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Temporal Synergy: multi-system animation of computer generated imagery

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multi-system animation
of computer generated imagery.

by Chad H. List

06.10.86

dedication

This production is for my family.

Special thanks to the members of my thesis committee.

contents

author's note

references to quoted sources are as follows: [15p132] refers to source number 15 from the reference section, page number 132 from the text.

intent

The intended purpose of this thesis is to create a visual piece using multiple computer animation systems. 1.0

Several factors were taken into account during the selection of hardware and software to be represented. The primary consideration was to question what systems are presently available to students at RIT. Other concerns included capabilities for generation of imagery in color, and facilities for the direct output of scenes to videotape. I believe that the final selections sufficiently meet these requirements (with the noted exception that output from the CAST system was originally to film, and later transferred to video) and form a representative cross-section of hardware and software packages from each of the categories outlined in section 5.0, as well as various methods of image generation and manipulation.

The finished videotape is experimental in nature, and explores the conceptual elements of color, shape, and motion set to music. The piece is entitled Temporal Synergy: **temporal** because animation deals in the element of time, and **synergy** which is the action of two or more elements to achieve an effect of which each is individually incapable-- in this case, the elements being the four different computer systems used and, to an extent, the background music.

As well as being created for the Master of Fine Arts show, Temporal Synergy was also intended to be used as a personal portfolio piece. It is not intended for instructional purposes.

The major portion of this paper is an overview of computer graphics animation in general, and is meant as both an introduction to computer animation, and a body of reference for later sections dealing with the production of _Temporal Synergy_. A final section presents unresolved questions and problems which I have encountered, dealing with the field of computer graphics in general. 1.0

computer graphics

2.0

Computer graphics is not only a term defining visual imagery that has been created or manipulated with a computer, but also refers to the hardware and software which has been developed specifically to generate and alter this imagery.

Computer generated imagery manifests itself in a wide variety of forms, from the relative simplicity of the early video arcade game to the vast complexity of breathtakingly realistic fractal landscapes. "While there is great diversity among these forms of computer graphics in the type and quality of image and in the degree to which a user can control the image dynamically, they all share one property: a picture of some object or objects is created and manipulated by a digital processor. Thus we say that **computer graphics is the creation, storage, and manipulation of models and objects and their pictures via computer.**"[11p3]

The computer is an artistic tool unlike any other, in that it gives the artist a previously unattainable level of control over his medium. At any time during the course of production, he is free to save imagery and explore in alternative directions without fear of losing the precious ground which he has already gained.

In addition, the computer takes care of many of the repetitive and time-consuming tasks of production, leaving the artist more time to conceptualize and experiment with his imagery.

characteristics of computer generated imagery

2.1

The characteristics which describe computer generated imagery can be divided into three categories: dimensionality, orientation, and representation.

The term dimensionality is self-explanatory. Two dimensional graphics refers to imagery which exists on a single plane, the screen plane. Three dimensional graphics can be represented by actual models which are defined using a 3D coordinate system, or may be simulated in 2D. Finally, there is something called 2 1/2 dimensional graphics in which objects can be scaled up and down as well as rotated through x, y, and z, but the objects themselves are only one pixel deep.

Orientation refers to the method by which an image is stored within the memory of the computer. In a bit-mapped system, a digital representation of a display image is stored as a pattern of bits, where each bit corresponds to one or more picture elements, or pixels. In a vector oriented system, objects are defined and stored in memory utilizing mathematical formulae.

Representation refers to the way that an image is presented on the display screen. An image is said to be wire-frame when all edges of objects are seen and no hidden line or plane removal takes place. In solid modeling, objects are displayed as solid entities and hidden lines and surfaces are removed.

Sophisticated modeling systems may have capabilities for the manipulation of virtual "light sources" which allow for shading and highlighting of solid objects. Reflection , refraction, and transparency are also examples of higher-level functions which can be utilized on more complex systems. 2.1

generating computer imagery

2.2

Although the creation of imagery with a computer paint system differs inherently from the generation of imagery by plotting, both utilize a keyboard, stylus, or similar device to input coordinate information. In plotting, objects are defined using vector-oriented coordinates, whereas computer paintings are generated using a raster display system.

In both painting and plotting, built-in computer functions help with repetitive tasks such as drawing geometric shapes, or filling areas with color. Other functions may include duplication of objects or areas, rotation, scaling, transformation, etc.

Another method of creating imagery involves the use of an optical scanning device. In raster systems, this practice is called **digitizing**, and the input device is generally a standard video camera.

Sophisticated computer systems sometimes utilize mathematical algorithms to generate imagery. In **ray tracing**, an algorithm is used to follow light rays backward from the viewpoint to the light source. Textures or images can be **mapped** onto surfaces using another algorithm. A final method of image creation uses a fractal generating algorithm. **Fractals** are a class of irregular shapes that are probabilistically defined and have come into favor for their ability to accurately model natural shapes, such as terrains, coastlines, snowflakes, and tree branches. [11p590]

3.0

An area of research which has contributed greatly to the development of computer graphics is the effort of the military and the aerospace industry to perfect the visual flight simulator. Training simulators allow students to practice a task such as flying an airplane without leaving the ground. Although the cost of producing a realistic simulator is immense, it is far more reasonable than actually expending fuel and ammunition, and risking the occasional destruction of an airship, or possible loss of life.

In their most sophisticated form, simulators reproduce the instruments, motion, and sounds of a vehicle, as well as the out-the-window visuals. The visual flight simulator is that part of the device which presents scenes for the crew to view out the windows of the mock aircraft.

