REAL-TIME COMPUTER GENERATED ART

A Thesis
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for the Degree Master of Fine Arts

by
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To the Memory of
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CHAPTER I

INTRODUCTION

For me the most important time in my experience as an artist, pursuing higher education, was the year 1968. Drawing from past educational, professional, and personal experience and an inner desire to bring all these experiences into one area of endeavor which would be harmonious to all my needs, I could visualize this culmination of learning manifesting itself within the area of computer animation/graphics.

My first experience with the computer as an artistic tool, its meaning, and implications in 1968 was quite different from what it is to me now in 1974. In 1968 I was quite naive in my expectations of what computers could do, let alone what the computer could mean as an artistic and utilitarian tool for the expression of my ideas and those of my contemporaries. Since my background was an artistic one and not one of computer and information science nor that of a programming specialist, I tended to think of the computer in a conceptual sense on the simplest rudimentary level. I believed that the limitations in this area would be purely in my ineptness at thinking creatively and communicating my ideas to those capable of implementing these
concepts into machine language. This I found to be true but, more important, I learned how to approach problem-solving in a way that I had not been accustomed to in my traditional art experiences. Perhaps, my accepting a new approach to problem solving from the outset allowed me to identify with the computer from my first exposure. I believe I reduced the whole notion of computers to such a rudimentary status in my mind that I was not intimidated by any facet of computer technology. I also entered my experience with computers with a desire to learn new approaches to decision making.

The environment, at this time, was such that I could have been intimidated by those outside of my interdisciplinary group structure, but I also realized from the outset that what the outsiders thought or felt about what I was doing was unimportant, for I had a commitment to myself, to an idea, and to the implementation of those ideas.

The computer offered me a point of departure from my previous endeavors with hard edge and optical painting and print making. I felt that the computer would act as an extension of my experiences in this area and would afford me the capability to work out visual ideas with a greater degree of complexity and flexibility. At this point I could utilize the visual results, generated by computer, as the basis for traditional image making. Many of the early images which I generated on the computer were reproduced by a variety of traditional processes, such as,
lithography, photographic serigraphy, and photographic enlargements. The main reason for reproducing these images by traditional methods was that I could make additions of them, which could then be marketed.
CHAPTER II

COMPUTER GRAPHICS

Digital computer graphics has been in existence since the late 1950's. Through the work of Ivan Sutherland and Stephen Coons, at the University of Utah, many of the early problems involved in computer graphics were recognized. In the early 1960's Coons and Sutherland developed and implemented software algorithms which enabled them to produce and display pictures on a cathode ray tube.

By looking back to this point in the history of computer graphics, perhaps, this was the first time anyone ever speculated as to the significance between computers and art and the implications of such an uncommon relationship between seemingly opposite and distant microcosms within reality.

Over the last 15 years computer graphics has come to denote many meanings to different people, the basic difference being in how people in different endeavors utilize this tool in problem-solving. Early computer graphics was thought of in terms of plotter graphs and simple electronic sketching upon the surface of a cathode ray tube. Today the word computer graphics has evolved to denote a more complex meaning and tends to encompass a greater variety of graphic representations. Some aspects
within the scope of its meaning are plotter graphics, electronic photographic scanning, traditional photographic techniques to reproduce graphic representations of objects generated upon a random vector or point plotting cathode ray tube, and also the use of motion picture photography to record digital graphic representations in motion, both in two and three dimensional space. It becomes apparent that computer graphics has developed and evolved to a greater degree of sophistication in the past 15 years, and the words have come to mean an all-encompassing creative expression in which digital computers are manipulated to create graphic visual forms.

The implication is that, within the definition of computer graphics, there exists an exponential meaning. The most important aspect, and where the potential is most prevalent, is within computer animated motion picture film. The production of film generated by computer can reach into many perplexing notions of problem-solving and dynamically illustrate this complex process. Thus, the implication of computer animated film as an art form, and as a means to educate, will necessitate creative thinking and implementation.

The implications of merging computers and art, as a viable means of expression, has now become an accepted and recognized means to create a new visual and physical reality, with the bulk of its potential still be be realized in the future. (See references 1, 2, 3, and 4)
Working within the existing structure of such a reality, certain basic notions become very apparent from the outset. One very important realization is that, in many situations, traditional criterion about art and computers have to fall by the wayside in order to implement and create new conceptual ideas. The basis of this idea can be found within the achievements in computer graphics, for if there had not been departure from the norm and accepted, we would be where we were 15 years ago. I am not trying to imply that traditional ideas are not useful; on the contrary, I believe they exist as a point of departure for truly creative expression and act as the balancing factor between reality and conceptual thinking. The necessity of understanding traditional ideas about art and computers is an important factor and, more often than not, the determining factor in regard to implementing a creative idea, for what was learned yesterday gives knowledge for development, growth, and departure for tomorrow's ideas.

