animation design" is simply the generating of animated imagery at a speed at which humans experience real life. This seems simplistic at first; however, a computer regenerates an image 30 times per second, and so would be capable of running through an hour of "real time" animation in a matter of minutes, if it were programmed to generate each frame of an animated sequence only once. In order for us to appreciate an animated piece, the images must be reproduced by "real-time animation design."

The "several viewing options" mentioned refer to how the images are displayed for the viewer. Image manipulation is done on a CRT screen--(display screen, cathode ray tube), a conventional television screen. The image may be displayed at any of many CRTs tied into a computer graphic system. The viewing options also include a video camera display. Additional options will be explained further.

The following describes the types of display options used in generating animated sequences. It also gives an overview of the animation system designed by PDI:

> Animation in our system is defined by scripts written in our animation language, by world coordinate polygon files, and by motion data.[57]

The "world coordinate polygon files" and "motion data" mentioned here are files that contain information about the general structure of objects in three-dimensional space and about the physics of motion. These files are accessed on command, or automatically, if certain conditions exist, to generate animation. Chuang and Entis continue their explanation of animation production:

> Data is processed by the script program, which interprets the animation script and creates one of several polygonal output files.
>
> Screen coordinate polygon files can be sent either to the renderer for the production of antialiased, shaded raster images, or to a wireframe display program that displays the polygon edges in antialiased vector form. World coordinate polygon files can also be displayed in wireframe form and can define models used by other scripts. Vector files are sent to the real time vector device for interactive viewing and animation design.

> Images are displayed on color monitors, vector terminals, and the system's real-time vector device; images can also be sent directly to one of two film recorders or to an . . . encoder for recording onto videotape. The color monitors are located at graphics work stations, which are equipped with terminals and data tablets for interactive use by animation designers.[58]

All this may sound incomprehensible; so, at this point, it is appropriate to clarify what exactly is being described. Images 20 and 21 visually exemplify the differences between shaded raster images and wireframe vector forms. In brief, a script program (the initial sequence of events to be graphically generated) may be further developed by two programs. The first is the renderer program, which will enable the artist to shade images that will be recorded with the raster scanning technique, explained earlier. The second program the script may be sent to is "the wireframe display program that displays the polygon edges in antialiased vector form."[59] Image 20 clarifies the rendering program capabilities, and Image 21 clarifies a wireframe vector program form. The wireframe vector form depletes much less of the system's memory and, consequently, makes manipulating images faster. If the kind of manipulation done on the vector system were done in the rendering system, the regeneration of the new image would take much more time due to the detail intrinsic within the rendering system. Consequently, when major adjustments to the script are being made, they are made in wireframe vector form, and then at a later time accessed by the rendering program to refine the image.

Image 20

Image 21

The following is an explanation of the initial steps of conceptualizing an animated project:

> We rely heavily on a script system for our animation design. Our script system is a special purpose graphics language supporting animation at a high level.[59]

When Chuang and Entis refer to a "graphics language supporting animation at a high level," they are saying that this system is easy to use--user-friendly.

> We use the name "script" because of the way the animation language is used in the production process. In the early stages of a job, the basic models and motion for animation are roughed out in the script language. This original script already includes elementary timing, lighting, viewing and modelling information that later will be refined and used in the construction of the final product. At each production stage, this script is updated to reflect production changes and to incorporate new models and motion data from other parts of the system. Thus, the script is much like a movie script in that it concisely describes <u>what</u> should happen <u>when</u> and <u>where</u> in the production. Unlike a movie script, however, the script also defines the animation and is run directly to create both the intermediate and final versions of a job.
>
> There are several advantages to this approach. The script was built to be a fast prototyping language for image building and motion testing. Typically, the preliminary rough script for an animation sequence is built in the very first session with a client. This capability for rapid prototyping is essential for design experimentation and flexibility.[61]

Although the technical terminology at times seems tedious when explaining computer-generated animation, it is enlightening to find out that even people as technically well versed as Richard Chuang and Glenn Entis are ultimately concerned about aesthetics, and the growth that comes from experimentation with a medium in producing a desired product.

Chuang and Entis have designed their system to make altering images and generating images as effortless as they possibly can. The system has been designed to be user-friendly. This does not negate the fact that much ground work had to be laid to make easy usage possible. Next is an explanation of how a simple image is generated:

> . . . the script (program) directly handles data types and modelling operations for lighting, viewing, and transformation, thus freeing the script-writer to concentrate on what has to be done, rather than how it has to be implemented. Most script values default to predefined values if not explicitly set by the animator, making simple object definitions fast and easy. For example, if a five-sided prism is required, the script command is: prism 5. (The command is typed on the keyboard.)
>
> Unspecified prism attributes, such as color, radius, height, and surface type, all default to standard and/or previously set values. In addition, viewing parameters, such as camera position, focal length, lights, window and viewport, are all set in the script (or, again, default to standard values) so that when an object is created, it can be transformed into its final screen position.
>
> Since the animation for a sequence is originally prototyped and refined in the same script that creates the final piece, the possibility for error and the necessity of tedious data transcription is greatly reduced.[61]

