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COMPUTER GENERATED ANIMATION AND MOVIE PRODUCTION AT LARC: A CASE STUDY

R. L. Gates
C. G. Matthews
W. H. von Ofenheim
D. P. Randall
K. H. Jones

COMPUTER SCIENCES CORPORATION
Hampton, VA 23666

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National Aeronautics and
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Langley Research Center
Hampton, Virginia 23665

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INTRODUCTION

The animation of kinematic processes and the dynamic visualization of computer generated space station and transportation models and large space antenna structures are receiving increased attention in research being conducted by the Systems and Experiments Branch of the Space Systems Division at the NASA-Langley Research Center (LaRC). This is illustrated by Nazemetz, et al. (1), Gates and von Ofenheim (2), and DeRyder, et al. (3), all of whom cite recent project work sponsored by LaRC in these areas.

In each case, the MOVIE.BYU software package (4), developed by Brigham Young University (BYU), has been utilized for such tasks as viewing solid models and for animation of the models to depict, for example, the deployment of a large space antenna or the resupply operation of a conceptual space station configuration. In addition, they each employ the LaRC Digital Display/Film Writer System to record animation sequences on 16mm film, and require services from the Photo/Graphics Branch of the Research Information and Applications Division.

Generally, these projects and many others use similar procedures from preparation of the model to production and development of a 16mm film. The entire process is relatively new at the Center and continues to evolve. The production of each film has identified problem areas in the movie production facilities. These include, for example, limitations in both the operating system and applications software, inadequate hardware, and operational constraints. Short-range solutions to many of these problems have been derived, and long-range solutions are being formulated as experience and knowledge are increased. Since film is becoming a more popular output medium at the Center, documentation of the process, problems, and solutions will benefit many future users. The intent of this report is to meet that objective.

OVERVIEW OF PROCESS

Figure 1 depicts a general overview of the movie-making process beginning with generation and/or enhancement of the geometric model. The Solid Modeler Program (SMP) (5), developed by Computer Sciences Corporation, and the MOVIE.BYU package are listed as specific examples of tools which may be used to either enhance or generate all or part of a model.

With a specific model "in-hand", the animator then proceeds to construct an illustrated script, or storyboard outlining the kinematics to be modeled. Key frames are generated next both as vector images and as continuous tone images. The vector images primarily provide a quick "snap shot" of the rigid body motion changes at various locations in the animation sequence. Continuous tone pictures enable the animator to experiment with and preview factors related to color, shading, and light sources. Key frame generation is accomplished by the MOVIE.BYU DISPLAY program in most cases.

"Inbetween" frames are generated next, again using the MOVIE.BYU DISPLAY program. These inbetween frames define the remainder of the rigid body motions to be performed. The number of frames produced is a function not only of the kinematics being