To bridge the gap between traditional art and art generated by computers is a situation that I have not had to justify to myself. I feel that art needs no justification whether it was created via a brush or a computer. The important fact is that a creative individual was the controlling factor in both instances, and if the work of art falls apart, it is not the medium of expression which caused the failure.

One of the problems associated with any new art form is that there will always be the critics and cynics attacking the
process by which the work of art was created, due to their lack of understanding concerning the complexities within the technology and their inability to accept change or growth within a technologically oriented society. So often the value judgments made concerning a work of art, created via technology, is negative because the tendency is to use the criterion utilized in the past to judge the new and the future. To me the artistic criteria of the past acts as the point of departure for the new; it is the model that I have at hand and feel compelled to extend within my artistic limitations.
CHAPTER III

INTERACTION WITH HARDWARE AND SOFTWARE

Upon entering the computer environment, I was first impressed with the machine itself. The basic components of the computer and all the peripheral devices were connected by electrical cables and connectors. The visual quality of the equipment excited my imagination and stimulated a desire to learn how to use the equipment as soon as possible. I believe the best way to explain how I learned to operate the computer could be described as on the job training. Here I am referring to the 32K I.B.M. 1130 computer and I.B.M. 2250 graphic display.

After learning correct procedures and the sequencing necessary to operate the machine, I had to learn to use the software (computer programs). I soon realized that different programmers had different eccentricities on how they approached programming. Thus, it soon became apparent that I had to learn and remember how each program was constructed and the correct way to sequence the software parameters. Once I had mastered this task, I could begin to concern myself with the creation of objects and visual representatives which are aesthetically pleasing to my visual sense.
Early real-time interaction with these electronic images was an experience that had given me a new sense of space and time. I could create an image and then control this image in a variety of ways in which space and time were out of the context of normal reality. The transformations that I would impose on the image or images seemed to be normal or a natural kind of behavior, and I accepted it as such.

The relationship between the artist and the software is very important. It is at this point that the artist is enabled to manifest his ideas into visual representations. The artist is capable of accommodating this only after he has a complete understanding as to the limitations of the software and system in general.

When I first started manipulating images via computers, I never expected to be in a position in which I would be pushing the computer to its limits in terms of memory and computation speed, but I soon found that I would be in just this situation. Once I realized these limitations on a practical level, I had to gear my thinking to accommodate these limitations. At this point I was confronted with the problem of being able to communicate my ideas based upon the machine's capabilities. At this time it was apparent that the I.B.M. 1130/2250 system was inadequate, and in order to grow and develop further, there would have to be evaluation as to the assets and liabilities (hardware and software) and then decisions made as to the direction which to pursue if growth was to transpire.
I am presently using the PDP11 model 45 mini computer made by the Digital Equipment Corporation as a tool for generating and creating art objects. The machine has a core capacity of 48K which will soon be increased to 98K memory. The computer is interfaced to a vector general display which has hardwired features, such as, rotation, scaling, half-tone gray level registers, cut of plane, and many other features which are under software control. The display is a random vector type which has a resolution of 4096x4096x4096 units, or could be described as a 13-inch cube. Analog input devices include a stationary disk drive, two removable disk pack units, 10 dials, 16 binary switches, a joystick light pen, sonic graf pen, and one alphanumeric terminal with input and output capabilities, commonly referred to as the VT05.

Once the user has loaded the disk pack and loaded the monitor, machine control is shifted from the dewriter, which is a peripheral device by which I communicate with the machine and by which I can shift control to the VT05. When this procedure is completed, the user runs under the Disk Operating System (DOS) which controls a high level graphics language called the Graphics Symbiosis System (GRASS) which was developed by Thomas A. DeFanti (5) in 1973. Tables 1 and 2, in Appendix A, are examples of the GRASS command statements. The Graphics Symbiosis System is an interactive mini computer animation graphics language designed for habitability and extensibility.
Within the extensibility aspect of this language exists what Defanti has named a "macro" facility, which is not a true macro facility in the purist sense. The macro facility could be described as a means to communicate within the structure of GRASS or what I call mini programing. Several examples of macros are illustrated in Appendix B, Figure 1 through 4. These figures are also accompanied by a brief description as to their basic purpose and what will occur in terms of visual representation.
CHAPTER IV