Inherent in all of the computer systems discussed is their ability to reduce tedious work. Chuang and Entis go on to discuss motion design, and although it is fascinating to discover the considerations taken in the cinematic facet of animation, computer graphic film study is beyond the scope of this paper. However, they also go on to discuss model design, and this specialized section is certainly within consideration:

> An animator may be called on to animate almost any kind of object, so it is important that his available modelling tools be flexible and fast. A prime objective of our modelling tools is to provide just such a set of general capabilities--one that allows quick object definition without the necessity of using custom software . . . .
>
> The script language . . . is used to create most models based on geometric primitives and to build up parts of models created on other programs. Quickly specified simple objects made from primitives are especially useful as stand-in objects. But the script is the basis of both the animation and modelling systems, so all script primitives can also be used as building blocks for more complicated models. Many models, such as buildings with multiple levels, windows and doors can be constructed by combining very simple geometric forms. (See Image 22.)
>
> Other modelling programs create various types of spline-based objects, including patches, free-form surfaces, and "swirls." There is also a special program for creating three-dimensional logos from two-dimensional contours. . . . Images 19 and 23 illustrate models defined with various spline-based surfaces.
>
> Still other programs form various geometric surfaces on polygonal mesh. For example, a recent job called for the animation of rocky surfaces, so a fractal modeller was used to create mountains.[63]

The term "fractal" is a new term, so new, it will probably be included in the <u>next</u> edition of <u>Webster's</u>. Fractals are worth defining in much detail. They are a new form of "shape" that can be generated on computer graphic systems and have implications for fields such as physics and mathematics. They are an immensely important discovery for many fields.

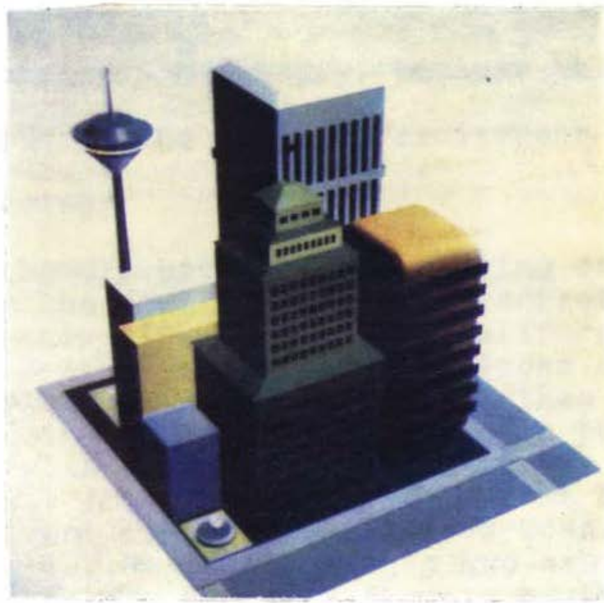


Image 22

Image 23

Including seemingly extraneous narration in the explanation of fractals is necessary, because this additional information imparts the sense of excitement this new "shape" is causing:

> At ungodly hours of the morning or the evening, when the town's computers are freed from mundane activities, Palo Alto, California hums. A simple two-story building which looks as though it should belong to a dentist rather than a computer company is no exception. Outside is parked a beat-up Volvo with paper coffee cups strewn across the back seat. Inside computer scientist Bill Gosper sits in front of a terminal, eyes scanning the screen. . . . He is lathe-thin and ashen from the hours he keeps. But with fingers as long as heron wings, he plays the computer and it plays back.
>
> Gosper is searching for an image that he made a few weeks earlier to please a friend. He finally finds it. It appears on the high-resolution color monitor, drawn in line-by-line. A white lightening bolt darts within an orange lightening bolt which darts within many more multi-hued lightening bolts. The jagged shape repeats itself with eye-pleasing regularity at different scales. "This is a very simple fractal," he nearly apologizes, but he obviously enjoys its aesthetics. (Image 24)
>
> Fractals are not so hard to find across San Francisco Bay in Marin County, where Loren Carpenter makes fractal images for Lucasfilm. . . . Carpenter is a member of the staff for computer graphics projects (the first such unit within a movie company). His specialty is coaxing imaginary landscapes out of mammoth computers. "We want the image to look indistinguishable from live action. It should look like someone went in there with a camera and made a movie," he explains.
>
> Tall order. But Carpenter and his colleagues are perfecting the techniques that will bring realistic computer graphics to the movie screen. In a darkened room with several shelves of video tape machines, he demonstrates what is already possible. "Everything that you see in this animation is synthetic," he says with pride. The tape begins with hills of green polygons, cold artificial shapes