In early systems, a visual environment was created by movies. Later, video imagery was produced by servo-driven television cameras which were "flown" over model boards by the actions of the simulator pilot. These approaches were very limited in scope and could not produce scenes in true perspective from a wide variety of viewpoints. Modern simulators attempt to overstep these problems by utilizing computer generated imagery.[16p1]

In their continuing efforts to realistically portray landscapes, objects, and atmospheric perspectives, the developers of training simulators have made enormous strides not only in the generation of computer imagery, but also in the real-time animation of this imagery. More recently, explorations have been made into the use of interactive videodisc technology to store extremely detailed imagery which would be otherwise impossible to animate in real-time. 3.0

animating computer imagery

Simply stated, animation is an illusion of movement which is produced by displaying a series of slightly different images at a given rate, generally 24 frames per second for film, and 30 frames per second for video. However, it is also possible for animation to exist without movement in situations of changes in color or light intensity, so perhaps a more concise definition would be that **animation creates a visual illusion of change over time.** 3.1

As technology has advanced, the computer has taken over an increasing amount of the work necessary to create an animated sequence. In the preparation and planning stages, storyboards and rough sequences can be drawn at computer workstations. In the generation of artwork, drawings of various degrees of complexity may be digitized with scanners or created directly with a computer paint system, or when precision and detail are critical, objects can be created through programming methods. In the animation stage, one can utilize the computer's ability to manipulate imagery in a variety of ways. During recording, virtual cameras can be programmed to execute all of the moves common to physical motion picture cameras.

It should be obvious that not all computer systems manipulate imagery in exactly the same manner to create animation, and therefore I will mention some of the most common methods in which they do so: 3.1

Page Flipping is an animation technique common to microcomputers in which graphic pages are alternately loaded, displayed, and updated.

Color Cycling is another simple animation technique in which a range of colors is shifted within the palette of an image at a given speed.

In **Keyframe Animation**, start and end frames are defined by the user, and the computer calculates the step frames in between. Keyframing usually allows only relatively slight changes of defined objects.

Tweening is similar to keyframe animation, however it allows for more extreme changes, such as addition and elimination of object vetices.

Sprites or **Actors** are user-defined entities that can be moved along the screen plane. This is a method of animating imagery which is common to microcomputers and video arcade games.

Models are user-defined entities which can be moved and manipulated in three dimensions.

Manipulation options utilized during the creation process of computer imagery are generally also available during the animation stage. Imagery can be altered in both form and color over a given number of steps, or frames. 3.1

recording animated sequences

3.2

When the time arrives to record an animated sequence, several factors must be taken into consideration.

Firstly, is the sequence to be recorded finished or in a test stage? If it is indeed a rough, the option of shooting in wire-frame should be considered. Wire-frame imagery takes significantly less time to film, and is fine for working on sequence timing and similar tests. On some systems, wire frame models can be viewed in real-time, thus eliminating the need for shooting roughs altogether.

Secondly, when recording finished sequences, what will be the destination medium, film or videotape? Unless one has access to state-of-the-art recording and transfer equipment, he should generally compile his finished animation on the material which it will be shown since every subsequent generation of visual material will lose quality.

Finally, will the sequence be recorded in real-time, or frame-by-frame? Perhaps the most common examples of real-time computer animation are the graphics produced by video arcade games. Video games are totally interactive- the motion on the screen corresponds directly to the input of the player.

Due to the scan rate of the CRT, a real-time image must be displayed in less than 1/15 second or there will be no illusion of continuous motion. This is possible on single-user systems like microcomputers, but both the resolution and color range are relatively limited.

In the past, real-time animation has only been possible with vector refresh displays, for with raster systems, the rescan of pixels takes too much time.[15p15] When recording complex sequences such as those produced for motion pictures, it may take several minutes to generate and film each frame. The recorded frames are subsequently displayed at 24 frames per second for film or 30 frames per second for video. 3.2

advantages of computer generated animation

4.0

Why work with computers as opposed to traditional animation methods? In some cases, traditional methods may prove more appropriate, but here are some reasons to consider using computer generated imagery:

Speed: On some systems, the possibility of immediate results in real time eliminates time lags for film processing during production. Keyframing and similar computer techniques radically decrease production time and eliminate the need for a large team of cel painters.

Versatility: Utilizing computer graphics animation, one can achieve effects which are impractical or impossible with other methods, and can simulate other techniques such as airbrushing and model photography both cheaper and faster. Similarly, it is more precise and practical for very detailed animated sequences. Variations and updates of sequences can be made quickly and cost effectively by utilizing a previously stored database. In computer graphics, there are none of the limiting factors inherent to film production, such as depth of field, or problems with size and manipulation of objects. As was stated in section 3.1, computer graphics can be used in all stages of production, from storyboarding to finished product.

Impact:"The animation gives such a strong image that it promotes visual retention."[2p12]

Cost:"Digitally, computer generated animation can only get faster and cheaper."[2p12]

applications of computer animation

4.1

In the past, access to computer graphics technology was limited by various factors, the greatest being the cost of acquiring hardware and software. With the introduction of low-cost mass-produced microcircuitry, this most difficult obstacle has been all but eliminated, and computer generated imagery has grown in both utilization and variety of application.

A few years ago, video arcade games were probably the most widely seen form of computer graphics animation.

In the cinema, computer animation has become a useful tool in the creation of titles and special effects. In feature films such as Tron and The Last Starfighter, the computer generated effects were a major element.

Industry has extended its utilization of computer graphics and animation beyond CAD/CAM (Computer Aided Design / Computer Aided Manufacturing) applications into areas such as marketing and education of personnel. Computer animation has also expanded in the areas of education and research. It is not only a useful element in simulations as previously stated, but is also utilized in motion analysis studies and in the visual display of fundamental concepts.