DATA GENERATION

The artist-user has a number of means by which he can create images on the cathode ray tube. The most common means of inputting data coordinates is by the user utilizing macros designed to create images. Real-time inputting of data is accomplished by macros called light pen draw (LP Draw), and keyboard draw (KB Draw). The user creates images either in real-time or by preplanning and plotting data, which is usually hand plotted on graph paper prior to recording the data coordinates on the system. Drawings which are preplanned and the coordinate (two dimensions X and Y or three dimensions X, Y, and Z) prerecorded on paper are also inputed via the keyboard draw macro. The advantage of using the keyboard draw over the other methods of inputting data is that the artist can control exact positions of elements and relationships in his image. There are also other means of creating and inputing data. When I utilized the I.B.M. 1130/2250 computer, data was inputed via keypunched cards and punched paper tape. In order to convert these drawings into a format in which the PDP11/45 computer would handle, I had to run the punched data decks through the I.B.M. 1620 computer which could then be inputed into the PDP11/45 and recorded on the deck pack magnetic recording disk.
Data generation has always been a problem in many respects. Generating data is usually very time consuming when creating a complex image. It took me 80 hours to generate the data for the airplane (Illustration 1). This example exemplifies the time necessary in inputting and debugging the data representative of complex objects.

Illustration 1

Illustration 2
There are many computer programs written in Fortran and as GRASS macros for creating mathematically designed images. This means of creating data was implemented by Dr. Leslie Miller (6). The unique aspect of generating images using Dr. Miller's programs, is that mathematically derived images have a unique appeal because of their symmetrical and asymmetrical character. Mathematically derived data gives me the ability to position segments of the objects in exact special relationships and to link these segments to create a more complex structure. This capability is the basis for the aesthetic appeal of mathematically created images.

The most important aspect of the data generation process that I have mentioned is that it is a real-time experience and that creative and aesthetic decisions are being made by the artist-user and not the machine. Thus, the same kinds of decision making processes that take place in traditional picture making are taking place when creating images via computers.

Once the images have been created, the artist-user has a number of options opened to him as to how he would like to store his data. The means of storage most often used is magnetic disk pack storage. The artist is allocated a segment of the disk storage area and is free to use this area at his discretion. This procedure is necessary when more than one person is sharing the disk pack. The artist can also record his images on magnetic deck tape, punched data cards, or punched paper tape, as a
back-up file in the event that the disk malfunctions or images are erased accidentally.

Several hundred drawings can be stored on the disk pack. For example, if the artist is considering a film on the history of flight, he would generate 3-D images which would depict a variety of flying machines past and present and would store them on the disk. These images could be accessed whenever the artist desired. Some of the images he may want to consider could be DaVinci's flying machines, a variety of biplanes, dirigibles, jets, propeller driven aircraft, and rocket propelled craft, such as the lunar landing module. Then the artist could use these images in animation sequences.
CHAPTER V

DISPLAYING IMAGES

Once the user has generated and stored his image, the next procedure is to look at the image in real-time and to deal with the extensive capability of the computer programs. Since the flexibility of the software is quite extensive, certain decisions have to be made as to what the image should do. For example, decisions have to be made concerning rotation, scale, size, motion, intensity, and within each of these options there are other options. Within the option of rotation, the user can specify on what axis he would like his object to rotate. These are either X, Y, or Z axis, or he could want a compound rotation dealing with two of the axis options simultaneously. Not only are there options within options, but any number of these operational commands can be initiated simultaneously, with few exceptions. A simple example of this would be rotation, scale, intensity being interacted with at the same time. Once the decision is made, these choices can influence any number of images being displayed as long as there is core memory available in the computer.

Since the user has an unlimited choice as to the variables which he can use on each image, it would not be long before the
image or images would become very complex in terms of motion
dynamics if all choices were utilized from the outset. At this
point the user usually will limit himself to only a few of the
options available, thus, creating more control of the visual
relationships.

The type of versatility and control described here is
applicable to both two dimensional and three dimensional data.
This data can either be in static form or in a dynamic relation-
ship. Since there are many ways in which this data (images) can
be viewed, the question that arises is "how does the user deal
with the motion variables inacted upon his images?" I do not
believe there is any consistent manner in which this is accom-
plished. Usually a variety of users will have particular
criterion for their choices. More often than not, the user has
a definite idea as to what he wants to accomplish visually with
his image before he sits down at the console. This, however,
does not exclude the possibility that the user may choose to
see his image in a variety of special relationships before a
final judgment is made.