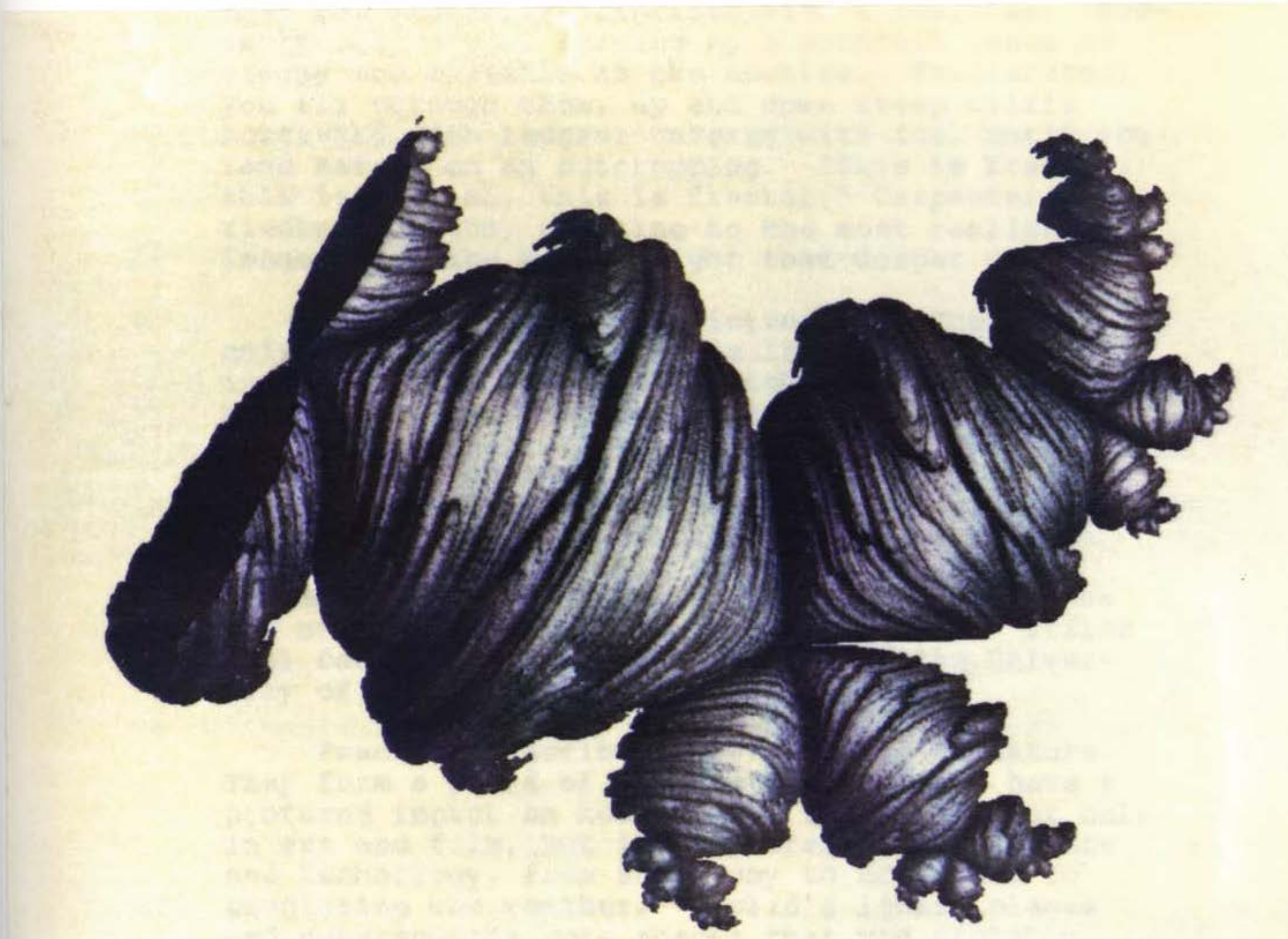


Image 24

> that you instantly associate with a computer. Suddenly they erupt, forcing up a mountain range as craggy and majestic as the Rockies. Exhilarated, you fly through them, up and down steep cliffs scattered with ledges, covered with ice, until you land safely on an outcropping. "This is fractal, this is fractal, this is fractal," Carpenter hurriedly explains, pointing to the most realistic images with the same delight that Gosper voiced.
>
> Fractal? Close the dictionary. The word was coined in 1975. But a sense is already building in fields as diverse as physics and ecology, pure mathematics and computer science, that fractals are changing the way we look at the world. "No one will be considered scientifically literate tomorrow who is not familiar with fractals," offers John Wheeler, professor of physics at the University of Texas in Austin." [Smithsonian, November 1983.] "Fractals delineate a whole new way of thinking about structure and form," writes Paul Davies, professor of physics at the University of New Castle-upon-Tyne, England.
>
> Fractals describe a new geometry of nature. They form a field of mathematics that may have a profound impact on how we view the world, not only in art and film, but in many branches of science and technology, from astronomy to economics to predicting the weather. Euclid's lines, planes and spheres--the pure shapes that you probably studied in high school geometry--describe the world of built things. Fractals tackle the chancy intricacies of nature--bark patterns in oak trees, mud cracks in a dry riverbed, the profile of a broccoli spear. . . . They are a family of irregular shapes with just enough regularity so that they can be mathematically described.[64]

A fractal modeller, as Chuang and Entis employ in the generation of irregular images, is an example of cutting edge development in computer graphics and in other fields. They give credit in their research to an article co-written by Loren Carpenter of Lucasfilms. Since fractal images are intrinsic in the development of computer-generated visual art, a brief history and further explanation of these images will be analyzed.

For now, though, it is essential to continue discussion of the computer animation process developed by Richard Chuang and Glenn Entis to understand the considerations given and the systems utilized in generating images. Some images are not efficiently reproduced by manipulation of geometric shapes, but must be drawn by hand. The approach used, when this is the case, employs an interactive graphics editor.