The greatest area for potential growth of computer animation seems to lie in applications for television. In the past, television has utilized computer animation for advertising, logos, titles and promos, as well as news and weather graphics. More recently, computer imagery has been introduced into cartoons and music videos.

animation systems

5.0

For purposes of clarity, I have taken the liberty of dividing computer animation systems into various categories. These are generalizations, and therefore specific systems may differ. The price ranges given are current, and will probably be inapplicable in a year or two. The classifications are as follows:

Microcomputers:
These are also called personal computers, and can be purchased at computer shops or department stores. Generally, micros cost less than $2500 for a complete system including all of the necessary hardware. Software usually costs under $100 for a basic paint program, and modeling programs are usually slightly more expensive.

Capabilities of microcomputer systems usually include sprite or page animation. The limitations of these systems generally lie in the areas of limited color range, low screen resolution, and lack of control over animation speed.

Applications of microcomputer animation most commonly lie in the areas of art, education, entertainment, and in-store advertising. Some popular examples of microcomputers are manufactured by Apple, Atari, Commodore, and IBM.

Expanded Micros:
These are also known as micro-based systems, and are available exclusively from special distributors or manufacturors. Expanded micros are basically personal computers that have been altered physically to increase capabilities. Unit costs range from $10-60,000 and usually include a basic software package.

Expanded micros usually have extended color range and high screen resolution capabilities, but are generally limited in animation capabilities due to a lack of memory space. 5.0

Applications include illustration and informational graphics, and to a limited extent, television advertising applications. Artronics, CGL, and Via Video are all examples of expanded micro systems.

Minicomputers:
Minicomputers are small, stand-alone business computers which are, in art and design applications, designed specifically for the generation and animation of artwork or models. Hardware costs range from $80-120,000 and a basic software package is generally included.

Capabilities and limitations of minicomputers are usually directly related to their originally intended function (i.e. solid-modeling systems are not intended for the creation of charts, just as graphics systems are not necessarily intended to create models). This, however, does not mean that crossover does not exist. For example, some solid-modeling systems which were originally intended for CAD/CAM have been found to be excellent for the manipulation of 3D imagery for advertising applications.

Applications of minicomputers include advertising, illustration, information graphics, and corporate applications. Some manufacturors of minicomputers are Bosch, Cubicomp, Cybervision, Dicomed, Dubner, Genigraphics, and Megatek.

Mainframe Computers: 5.0

Mainframes are sophisticated multi-user machines which may support a number of applications at any given time. These machines cost in the range of $100-400,000. Mainframe users commonly generate their own software, however when it is purchased, software costs are upwards of $80,000 for a single workstation implementation.[3p28]

Capabilities of mainframes are generally limited only by the sophistication of the software which they run.

Artistic applications of mainframe computers lie in the areas of animation for advertising and motion pictures, as well as simulations. Manufacturors of mainframe computers include Digital Equipment Corporation, and Evans and Sutherland. Software packages are available from leading agencies such as Able Image Research and Wavefront Technologies.

Supercomputers:

A supercomputer is really a state-of-the-art mainframe capable of performing billions of calculations per second with hardware costs of up to $13 million. [3p18] There are relatively few supercomputers in existence and access time is both limited and expensive. Needless to say, it was not possible to gain access to such a system for use in this thesis project.

6.0

During the creation of Temporal Synergy I was faced with several obstacles. Developing the overall concept of working with multiple computer animation systems was the first, and probably the most difficult given the vast range of possibilities.

systems

Secondly, I had to decide on the systems and production methods which would be used (the limiting criteria are listed in section 1.0). The selected systems and software are listed below, and included is a list of problems and annoyances which I encountered while working with each package.

In the microcomputer category, I used an Apple II Plus with Koalapad and 64K memory running Fantavision animation software which features both keyframing and tweening capabilities. Some problems were that I had only a limited degree of control over animation speed, and that I was restricted to only eight colors.

The finished imagery was output to a Sony VO-5600 3/4" video recorder using an Arwad Progmod video card. In order to overcome the lack of control over the animation speed, this imagery was dumped several times at a variety of speeds so that I would be able to select the most appropriate sequences during editing.

In the expanded microcomputer category, I selected the Artronics PC2000 which allowed me a range of 256 colors, and animates using the color-cycling method. Fractal imagery was generated utilizing original software which I had developed as a side project. This raw material was later altered through standard Artronics PC Paint software. All imagery, fractal or otherwise, was subsequently animated using the cycle function of the PC Paint software. 6.0

The main problem which I encountered was, again, a lack of control over speed during color cycling. Although the Artronics offers more control over animation than the Apple, the fact that the speeds are controlled through numerical values input through the keyboard creates unnecessary calculation problems that could have been easily resolved by using the digitizing tablet to vary cycle speed in the same manner as it is used to alter color palette elements.

Artronics imagery was output to a Sony VO-5600 3/4" video recorder through a Lenco PCE-466 Color Encoder and CSL-710D Sync Generator.

In the minicomputer category, I utilized Genigraphics 100 Series computers which utilize the keyframe animation method and feature a variety of built-in rate curves. Each machine had extended artwork software which allowed for the manipulation of large numbers of objects, thus three dimensional space could be simulated with relative simplicity.

The main problem that I was faced with when working with these machines was that they were breaking down constantly which resulted in a drastic lack of access time. Another problem (really more of an annoyance) was that these machines became somewhat sluggish when manipulating a large number of objects. 6.0

Geni imagery was output to tape using the Genigraphics 100V editing console which utilizes a Sony VO-5850 3/4" recorder, along with a Lenco PCE-462 Color Encoder and a CSL-710D Sync Generator.

In the mainframe class, I utilized a Digital Equipment Corporation VAX 11/780 using CAST animation software version 2.3 on a DEC Gigi terminal. The CAST system is an amazing tool, capable of true three dimensional animation in both wire-frame and solid representation.