The basic difference between computer created images and
traditionally created images is that once the traditionalist has
created a particular view of his image, he is likely to want a
little different view of the same object in which case he has to
create the next view, whereas the computer drawing, through
software manipulation, can present the drawing in an infinite
variety of positions without the exhausting task of creating the new view. This example objectively shows the flexibility that computer created and controlled images have over traditionally constructed images.

The user-artist will become aware that there is a definite interplay between traditional thinking and knowledge learned from interacting with computer images and that both types of knowledge are the basis for departure and implementation of a new visual idea. The same elements found in traditional artistic endeavors are also being considered, recognized, and used in the construction and manipulation of computer images. These elements include color, texture, size, position, shape, light, dark, gray levels, and all other formal elements found in design.

Examples of half tone and linear images can be found in Illustration 3 through 10.
CHAPTER VI

RECORDING INPUT DATA AS A VISUAL REPRESENTATION BY MEANS OF MOTION PICTURE AND STILL PHOTOGRAPHY

Once the user has implemented his visual data on the cathode ray tube, the decision concerning the best means to record his results has to be made. The normal procedure is the construction of a story board. In simplified terms, this is where final decisions about the images are formulated. There are a number of ways to implement the story board. When the artist-user determines specific relationships in time and space, he uses the macro facility to expedite his conception. The macro facility offers the user the opportunity to establish his exact conceptual idea into elements which the graphics language can execute with precision. The components within the visual idea are elements and commands found within the graphics language. For example, the image in the story boarded macro may only concern itself with the elements of time, speed of motion, duration, path intensity, rotation, and multiple objects which interact in predetermined relationships. The elements in this example are only a fraction of the graphics language command capability.
The types of visual recording devices vary in terms of desired results. These recording devices include 35mm still camera, 4x5 still camera, 16mm motion picture camera, and videotape recording. The visual results obtained by each of these means is obvious.

Depending on the recording device chosen, the user will determine the exposure time, relative to the intensity of the image, film stock A.S.A., CRT phosphor, camera distance from the surface of the scope, and the filtration factor. These are the primary concerns of the photographer and differ quite extensively from traditional methods of photographic recording. For example, let us assume that a picture is being displayed on the CRT. As the image moves back in space (the Z coordinate), the intensity of the image will increase because of the vectors being compressed in the electronic hardware of the CRT and will necessitate a greater F/stop setting on his camera. Whereas in formal photography, as the subject moves away from the camera, there would normally be a need for more light or a smaller F/stop to obtain the best photographic results. The other major difference between conventional photography and photographing from a CRT is that photographs recorded from a CRT lack depth of field in the conventional sense. This idea can be simulated by a number of means if the artist decides this is necessary to understand his image. Traditional means of metering light from the CRT is insufficient and is relative to many factors which have
to be considered and understood if professional results are to follow.

Many of the photographic procedures which affect recording image from a CRT by a still camera are also relevant when recording with 16mm motion picture cameras. The main difference is that, when animated sequences are recorded, they are shot frame by frame. The basic difference between still and motion picture images to begin with is that motion pictures are but a series of still images simulating movement in the real world.

The advantage of recording animated sequences frame by frame is that by software control the refresh rate of the image displayed on the CRT can be controlled. What this means in terms of photographic results is that the intensity from frame to frame is consistent, which is vital if exposure is to be correct and the film is to be flicker free.

Not all CRT display units have phosphor which will accommodate a quick decay of the image from position to position. The vector general display is equipped with a display tube which has a P-4 phosphor. Three important characteristics of this phosphor are as follows: it allows the emitted light by incident radiation to decay very quickly, it allows for the displayed image to be sharper (sharper vectors), and the light emitted is in the blue range of the spectrum. All three of these characteristics can affect the photographic recording quality. The quick decay of the image from position to position means that there
will not be any trailing created by the image on the phosphor, as it rotates or moves in space. If trailing is present on the CRT, it is an indication of the type of phosphor used, and, in terms of design, can add another visual element which may or may not be desired in the creation of an animated film sequence. The other factor, which can adversely affect photographic results, is the blue light which is emitted by the phosphor. For example, if an image was recorded with high speed Ektachrome daylight 160 A.S.A. film stock, the color obtained would be in the blue range from a high key blue to a low value blue, depending on the intensity of the displayed image. Since this is the case concerning the light quality, if another color was desired, the light would have to be filtered by an appropriate color filter and adjustments in display intensity, camera shutter speed, and F/stop would accordingly have to be made.