> As the artist draws the model with a data tablet and interactive display, the computer stores the artist's drawing in a file. This information is converted into polygons, which can then be used as a model or as input into other modeling programs.[65]

There is a third method of generating non-geometric images which involves "scanning the original art into the display memory with a video camera."[66] This method is used when the desired image is free form and already in existence in another medium. After a desired image has been either built, drawn or scanned and stored in memory, the next step in refining the image is rendering.

> Rendering a computer graphics model, which is done after a model has been defined, means displaying it in color on a CRT screen as a solid object with hidden surfaces removed and proper 3-D shading. Stand-in models are . . . useful . . . for the determination of color, object placement in the scene and scale. An example of a scene of rendered stand-in models (polygonal stand-ins in a still life) is shown in Image 20. The colors and final placement of the objects were determined using those stand-ins, after which the final, detailed scene (Image 18) was created.[67]

The computer images produced by Chuang and Entis are certainly more complex than Barbara Nessim's, at face value.

They also convey a higher sense of design than Jim Squires' work. While each is generating computer graphic images, the results--and this in art is as it should be--are strikingly different.

Ms. Nessim's work has been in the field of art and design. Her work displays the lyrical qualities often expressed in traditional media. Her computer work appears coarse in some respects in comparison with the work of Squires, and of the Chuang and Entis team. It is likely that if Ms. Nessim had been utilizing the more advanced systems of Squires or PDI, her work would still contain the ethereal qualities apparent in her pen-and-ink and watercolor sketches. Whether this is desirable is not the question; it is sufficient just to indicate that the probability exists.

Jim Squires' work is still developing, considering he is yet a student. He has a full understanding of the technical groundwork that must be laid to produce computer imaging, though the images he generates indicate room for further aesthetic growth. The considerations he is faced with are different from either Nessim, or Chuang and Entis, in that they are not wholly aesthetic, nor involved with the practical production dimension. Consequently, Squires' work, overall, is more experimental and exploratory.

Chuang and Entis combine the technical expertise and design sense to produce images for profit. They must consider the practical approach to animation. They are able to do this by keeping their standards high. The medium is high-tech and the images are high quality. Their cooperative effort is exceptional and, hence, provides impetus for potential computer graphic artists.

Fractals

Fractals were mentioned briefly when Chuang's and Entis' modeling systems were discussed. Fractals are considered further because of the anticipated effect their discovery may have on the arts and sciences. The effect their discovery has had already has been profound. A brief history of their discovery will help tie in their importance in computer graphics and the importance computer graphics commands in the understanding of fractals.

Thus far, the history of computer graphics has been surveyed, as well as some of the medium's current peripheral applications, and artists exploring the medium also have been discussed. The use of fractals in computer-generated imaging is occurring presently--concurrently with the work of Nessim, Squires, and Chuang and Entis--and it is also a topic of speculation on the further development of computer graphics, as well as other fields.

The definition of a fractal has yet to be explained, and so it will be done here:

> Fractals wriggle and wrinkle, meander and dawdle while remaining infinitely rich in detail. Magnify one again and again and more detail always emerges. Just as a twig resembles a branch and a branch resembles a tree, each part of a fractal is like the whole. (Images 24 and 25)
>
> That indeed is the definition of fractal, according to Benoit Mandelbrot, who coined the term. "If you look at the circle," he explains, "then look at it more and more closely, you will

Imperfect form of ginger root is no mathematical match for fractal dragon, but strangely resembles it.

Image 25

> see a smaller and smaller segment of the curve and it will appear to become straighter and straighter." There is no new structure in a circle at higher magnifications. It simply looks more like a straight line. But imagine a shape in which increasing detail is revealed with increasing magnification, and the newly revealed structure looks the same as what you have seen at lower magnifications. This shape is a fractal.
>
> Within the family of fractals are two clans. Geometric fractals, like Gosper's [mentioned earlier], repeat an identical pattern over and over at different scales. Random fractals, like Carpenter's [also discussed earlier] landscapes, introduced some elements of chance.[67]

The analysis of fractal shapes is pertinent to the study of computer graphic art. In one sense, the analysis attempts to show where and how the structure may be utilized. A broader understanding of the tool at hand is essential for its worth to be realized.

Benoit Mandelbrot is considered the "father and champion"[68] of fractals.

> "His colleagues describe Mandelbrot as a genius--eccentric, literate and contrary. He describes himself as a self-taught nonconformist. Whatever else, he is one mathematician who does not speak in dry, perfectly balanced equations."[69]

Mandelbrot was born in Poland in 1924. He skipped most of college, but passed the entrance exam to the Ecole Polytechnique, the leading French science school. He received a master's degree from the California Institute of Technology in aeronautics. He then returned to the University of Paris, where he earned a doctorate in mathematics. "Mandelbrot accepted a position at IBM's Thomas J. Watson Research Center in Yorktown Heights, New York, where he is now an IBM Fellow and manager of a group working on fractals.