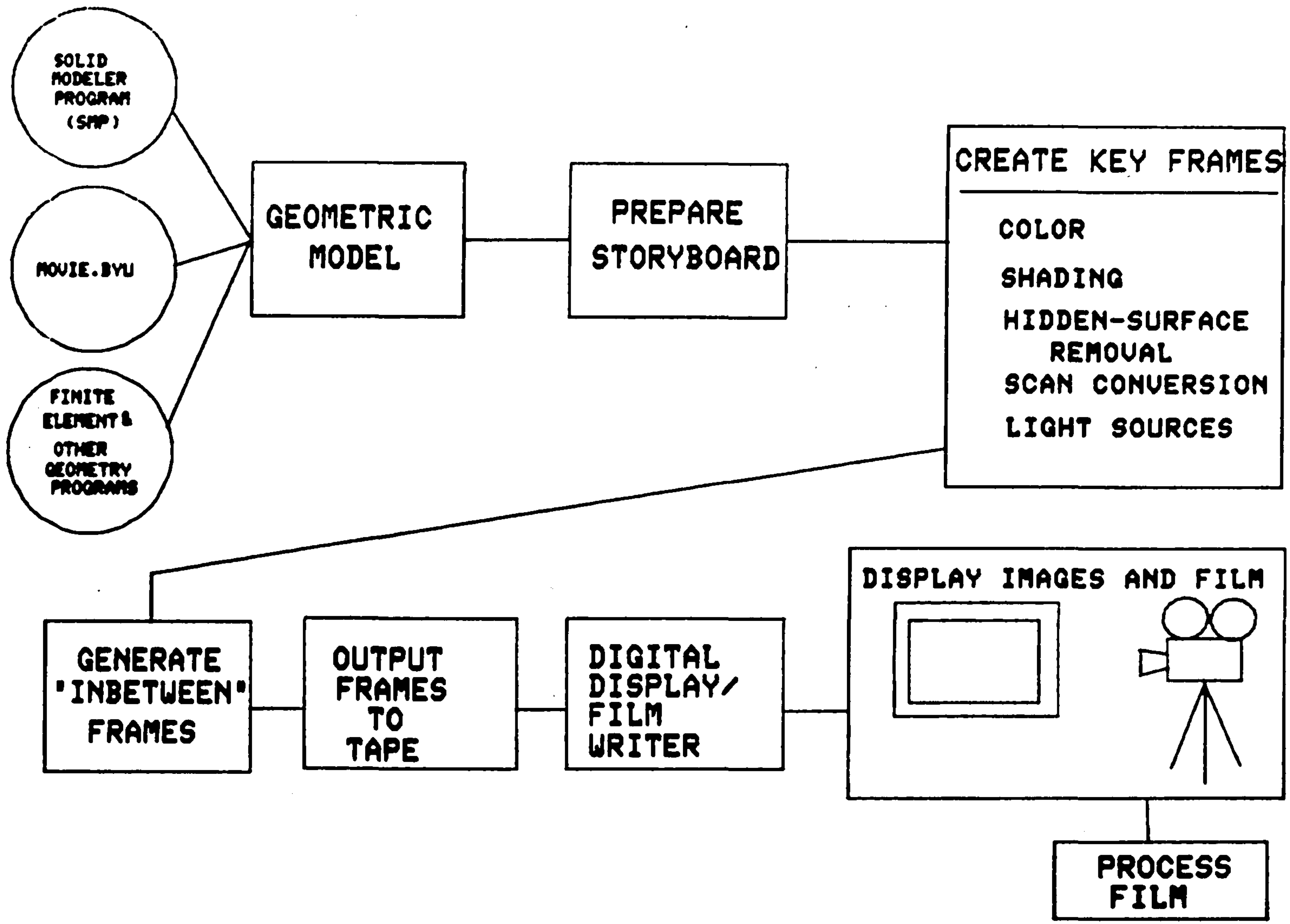

FIGURE 1: GENERAL OVERVIEW OF THE MOVIEMAKING PROCESS

modeled, but also such factors as the desired smoothness of the motion and the time span over which the sequence is to occur.

Geometry representing two- and three-dimensional character strings may be generated with the MOVIE.BYU title generation program known as TITLE to create movie titles and credits. This geometry may then be displayed like any other model with the DISPLAY program to produce movie frames.

Once the movie frames or images have been previewed, they are output to magnetic tape and displayed on the Digital Display/Film Writer System. The recording of the images on 16mm film is accomplished with a 16mm movie camera linked to the Digital Display/Film Writer System.

In the next sections, the process of filming an animation sequence will be described, beginning with a description of the geometric model, and concluding with delivery of a 16mm film. The specific application illustrated depicts the kinematic modeling of a space shuttle docking with a space station configuration and the resupply of life support systems aboard the station. Figure 2 shows a vector image of the space shuttle model "docked" with the space station model. A discussion of the problems encountered in each step then follows. Short- and long-range solutions are noted in each case. Conclusions and recommendations are summarized in the final section.

DATA DESCRIPTION

The geometric model representing both the space shuttle and the space station in a fixed orientation was obtained from Johnson Space Center (JSC) for use in this application. The