The other factor which affects photographic results, when recording CRT displayed images, is the distance the camera is in relationship to the surface of the CRT. The standard relationship derived is as follows: the greater the distance between camera and scope, the longer the exposure will have to be. For example, if the camera is two feet from the surface of the screen and you are shooting with a still camera, you can use this distance as a guide for setting the F/stop and shutter speed. The other variables which have to be taken into consideration are intensity, color filter used, type of image or images, and whether the image
is in line or half tone format. Based on this information, it is quite obvious that different images will call for different exposure techniques and that what was the correct procedure for a still image will not necessarily be correct for a time exposure or a motion picture sequence. Since there are such a great number of variables which have to be accounted for, it appears that the best way to accommodate the variables is to develop an intuitive sense of how different images will photograph under different circumstances. This can be accomplished by two means, the first being photographic experience based upon similar conditions, and the second by means of recording the variable conditions and comparing them to the photographic results. With this information, a photographic information table can be documented to establish a reference guide.

There are many shortcomings when using photography as a means of documentation of computer images. Photography is basically a two dimensional means of recording objects which are in three dimensions. Traditional photography depends upon depth of field, light source, and light to dark relationships to emphasize the three dimensional quality of real world imagery. Whereas in computer generated images, electronic 3-D representations have to be juxtaposed in such a way as to simulate and qualify the three dimensional space, since the image is being displayed upon a two-dimensional surface (CRT). While interacting with the images in real-time, there is an acuate awareness of three
dimensional space, but it is lost when photographically recording the image if light source, physical intensities, and juxtapositions of images are not taken into consideration.
CHAPTER VII

SIMULATED THREE DIMENSIONAL IMAGES
IMPLEMEN TED BY STEREOGRA PHY

The word stereoscopy is compounded from the Greek word "stereos" which means solid or firm and the word "skopos" defined as the act of vision. Therefore, stereoscopic means the act of seeing solid or seeing in three dimensions.

Stereoscopic photography is one of the only mediums known by which the appearance of an object or setting may be reproduced with every detail so that the image appears to the eye exactly as did the original image. This description of stereoscopic photography seems to be descriptive of what we know and how we think about ordinary planar photography. The exception in stereoscopic photography, however, is that ordinary photography falls short of reproducing every detail perceptually in perspective. Planar photography does not reproduce definite size or distance, it does not separate every plane within a particular frame of reference, and it does not definitely exhibit the depth of the contour of an object.

To sum up this evaluation of planar photography it does not
reproduce more than a fraction of the essential visual detailed information of any given object.

Stereoscopy as used in stereography is a matter of producing a desired three dimensional visual effect. The appearance of the object or scene is the most important goal of the whole process. The stereographic composition is not limited to one plane, therefore, pictorial compositions lose much of their visual force when applied to the stereogram, and often that which produces an excellent planar picture may not enhance the characteristic value of the stereoview.

The planar photographer, with all his technical knowledge, needs no extensive knowledge of the principles of human vision to produce pictures, however, the stereographer can never approach the ultimate possibilities in stereographic photography unless he has a working knowledge of the principles of stereoscopic vision.

Through computer graphics and software, stereographic images can be simulated. Two individuals in the Computer Graphics Research Group have implemented such a means of generating both real-time and still stereo paired images. Dr. Miller has implemented a stereo 3-D macro facility in the graphics language GRASS. A simple explanation of this macro is as follows: a picture is displayed on the CRT which simulates what one of the eyes would see, and a copy of this image is created to simulate what the other eye would see in regards to a real world situation. These images are both calculated in perspective and give
a very convincing three dimensional representation of the object when viewed with a stereo scope. The other individual who has created a real-time three dimensional stereo paired macro is Ph.D. candidate Robert Reynolds (7). His macro is basically the same as Dr. Miller's with the exception that no perspective calculation is being made. The basic means of creating the stereo effect is accomplished through rotation of one of the objects in a paired situation between $2\frac{1}{2}$ and 10 degrees ahead of its paired mate. Other features included in this macro are the capability under real-time operation to scale the paired objects, control the rotation speed, rotation separation between the images, distance between the two paired images, and the capability to use any of the GRASS commands at will.

Photographically recording these images can be accomplished in several ways. Still images can be photographed as stereoviews which are two views of the same image, recorded on the same piece of film with one of the images red and the other green which are also superimposed except for rotation of one view. In the stereoview only one image appears on the photographic negative, which simulates what one eye will see and on another negative what simulates the other view will be recorded. Hence, what is called paired images, which simulate three dimensional images, are created. These paired images can be viewed either by a stereoscope, or the images can be projected through polarizing disks and can be superimposed upon one another on a metal surface or
special projection screen. When the projected polarized views are projected, it is necessary to wear special polarized glasses in order to perceive the image in three dimensions.