IBM's Research Center is considered the "ivory tower of the corporate world, a university without teaching responsibilities."[70] Mr. Mandelbrot's office is described as "spartan, windowless, bare-walled, and sits at the end of a hallway because he can't stand noise." In describing the origins of his work on fractals, he looks back 25 to 30 years, "to a time when science looked at things that were regular and smooth."[71]

> He was intrigued by what are called chaotic phenomena. At IBM he turned his attention to a chaotic problem in data transmission by telephone. Every electrical signal is subject to random perturbations called noise. Usually the noise is not so overpowering that it interferes with the signal's message. But under certain conditions noise does interfere with the signal in destructive ways. Mandelbrot found a way to describe the chance fluctuations.[72]

The foundations on which Mandelbrot built his ideas came from the work of mathematicians who worked beween 1875 and 1925. The work the men pursued involved describing shapes which their colleagues described as "pathological" and "monsters." "Scientists of the day were convinced such shapes were . . . no relation to nature."[73] A summary of three of these scientists' work is described:

> Helge von Koch added ever smaller triangles to the side of a large triangle to create an infinitely intricate snowflake curve (Image 26). Guiseppe Peano's curve writhed in contortions until it nearly filled a plane. Georg Cantor's shapes evaporated into mere dust particles while they repeated a pattern into infinity . . . Mandelbrot . . . saw their similarities and called them "fractals" (from Latin <u>fratus</u>: broken or fragmented).[74]

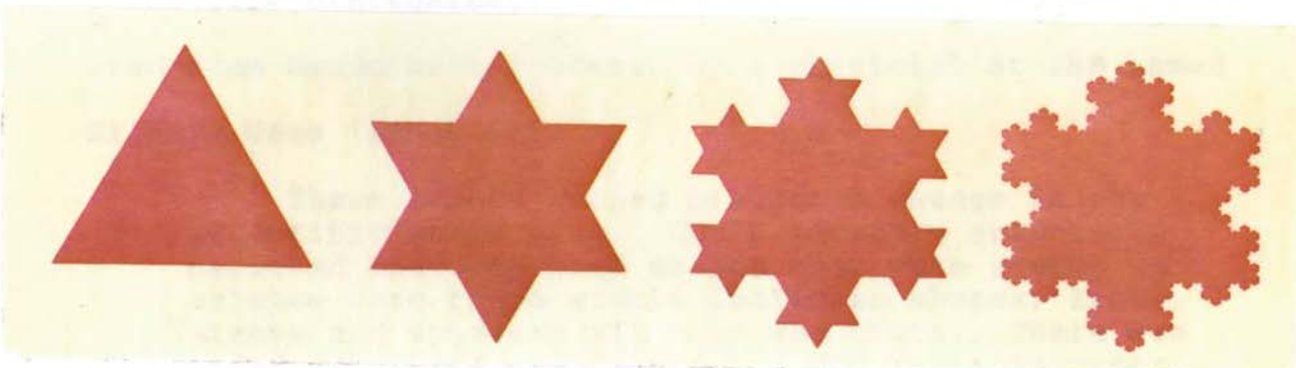


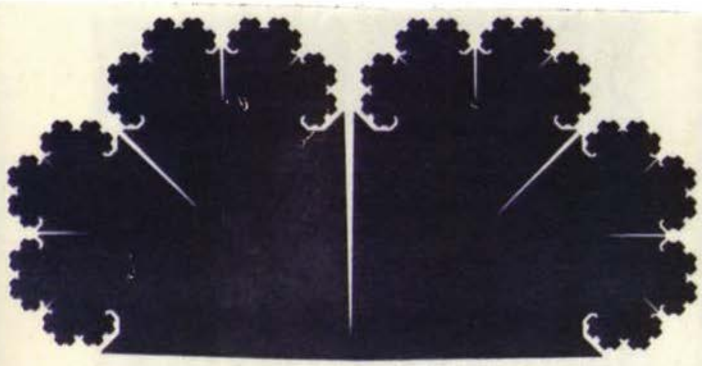
Image 26

Mandelbrot wrote a paper in the late 1960s on fractals and later, in 1975, a book. In it he used computer graphics to illustrate fractals, and acknowledges "without computer graphics, this work (research of fractals) would have been completely disregarded."[75] Wonderful landscapes were created from Mandelbrot's ideas, by a physicist at IBM named Richard Voss (Image 27).

> These images helped produce a change in the scientific world view. Until recently scientists believed that the only shapes that were useful in science were those simple Euclidian shapes, lines, planes and spheres; all else was chaos. There was order and there was disorder. Now there is order (simple shapes), manageable chaos (fractals) (Images 28, 29, and 30) and unmanageable chaos.
>
> The aesthetic beauty came as a total surprise . . . a premium. When people first came to work on this project, their first reaction to making the images was invariably a kind of intoxication.[76]