There were, however, problems with this system: both hardware and software related. On the software side, I was frequently disturbed by the fact that when I wanted to preview a section of my film, I had to look at the entire film and could not concentrate on that section alone. A related problem was that the length of regeneration time of complex images during these previews was up to five minutes per frame when using complex movements with extensive artwork. I was also annoyed by the lack of built-in rate curves.

As far as hardware problems go, I was most bothered by the fact that I was limited to a range of only eight colors by the Gigi-based CAST application which did not allow me to take advantage of the shading or multiple light source features within the software.

CAST imagery was output to 16mm Kodachrome on a Dunn Instruments film recorder. The filmed imagery was transferred to 3/4" videotape at the RIT Instructional Media Services center. 6.0

One of the most difficult obstacles which I encountered during the course of production was the selection of a musical piece to accompany the visual material. In order to narrow down the vast sea of possibilities, I outlined what I believed to be important factors for the piece to contain. **audio**

First of all, given that this was to be background music, I thought that the piece should be interesting, but not overpowering since I wanted the visual material to remain the strongest element. For similar reasons, I thought that the music should not be widely recognized since those watching the film may be distracted by a familiar song.

Since I wished to determine the final length of the film during the editing process, I decided that the song must also be instrumental, which would leave me the freedom to fade out the soundtrack at any time, thus an open-ended song would give me more control over the final length of the film. Finally, the music had to reflect a mood which I wanted my film to project-- obviously a personally subjective choice.

Due to various equipment failures, I was finally ready to edit my piece two weeks behind schedule. To complete this great task, I utilized a Sony 3/4" editing station with capabilities for the direct input of stereo sound from cassette. **editing**

To begin the procedure, I recorded the open-ended soundtrack to the videotape so that I would be able to cut the imagery to the music. When this was finished, I inserted the visual segments following the plan which I had laid out in my storyboard. Next, I previewed the piece in order to pinpoint any rough spots in the continuity. I then went back and smoothed these spots over by inserting visual material. Finally, when I was satisfied with the visual content, I went back and re-taped the audio track, fading it out at the appropriate time. 6.0

stills

Usually one thinks of stills as being shot from a finished film, however given my limited time schedule, I was forced to shoot the stills for Temporal Synergy several weeks before the actual sequence was completed. Inevitably, this meant that I had to shoot stills from all of my animated stock, and wait until the film was completed to select images from the sequences which were utilized in the finished piece.

Stills from Artronics and Apple sequences were shot off-the-screen with a 35mm camera using a telephoto lens in an attempt to reduce screen curvature. Admittedly, this is not the most desireable method (it is both time consuming, and inaccurate) however it was the only method available.

CAST imagery was shot with a 35mm camera attached to the same Dunn film recorder which was used to shoot the animated imagery. This was not only more convenient, but also more accurate than shooting from the screen.

Genigraphics imagery was shot on a 2000 x 2000 line film recorder attached to a 100D Plus console. The results obtained using this system were definitely the best quality of all the images. 6.0

Since all stills were recorded on Kodak Ektachrome slide film, 3 x 5 prints were made for the exhibition using the Kodak R process direct slide to print method.

thesis film: concepts

6.1

As previously stated, Temporal Synergy is experimental in nature, and explores the conceptual elements of color, shape, and motion set to music. At best, I can only attempt to convey some of the concepts behind the piece.

As the film begins, there is a strong, steady beat from the soundtrack and a dot moves across the screen corresponding to the beat. This imagery and that immediately following (a line traveling in the opposite direction, then dot and line passing through one another) are reminiscent of video displays common to technical machinery used for measurement, such as is found in hospitals or television repair shops. The beat could be analagous to a heartbeat, or life.

As the imagery progresses from dot to line to combination, there is also a building progression of elements in the background: first a spatial environment, then a grid, then a 3D grid. Originally, this progression was only meant to add visual interest, however in the finished piece it does seem to communicate a "building concept".

As the rhythm guitar enters the soundtrack, the titles begin to appear from top to bottom, as opposed to the side to side motion in the previous sequences. Originally, I had intended to create the opening titles on the Apple, however the animation was too jumpy to correct during editing and the type quality was atrocious, so I ended up using the Genigraphics system. The elements have a drop shadow, continuing the dimensionality of the previous scene. The action progresses with the music, the titles fading from top to bottom in the same manner that they appeared.

Next, a cell-like structure appears on the screen and begins to divide (fig.1). Again, this is symbolic of life, more specifically the beginnings of life. When the screen is filled with these cells, the viewer is pulled through the structure and into the next scene. 6.1

In this sequence, atoms fly together to form a structure (fig.2). The resulting molecule begins to pulsate in an up and down manner. To me, this is another manifestation of synergy, where the elements combine together resulting in a creation which is greater than the sum of the parts.

In this and a similar sequence, the molecular structures were chosen purely on the basis of form. The fact that this is a methyl alcohol molecule has nothing to do with the content of the film. I suppose that on the outside chance that someone knew that this was a methyl alcohol molecule, they might subliminally make the connection that this substance is poisonous and therefore relate it to death, which would simply add another level of meaning to the film.

In between the fluctuations of the molecule, we begin the transition into the next series of sequences when we cut to a three dimensional structure. Within the structure, a dot fluctuates in a sine wave similar to the motion of the previous molecule. We cut back to the molecule in motion, and then to the same structure, which now holds a line that pulsates in the same sine pattern. Finally, a combination of dot and line to complete the series, and the similarity to the first series of instrument-like imagery.

The next sequence is another "molecular construction" and relates back to the first. The horizontal motion continues as atoms slide in from opposite sides and meet in the middle to form the core of the molecule along the x-axis. Next, the arms of the molecule are formed as more atoms slide in alternately from the y and z directions. Finally, the completed molecule slides off to the right to end the sequence. Again, the fact that this is a butane molecule was simply related to the visual structure. 6.1

In the next sequence, two pyramids approach each other, again horizontally, from opposite sides of the screen (fig.3). They are also opposite in color, one red and one green, to emphasize that they are opposing forces.