Motion picture film can also record stereographic images. This is accomplished by photographing two successive 16mm film frames which will simulate what the left eye and then what the right eye will see. The photographed sequential views are then projected through alternating color filters (red-green) or polarized disks.

Stereo images are a dynamic means to communicate intellectual conceptual visual concepts because they more accurately simulate what is perceived as a real world experience. Until holographic motion picture film becomes a reality and is accessible as a means of communication, it is quite possible that there will be a rebirth of the stereographic image as a visual tool between this span of time.

Illustrations 11 through 14 are examples of stereo paired images generated on the computer. Illustrations 15 and 16 are examples of anaglyph stereoscopic images.
CHAPTER VIII

COMPUTER GRAPHIC IMAGES PRESENTED THROUGH

TRADITIONAL IMAGE MAKING PROCESSES

Within any creative decision-making process, there has to be artistic criteria established if the finalized results are to be meaningful. Since the creation of objects, by means of computer graphics, is a real-time experience, I believe the essence of the artistic experience and the intellectual meaning of this experience occurs at this moment. Thus, the artist-user is confronted with the problem of best exemplifying this experience. Since accomplishing this task can only be exemplified through traditional methods of representation and communication, hence, the artist is again confronted with the problem of how best to display its ultimate meaning. There does not appear to be any specific means to accomplish this task, and because of this idea, there is a good chance that the meaning will become lost or never manifest itself.

The meaning within the images or objects and the philosophical statement they may try to convey in their uniqueness are subject to distortion because of the means in which they have to be presented. The only means by which the idea can be
presented is locked into traditional means of communication. The artist has to determine which method of communication can best present his ideas with minimal amount of distortion to its meaning.

Many of the images and objects, which have been created via computer graphics, are so far removed from the original point of creation that the visual results are only a fragment of the original concept of the computer image. This idea can be compared with the motion picture and television industry, where the original visual creation is never the final presentation viewed. What is usually transmitted is removed four or more times from its original creation. This removal from the original state can both be a hindrance and an enhancement to the meaning, but more often than not a detriment.

Some of the traditional reproduction methods by which I have utilized computer images as the basic pictorial element are as follows: photographic serigraphy, photographic enlargements, and motion picture recording. Examples of these processes can be found in Illustration 17 through 24. The format of the finished panels differ in color, pictorial image, size, and placement. Many of the images were created to give the illusion of being three dimensional. This was accomplished by stacking pieces of plastic, with the images being screened, in slightly different orientations.

The idea of merging traditional images with computer imagery can best be exemplified through computer animated films.
Since I do not have a visual example of these films in my thesis, I will discuss one of the ideas which I am utilizing at the present. I am in the process of filming and co-directing a film on astronomy. The film deals with some of the basic concepts in astronomy which are difficult to grasp. An example of merging traditional recorded images and computer animation, in this film, I projected a 35mm slide of a galaxy on a screen, photographed this image at 12 frames per second with a 16mm motion picture camera, and simultaneously zoomed into the projected slide. Once I had recorded as much footage as I desired, I rewound the film in the camera and loaded it into the animation camera. Here a macro was enacted which simulated star fields moving toward the viewer at a rate which was similar to the previously recorded zoom into the slide. The visual results, by double exposing, were quite surprising and surpassed my speculation as to the quality that would be attained. It is apparent from this example that the reality present in the slide, or the realities found in video-recording, traditional motion picture film, and traditional photography can be merged with computer animation sequences to create a new and exciting art form. It is within this capability of combining different visual media that their collective meaning can be extended to create a new perception of reality.
CHAPTER IX

CONCLUDING REMARKS

I have touched upon some of the artistic learning situations in which I have been involved for the past six years. Within this span of time, I have felt an intellectual growth in both understanding and implementing visual ideas through a process which I have found to be a tremendous stimulus in my artistic career.