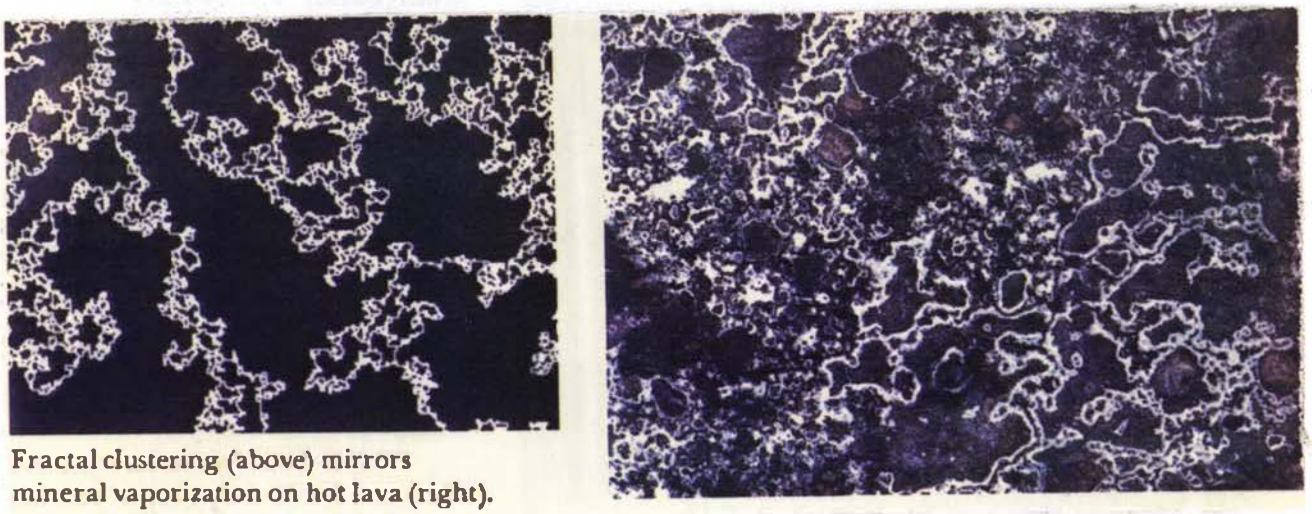
It appears that the discovery of fractals is an instance whereby the growth of science and of art proceed simultaneously. It is an enlightening experience for all concerned to see that diverse disciplines are related. The realistic mountainscape generated by Richard Voss is exemplary of the realism possible now with computer graphic systems, thanks to Benoit Mandelbrot's equations. And, again, it must be emphasized that Mandelbrot's equations would mean very little if there were no medium to generate the striking images and were no appreciation for the beauty of the images.

Image 27



Computer-generated fractals (left side of page) reflect fractals in nature, as with broccoli (right).

Image 28



Fractal clustering (above) mirrors mineral vaporization on hot lava (right).

Image 29

A "Cesàro curve" (below) shows fractal pattern of fern (right).

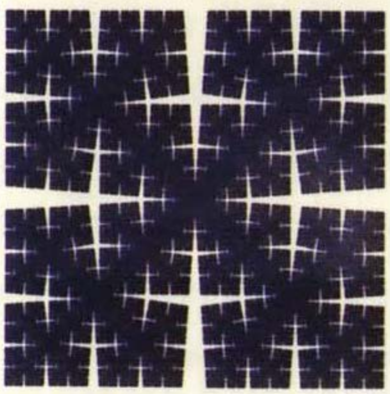


Image 30

Doug McKenna had been working on the fractal problem at IBM. His interests lie in the synthesis of art and this new mathematics field. Mr. McKenna holds a master's degree in electrical engineering from Yale. He is not certain that the term computer graphic artist is the proper label for what he is. He calls the field he is exploring "Mathemes-thetics."

Another computer artist fractal images inspired was Loren Carpenter, who was mentioned earlier. The methods Dr. Mandelbrot used for generating images were found unsuitable for animation by Carpenter. So, Mr. Carpenter devised tech-niques to produce many images quickly.

> Carpenter made an animated film to demon-strate this technique; it won him a job at Lucasfilm . . . random fractals capture the texture of reality. In another three or four years, Carpenter expects computer graphics to replace some movie sets and models.[77]

These artists are on the cutting edge of what is being done in the medium. Fractals are having an impact in many fields. Computer-generated images are beginning to be used to aid mathematicians, ecologists and meteorologists.

> The practical uses of fractals have developed at a slower pace. "A lot of people say, 'Okay, so you have a new name for these things, you call them fractals. But what can you do with them?'" says Alan Norton, a former associate of Mandel-brot's who is now working on computer architecture at IBM. It is a question currently being asked by physicists and other scientists at many profes-sional meetings. For a young idea still being translated into the dialects of each scientific discipline, the answer Norton says is: Quite a bit. The fractal dimension (a number expressing

the complexity of a particular fractal form) may give scientists a way to describe a complex phenomenon with a single number.

Harold Hastings, professor of mathematics at Hofstra University on Long Island, is enthusiastic about modelling the Okefenokee Swamp in Georgia with fractals. From aerial photographs, he has studied vegetation patterns and found some key tree groups, like cypress, are patchier and show a larger fractal dimension than others. In analyzing shapes that are hard to describe with any exactness--"patchy" ones, for example--using fractals may provide a more precise measure. Eventually, he hopes that slight and unexpected changes in the fractal dimension of key species can be used as an early-warning system for harmful disturbances like pollutants and acid rain.

Shuan Lovejoy, a meteorologist who works at Meteorologie Nationale, the French national weather service in Paris, confirmed that clouds follow fractal patterns. Again by analyzing satellite photographs he found similarities in the shape of many cloud types that formed over the Indian Ocean. From tiny pufflike clouds to an enormous mass that extended from Central Africa, to Southern India, all exhibited the same fractal dimension. Prior to Mandelbrot's discovery of fractals, cloud shapes had not been candidates for mathematical analysis and meteorologists who theorize about the origin of weather ignored them. Lovejoy's work suggests that the atmosphere on a small-scale weather pattern near the Earth's surface resembles that on a large-scale pattern extending many miles away, an idea that runs counter to current theories.