As they move together, a column of dots descends. They are in groups of three, each orbiting around a common center to suggest orbits of electrons around the center of an atom. Though each element of this column is in motion, the overall structure remains stationary throughout the sequence, and serves as a reference point as the camera begins to move.

When the pyramids meet in the center of the screen, they stop abruptly, as if they have collided. They spin back and forth as if to get by one another. They stop for a second, and the green pyramid spins so that it is no longer aligned with the red one. Slowly, they begin to pass through one another as the camera begins to move around to the back of the action. Finally, they pass through one another, the green pyramid rotates back to its original orientation, and the figures continue on their way horizontally off the screen.

This sequence was meant to say something about cooperation: that two opposing entities can overcome a common problem with a slight adjustment. It was also somewhat of a visual experiment in order to determine the effect of passing a solid through a solid on the CAST system. 6.1

The next sequence begins with two triangular planes, similar in both form and color to the elements in the previous sequence, approaching each other from opposite corners of the screen. Again, this is largely a horizontal movement.

They speed toward each other and spark when they meet in the center (fig.4). They perform several orbits around their common center point, and then fly off in opposite directions, one up and the other down. Again, this sequence has much to do with cooperation, as well as attracting and opposing forces.

There is a combination of vertical and horizontal motion in the next sequence which corresponds to that in the previous one. To begin, a grid of dots slides in horizontally, and then expands toward the viewer in 3D as wire-frame boxes descend from above. They fall through each other, each new box larger than the previous one, and eventually form a pyramid structure (fig.5). For a change of viewpoint, we move above the structure, the elements begin to spin differentially around the center point (fig.6). As the elements come to rest, we travel down the side of the pyramid and into space.

In the next set of sequences, we encounter a number of abstract patterns which move in different directions: outwards from the center, from side to side, pulsating and stationary (figs.7,8). 6.1

These sequences are visually very different from all of the previous imagery and were meant to present a mystical quality which is difficult to put in words. Perhaps these are images which are found in deep space, or in the recesses of the human mind.

In the final sequence, we are confronted with patterns converging from all sides of the screen (fig.9). The patterns meet to form a single unit field. Elements expand and change to form a distorted 3D space. Elements fade leaving a field of squares which tilts back into space (fig.10). Spheres drop and lodge in the field, which tilts up to form another pattern (fig.11). The pattern fades leaving a single sphere which grows to fill the screen. The sphere is stretched out to its limit, it snaps back and explodes in all directions. Finally, the closing credits begin to form from elements flying onto the screen, as if they were pieces of the exploded sphere.

The last sequence has to do with elements in harmony and disharmony, cooperation, and tension.