It is quite obvious to me that this technology can enhance the artist's creativity. If the artist is to grow and develop intellectually with this technology, he has to augment his traditionally learned skills in a manner which will complement the best aspects of both entities.
<table>
<thead>
<tr>
<th>Key</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROTATE</td>
<td>GETDSK GROUP DELETE PUTLIB GETLIB FILLING</td>
</tr>
<tr>
<td>UNFILM</td>
<td>RESUME READ WRITE RENAME MOVE PATHMOV</td>
</tr>
<tr>
<td>RESTART</td>
<td>SCALE FIX GETCOM PUTDSK TEXT SHADE</td>
</tr>
<tr>
<td>SHADE2</td>
<td>WARP FILL INTERP SETCUT SETORG SETDULA</td>
</tr>
<tr>
<td>SMOOTH</td>
<td>SETINT CORE COLOR COMPILE BIRDSK DIRCORE</td>
</tr>
<tr>
<td>CIRCOM</td>
<td>DIRALL HELP TREE CLEAR RTE COPY</td>
</tr>
<tr>
<td>BLEND</td>
<td>TYPE PRINT XLIST LIST PROMPT RES EQ</td>
</tr>
<tr>
<td>INSLIN</td>
<td>GETBUF CLOSED SKIP GOTO RETURN WAIT</td>
</tr>
<tr>
<td>FLAP</td>
<td>HIDE SOFTROT DASHES POINTS LINES OPENO</td>
</tr>
<tr>
<td>GETPOIN</td>
<td>GETLIN PUTPOIN EXIT REMARK INPUT OPENED</td>
</tr>
<tr>
<td>CLOSED</td>
<td>RESET LPNAME PENSEN PENOFF GETHIT GETVRD</td>
</tr>
<tr>
<td>CLOSED</td>
<td>PUTVRD FSON FSOFF DELPOI TICK DELLIN</td>
</tr>
<tr>
<td>LOGIN</td>
<td>KEEP MATCH SOFTEX DPTON SETBK MODIFY</td>
</tr>
<tr>
<td>DUMP</td>
<td>SETREL SETRAD BEGIN STOR GS VG</td>
</tr>
<tr>
<td>AL</td>
<td>SUBSER SYMTAB</td>
</tr>
<tr>
<td>CALL</td>
<td>DO IF ON IFE NEW</td>
</tr>
<tr>
<td>EDIT</td>
<td>MANI REFELC DIGIT2 THICKR PATHMOV DIGIT3</td>
</tr>
<tr>
<td>EXE</td>
<td>JSDRAW KBDRAW LPDRAW SAVE MERGE DELPOI</td>
</tr>
<tr>
<td>TRASCL</td>
<td>SH2REG REDUCE</td>
</tr>
<tr>
<td>Command</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>LOGIN</td>
<td>logs user onto the system</td>
</tr>
<tr>
<td>FIX</td>
<td>ends the action of the following three functions</td>
</tr>
<tr>
<td>MOVE</td>
<td>interrupt level translation</td>
</tr>
<tr>
<td>ROTATE</td>
<td>interrupt level rotation</td>
</tr>
<tr>
<td>SCALE</td>
<td>interrupt level scale</td>
</tr>
<tr>
<td>GETDSK</td>
<td>disk and core library input/output</td>
</tr>
<tr>
<td>PUTDSK</td>
<td></td>
</tr>
<tr>
<td>GETLIB</td>
<td></td>
</tr>
<tr>
<td>GETCOM</td>
<td></td>
</tr>
<tr>
<td>SHADE</td>
<td>fills an outlined area with straight lines</td>
</tr>
<tr>
<td>FILL</td>
<td>fills an outlined area with copies of an image</td>
</tr>
<tr>
<td>MATCH</td>
<td>matches points in 2 images which are to be blended</td>
</tr>
<tr>
<td>BLEND</td>
<td>blends one image into another</td>
</tr>
<tr>
<td>FLAP</td>
<td>flaps two images simultaneously about the same point of origin</td>
</tr>
<tr>
<td>RENAME</td>
<td>changes the internal name of an image</td>
</tr>
<tr>
<td>CLEAR</td>
<td>clears the alphanumeric terminal screen</td>
</tr>
<tr>
<td>PROMPT</td>
<td>displays characters on the alphanumeric terminal</td>
</tr>
<tr>
<td>DELETE</td>
<td>deletes and garbage collects from core an image or routine</td>
</tr>
<tr>
<td>FSOFF</td>
<td>resets an activated function switch</td>
</tr>
<tr>
<td>FSON</td>
<td>activates a function switch</td>
</tr>
<tr>
<td>HIDE</td>
<td>puts an image in a hidden line format</td>
</tr>
<tr>
<td>FILIMG</td>
<td>sets an image or images for automatic filming or stop action single framing advancements</td>
</tr>
<tr>
<td>UNFILIMG</td>
<td>resets the filming command</td>
</tr>
</tbody>
</table>
APPENDIX B