The occurrence of earthquakes. The surface of metal fractures. The path a computer program takes when it scurries through its memory. The way our own neurons fire when we go searching through <u>our</u> memories. The wish list for fractal description grows. Time will tell if the fractal dimension becomes invaluable to scientists interested in building mathematical models of the world's workings.

Whatever the purpose, fractals touch the imagination in a way that no other computer-generated image has. "They produce unprecedented visual effects. They are pure art, pure play things," says Bill Gosper. But their images have changed the

> world of mathematics as well. Mandelbrot explains: "Imagine 100 years ago that singing was outlawed and a great science of analyzing scores arose. Now think that 100 years later someone looked at these scores and found they were really much more beautiful and accessible when sung. Beautiful opera scores were appreciated by only a few but beautiful music was appreciated by everyone. I have done that for branches of mathematics."[78]

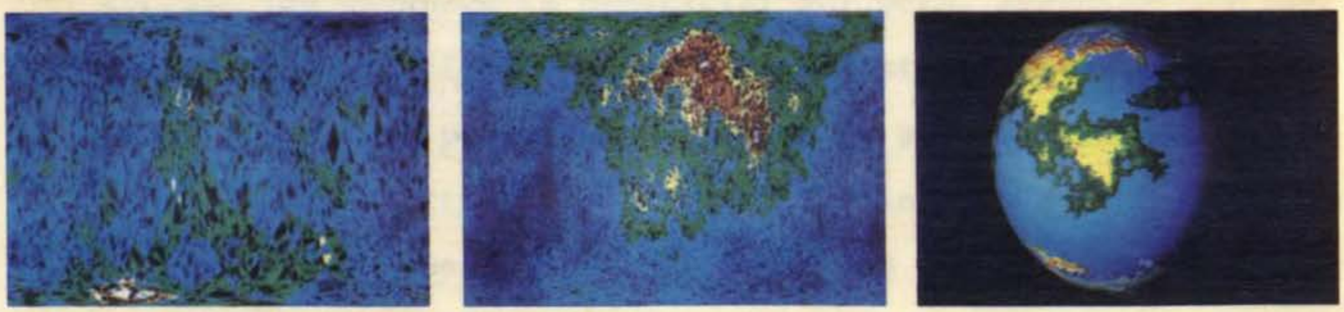
Images 31 and 32 are also examples of fractal generated imagery. Fractals are food for thought, no matter what discipline is followed. They are another facet that complements the pursuit of computer graphics. Being involved in this infant field is stimulating because it encourages so many diverse disciplines to overlap and exchange ideas. The consequence of which is a sense of interrelatedness and responsibility to a larger society.

Programmers at Lucasfilm used fractals, mathematical shortcuts to compose a scene, *Road to Point Reyes.*

Says one programmer: "It should look like someone went in there with a camera and made a movie."

Image 31

Fractals are used by Richard Voss to simulate evolution of authentic-looking imaginary planet.



By using a process modeled on earthquake faults, computer generates oceans, continents, ice caps.

Image 32

Conclusion

In summarizing what has been discussed, it is apparent that the computer revolution is, indeed, upon us. Educational methods are being reconsidered; businesses are working with universities to nurture students as potential employees; government is encouraging for the economic stability of the country; and artists are beginning to utilize the revolutionary technology in ways that have meaning for the larger society. Computer graphics are the essential, inextricable strength of computers, in general.

Computer graphics are what fascinate children, and most of the rest of the population, enabling them to become involved with and learn from interactive systems. Visual stimulation is the key. By having this marvelous tool, however--a tool which makes so many tedious tasks less burdensome--the traditional methods of accomplishing many tasks is devalued. The consequence displaces much of the population, previously described as skilled. Making tasks simpler has produced a serious problem.

Solving the problem is taking the combined effort of education, business and government, and well it should. Within these institutions lies the heart of social responsibility. This is awareness that through the efforts of each individually, and with the others collectively, society recognizes the problem and takes steps to alleviate it.

Elementary education has recognized the necessity of restructuring programs to accommodate computer-enhanced education. Difficulty remains for educators who are unfamiliar with the new technology, a technology their pupils may already be more familiar with than they, themselves, are. However uncomfortable, this problem remains. Educators must maintain an adaptable posture, while aiding student development.

Universities recognize the economic necessity of exchanging personnel and facilities with those of the corporate world. The exchange is beneficial for both, avoiding duplication of facilities. Facilities are state-of-the-art technologically; personnel and students are exposed to research and production procedures simultaneously; students are in contact with potential employers; and corporations have an "inside track" on talent. The cooperation of businesses and universities is regulated by government, thus making the triumvirate reflective of government itself, enabling a system of checks and balances to be effective. This triumvirate of institutions is responsible for ensuring the socioeconomic stability of the society which supports it.