6.2

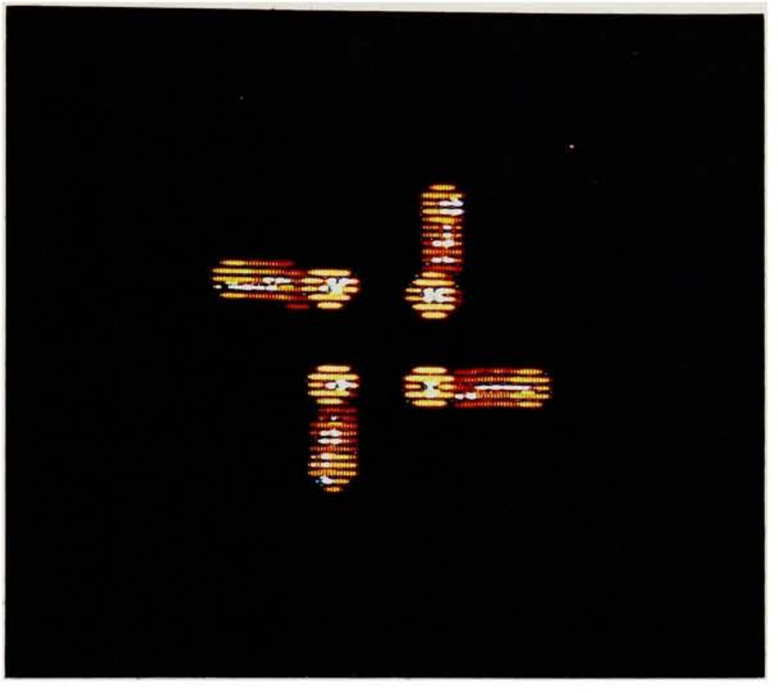

figure 1
cells
Apple II Plus

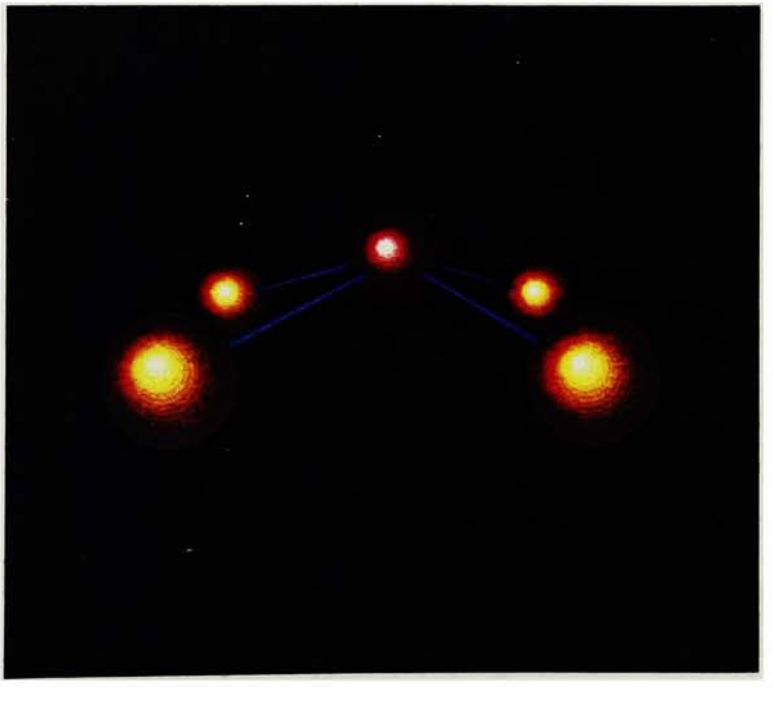

figure 2
methyl alcohol
Genigraphics
100 Series

6.2

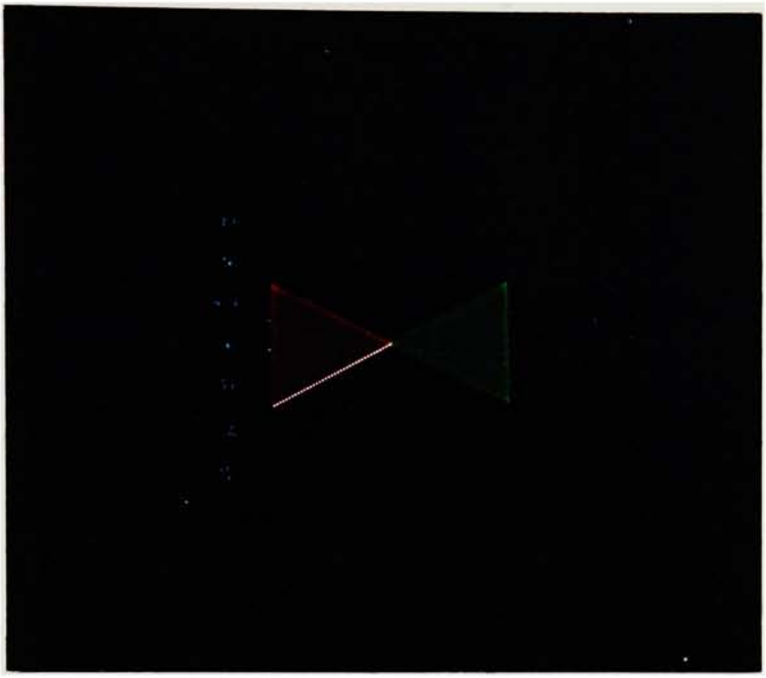

figure 3
pseudofusion
DEC VAX 11/780

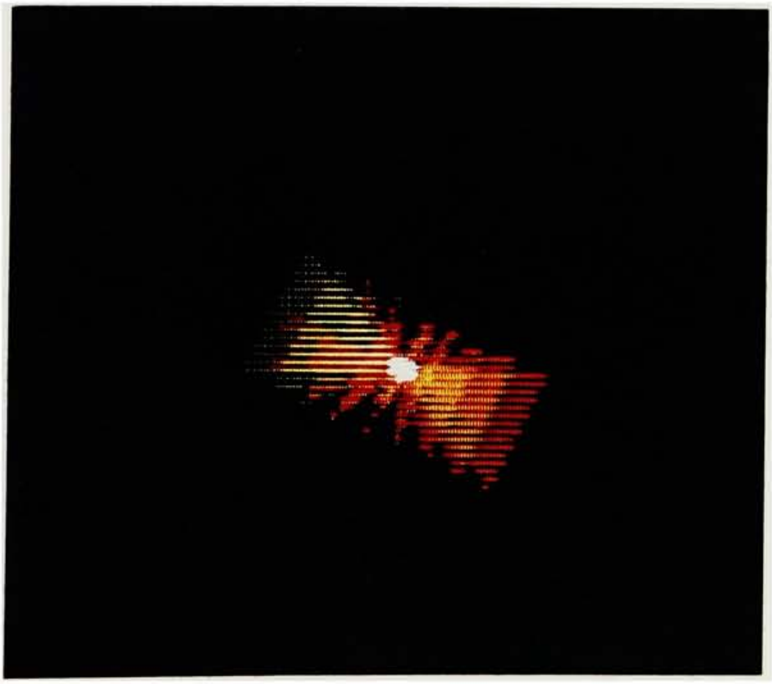

figure 4
co-orbitation
Apple II Plus

6.2

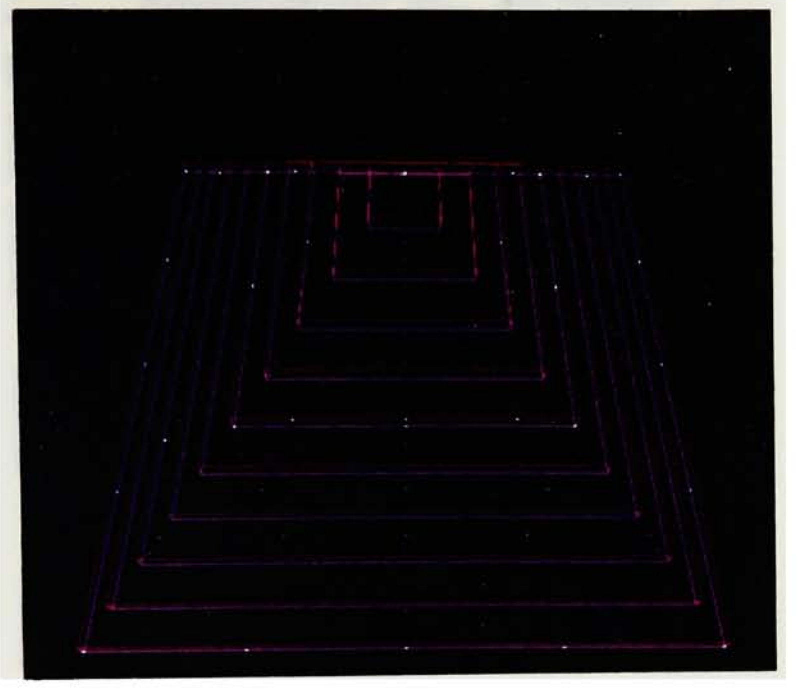

figure 5
pyramid
DEC VAX 11/780

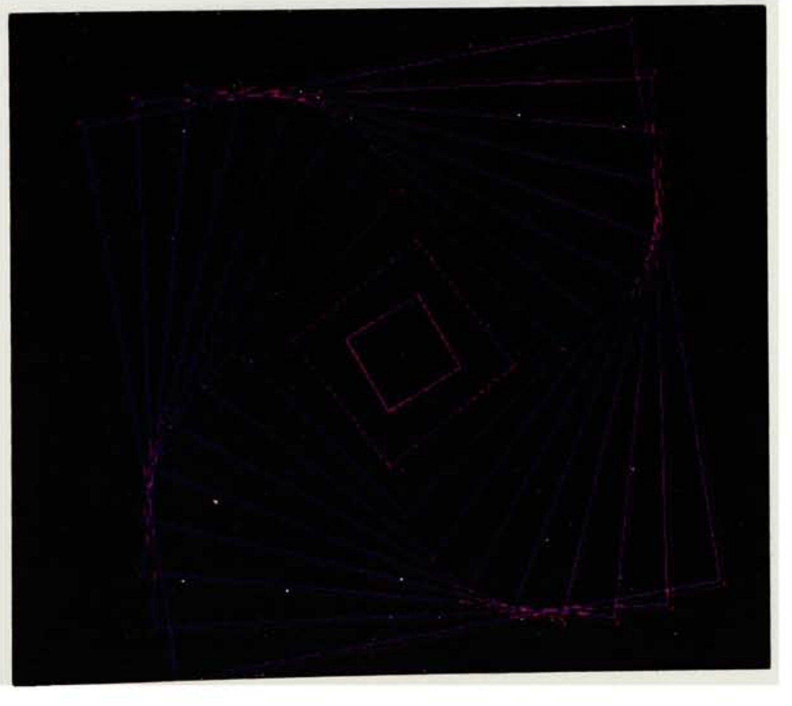

figure 6
differential rotation
DEC VAX 11/780

6.2

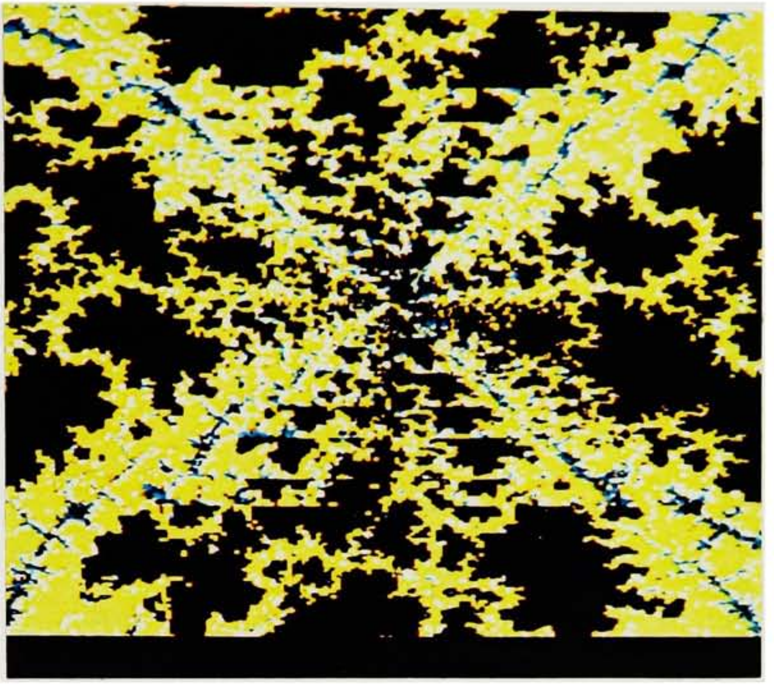

figure 7
fractal implosion
Artronics PC2000

figure 8
fractal wave
Artronics PC2000

6.2

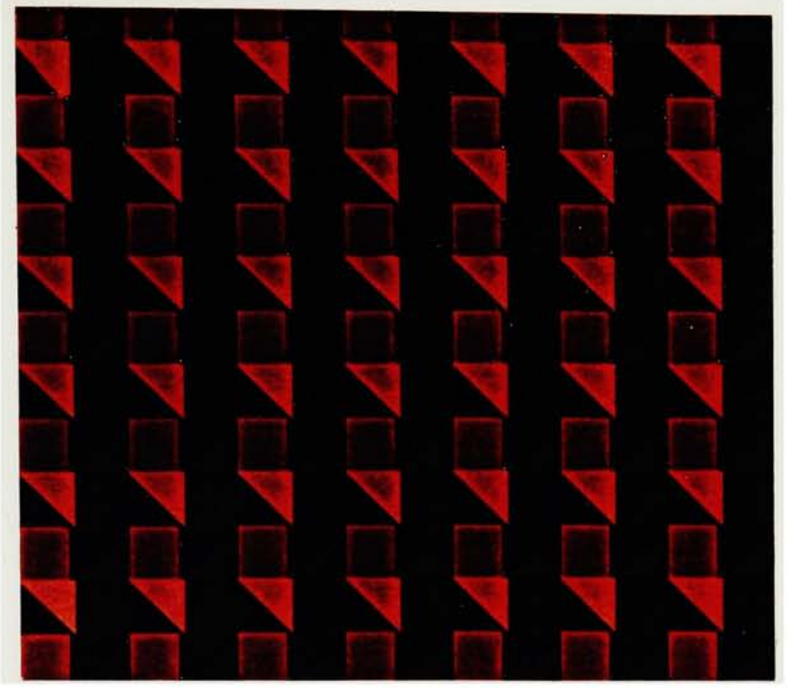

figure 9
intersection
Genigraphics
100 Series

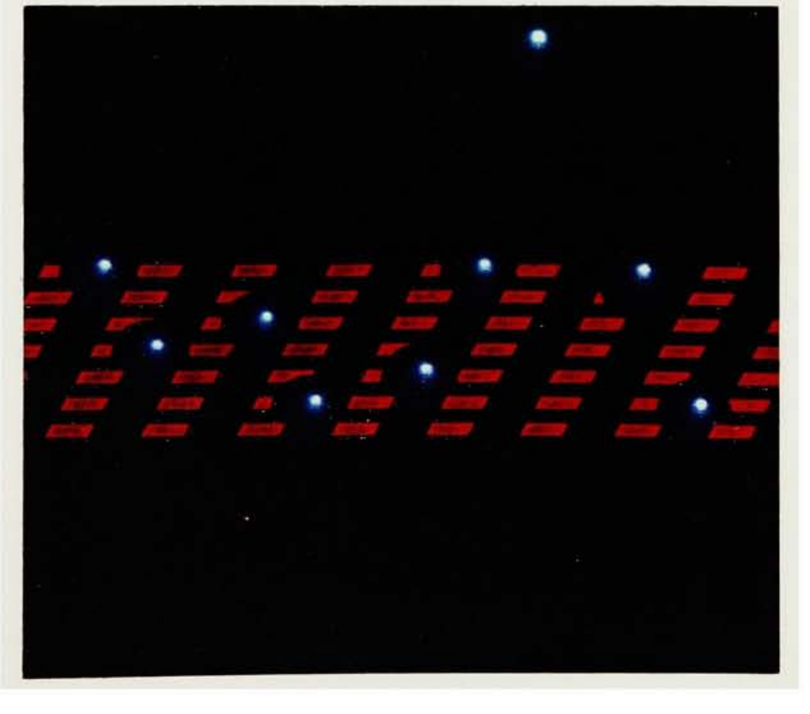

figure 10
combination
Genigraphics
100 Series

6.2

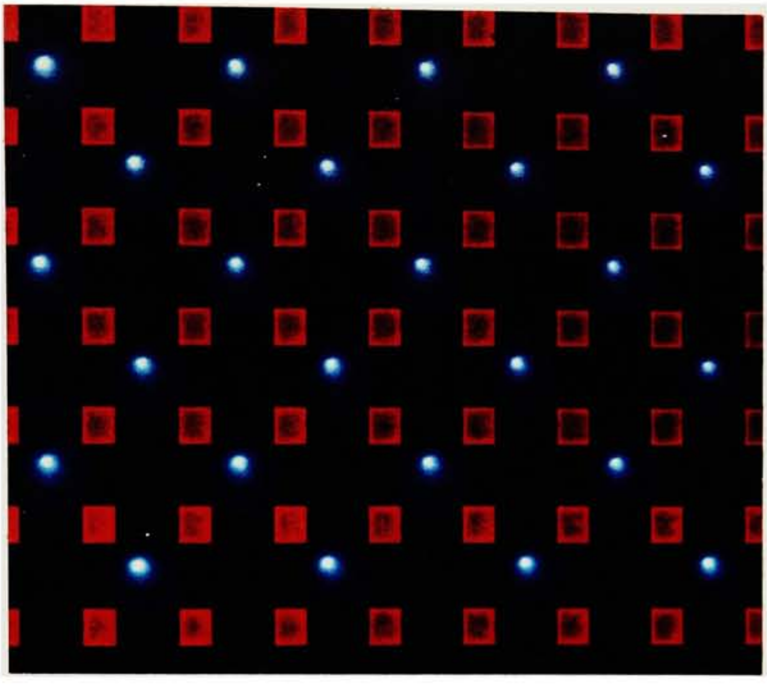

figure 11
tension
Genigraphics
100 Series

6.3