MACRO EXAMPLES
MACRO: THREEED

PROM "THREEED IS A MACRO FOR PHOTOGRAPHING 3-DIM"
PROM "DRAWINGS (BUT WITH FILTER CHANGE EACH FRAME)"
PROM "PICTURE WILL ROTATE ABOUT THE Y-AXIS"
PROM "WHAT IS THE DRAWING NAME"
INPUT $A
GETD $A
PROM "WHAT SEPARATION"
INPUT $K
PROM "ROTATION RATE"
INPUT $J
ROT/D $A, $Y, M
$M=-J
PROM "SHOOT COLOR 1 AFTER YOU HIT CR"
INPUT $D
$M=$M+$J
PROM "SHOOT COLOR 2 AFTER YOU HIT CR"
INPUT $D
$M=$M+$K
INPUT $D
$M=$M-$K
SK -8

Fig. 1.—Macro for filming static stereo paired images.
MACRO: NFCOD

PROM "NAME OF DRAWING"
INPUT $A
GETD $A
PUTLIB $A
N=1
GETPOI $A, N, X, Y, Z, K
IF K LT Ø, SKIP 3
N=N+1
SKIP -3
N=N-1
IF N GT Ø, SKIP 2
EXIT
PROM "HOW MANY FRAMES SHOULD IT TAKE"
INPUT K
B=N/K
IF B LE Ø, SKIP -3
PROM "NEW DRAWING NAME"
INPUT $B
OPENO $B
PROM "SET FOR INTERACTION WITH DRAWING"
PROM "TYPE RESUME WHEN INTERACTION COMPLETED"
WAIT
N=1
C=B
GETPOI $A, N, X, Y, Z, K
IF K LT Ø, SKIP 9
PUTPOI X, Y, Z, K
C=C-1
N=N+1
IF C GT Ø, SKIP -5
PUTPOI Ø, Ø, Ø, Ø
INPUT A
DELP0I
SKIP -1Ø
PUTPOI Ø, Ø, Ø, -1
DELE $A
DELE NFCOD

Fig. 2.---Macro designed to bring the drawing off the disk one or more lines at a time. Any GRASS commands may be used.
MACRO: FADE

CLE
PROM "FADE FADE FADE"
PROM ""
PROM "PICTURE NAME:"
INPU $A
PROM ""
PROM "FILM PARAMETER:"
INPU $G
PROM ""
PROM "# OF FADE IN FRAMES:"
INPU $A
PROM ""
PROM "# OF DISPLAY FRAMES:"
INPU $B
PROM ""
PROM "# OF FADE OUT FRAMES:"
INPU $C
D=32766/A
E=32766/C
F=-32300
SETI $A, F
FILM/A $G
IF A EQ $, SK 5
F=F+D
A=A-1
TICK 1
SK -4
TICK $B
IF C EQ $, RET
F=F-E
C=C-1
TICK 1
SK -4

Fig. 3.--Example of a macro designed to automatically fade out an image when filming with the automatic camera.
MACRO: TVZ

CLEAR
PROM "TV ZOOM"
PROM "PICTURE SET"?
INPUT $A
IF $A NE 'X', SKIP 5
GETD TV1X
GETD TV2X
GETD TV3X
GETD TV4X
IF $A NE 'Y', SKIP 9
GETD TV1Y, BIN
GETL TV1Y
GETD TV2Y, BIN
GETL TV2Y
GETD TV3Y, BIN
GETL TV3Y
GETD TV4Y, BIN
GETL TV4Y
IF $A NE 'Z', SKIP 9
GETD TV1Z, BIN
GETL TV1Z
GETD TV2Z, BIN
GETL TV2Z
GETD TV3Z, BIN
GETL TV3Z
GETD TV4Z, BIN
GETL TV4Z
IFE
S=-32768
SCALE TV1, S
SCALE TV2, S
SCALE TV3, S
SCALE TV4, S
PROM "SCALE INCREMENT"
INPUT VS
PROM "TRANSLATE INCREMENT"
INPUT VT
T=0
MOVE TV1, X
MOVE TV2, U
MOVE TV3, VX
MOVE TV4, VU
MÁCRO: TVZ (Continued)

PRM "TYPE RESUME TO CONTINUE"
WAIT
S=S+VS
X=X-VT
Y=Y+VT
U=U+VT
V=V+VT
VX=VX-VT
VY=VY-VT
VU=VU+VT
VV=VV-VT
TICK 1
SKIP -1Ø

Fig. 4.—Macro designed to effect a zoom on any four drawings simultaneously and tends to simulate perspective. Any GRASS commands may be used.
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