The computer graphic medium may be appreciated as a breath of life for the visual arts community. It provides the opportunity for artists to contribute their strengths to society in practical ways, while being able to explore and experiment with a medium foreign to most. Intellectual stimulation is an important benefit in the exchange between artists and other professionals. Computer graphics provide situations whereby artists are able to explore new methods of working, experiment with a new medium, generate images of practical and aesthetic value and be stimulated intellectually. Artists who work in like situations are bound to communicate more optimistically, enthusiastically and effectively. Computer graphics is a medium that necessitates integration of all disciplines and, hence, fosters the understanding of society, as a whole.

Individuals experiencing the exhilarating benefits of the computer graphic medium are those who are pioneering it, as well. Barbara Nessim, Jim Squires and the Pacific Data team of Richard Chuang and Glenn Entis are confident of their abilities to communicate, regardless of the medium. Each must also possess curiosity and courage in choosing to pursue a medium without historic precedent. Conversely, parameters of style, technique and schools of art are absent, providing a freedom seldom experienced by artists throughout history. The element of risk is acknowledged. Embracing new technology--the computer graphic medium--an artist relinquishes the tactile pleasure of modeling with pencil and brush, in exchange for comparatively effortless, time-saving alterations. Additionally, there are benefits fostered by the exchange between disciplines.

A discovery mutually beneficial in the development of computer graphics and to mathematics, especially, is the fractal. For computer graphics, however, it enables artists to generate images of awesome beauty in practical application, as well as aesthetic application. Computer graphic imaging has made a mathematical equation comprehensible and, hence, added another dimension to the definable world.

Overall, computer graphics may be considered a progressive development of society. It is an important outgrowth of the computer revolution. Consequently, it will aid in altering the present order of everyday life. Computer graphics must be viewed and utilized with optimistic and socially-responsible objectives; in this way, its advent cannot help but be beneficial for society. If looked at as parallel to the machine age, where machine-harnessed power freed men of much physical toil and fostered the recreational enjoyment of the present, computers may be viewed as machines that will free us of the tedious, menial and repetitive chores of the mind, leaving us free to exercise our intellect.

FOOTNOTES

[1]Newman and Sproull, Principles of Interactive Computer Graphics. William McGraw-Hill, 1979, p. 6.

[2]Bernstein, "History Profiles . . . ," New Yorker., December 14, 1981, pp. 50-2.

[3]Ibid.

[4]Ibid.

[5]Kepes Center at MIT, Art International.

[6]See Footnote 5.

[7]Nagy, Leonardo, Painting Photography Film., p. 80.

[8]Same as Footnote 7.

[9]Frann, "Computers and Education." Technology Review. November 1979, p. 77.

[10]Ibid.

[11]Ibid.

[12]"Why Innovation Fails Our Cities and Schools," Technology Review. November 1979, p. 79.

[13]Ibid.

[14]Ibid.

[15]Ibid.

[16]Frann, "Computers and Education," Technology Review. November 1979.

[17]"Joining Hands Against Japan," Business Week, November 10, 1980, p. 108.

[18]Ibid.

[19]Ibid.

[20]Ibid.

[21]Ibid.

[22]Ibid.

[23]Ibid.

[24]*Ibid*.

[25]*Ibid*.

[26]*Ibid*.

[27]*Ibid*.

[28]*Ibid*.

[29]Skidmore, Owings and Merrill, "Energy requirement analysis at design stage allows timely evaluation." *Architectural Record*. August 1980, pp.84-91.

[30]*Ibid*.

[31]Bylinsky, "New Industrial Revolution is On the Way: Computer-Aided Design/Computer-Aided Manufacturing," *Fortune*, October 5, 1981, 106-14.

[32]*Ibid*.

[33]*Ibid*.

[34]Greenebaum, "Little Known Industry with Superhigh Computer-Aided Design," *Fortune*, October 8, 1980, 113-4.

[35]*Ibid*.

[36]Nessim, *Pixels, from Pencils to Pixels: Artist Barbara Nessim Explores the New Tool*. Courtesy of the Time Video Information Services. December 1983, pp. 36-44.

[37]*Ibid*.

[38]*Ibid*.

[39]*Ibid*.

[40]*Ibid*.

[41]*Ibid*.

[42]*Ibid*.

[43]*Ibid*.

[44]*Ibid*.

[45]*Ibid*.

[46] Ibid.

[47] Ibid.

[48] Ibid.

[49] Ibid.

[50] Paine (ed.), Computer Graphics and Applications, March-April 1983, p. 6.

[51] Ibid.

[52] Ibid.

[53] Ibid. (For a more detailed description of visual music, see: Meyers "Selective Update," IEEE GG&A, January-February 198 , p. 80.

[54] Ibid.

[55] Chuang and Entis, "3-D Shaded Computer Animation, Step-by-Step," Computer Graphics and Applications. December 1983, pp. 18 - 25.

[56] Ibid.

[57] Ibid.

[58] Ibid.

[59] Ibid.

[60] Ibid.

[61] Ibid.

[62] Ibid.

[63] Ibid.

[64] Ibid.

[65] Ibid.

[66] Ibid.

[67] Ibid.

[68] Ibid.

[69] Ibid.

[70] *Ibid*.

[71] *Ibid*.

[72] *Ibid*.

[73] *Ibid*.

[74] *Ibid*.

[75] *Ibid*.

[76] *Ibid*.

[77] *Ibid*.

[78] *Ibid*.

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