Temporal Synergy, in its finished form is meant to be, and hopefully will be, viewed and interpreted on several levels. On the surface it is an interesting visual piece-- a conceptual music video. On another level, it can be seen as a working study of various computer animation systems. Ultimately, it is something to be contemplated by each viewer individually-- a self-administered moving free association test.

I believe that the finished piece fulfills both the technical and conceptual guidelines established in section 1.0 of this paper.

problems and questions

7.0

This section of my paper presents some of the problems and questions which I have encountered dealing with the field of computer graphics in general. They are things to think about, and possibly topics for future thesis projects.

Standardization of Industry Hardware:
The most pressing problem facing the computer graphics industry today lies in the area of hardware standardization. Standards for color displays and output peripherals, such as printers and film recorders must be established and followed. This is a serious problem when one wishes to compensate for differences between original computer generated imagery and output reproduction. Indeed, this proved to be a major problem during the production of my thesis film: when imagery was output to videotape, it often appeared drastically different from the original artwork.

Applications of Computer Graphics:
One aspect of computer graphics which interests me is the idea of exploring the different applications of computer generated imagery. This could be expanded into the area of experimental computer graphics, as well.

Ergonomics:
A problem inherent to computer graphics workstations is their usability. Studies of user comfort, and ease of use of machinery are becoming more necessary as the number of computer graphics users increases.

Some studies should also be made into the physical effects, if any, of computer hardware, such as display screens on the user.

8.0

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approvals

9.0

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