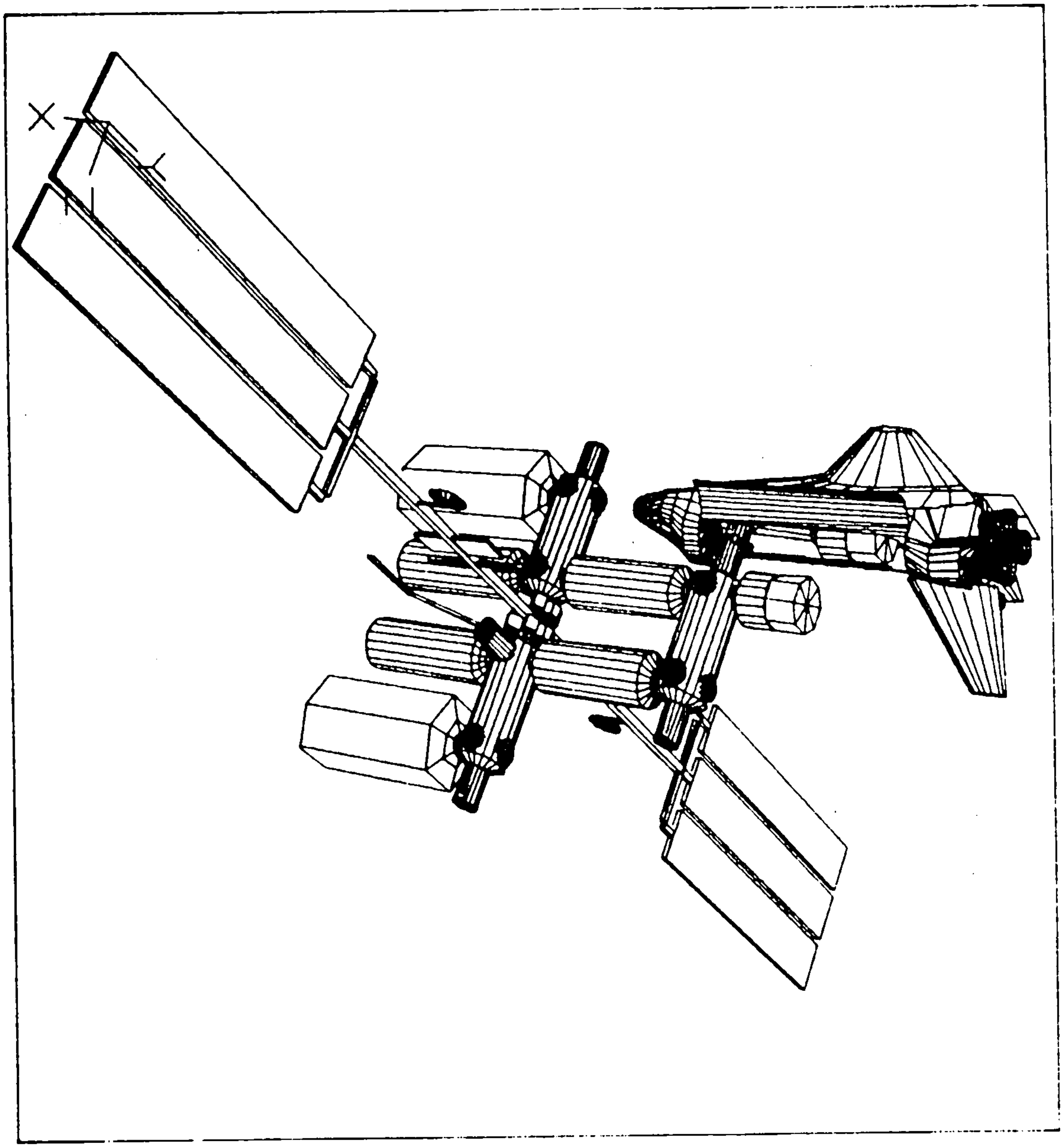

FIGURE 2: VECTOR IMAGE - SPACE SHUTTLE DOCKED WITH SPACE STATION

geometry data was received in Hypersonic Arbitrary Body (HAB) format (6) which consists of geometric entities organized into points and cross-sections. A locally developed processor converted the HAB format to the MOVIE.BYU compatible format which again consists of geometric entities (parts) comprised of points and information describing the connection of the points to form polygonal elements (faces).

The HAB format allows cross-sections to be defined in any given direction, which presents difficulties when attempting to maintain a consistent clockwise (or counter-clockwise) orientation for visible faces. The ordering of the faces is important for the application of a back face cull algorithm which determines the normal of a face (based on the order of the points) and discards the face when the normal points away from the observer. In the application described here, utilization of the back face cull algorithm in MOVIE.BYU could have reduced compute time significantly by reducing the computations necessary to eliminate hidden lines or surfaces from an image.

With conversion from HAB to MOVIE.BYU format complete, the model was ready to be displayed. The MOVIE.BYU DISPLAY program produced a vector image for this purpose. Several modifications to the data were implemented to improve the model, including the removal of parts. The shuttle, for example, was removed from the geometry data via the PRIME editor. Additional parts such as the Remote Manipulator System (RMS) and the Extra Vehicular Activity (EVA) docking tube were constructed using the Solid Modeler Program. A new shuttle, already represented in MOVIE.BYU format, and the other generated parts were then merged with the JSC model using the MOVIE.BYU UTILITY program with appropriate translations and scale values.

The relative difficulty in modifying a model is a function of how effectively the geometry of the model is subdivided into components. In the case of the JSC model, several model components could not be referenced directly because they were embedded in other geometric entities. This difficulty was overcome only by forcing one individual to become unnecessarily familiar with the JSC model. The SMP software provides for the easy generation and manipulation of primitive parts (spheres, boxes, cones, paraboloids, tori, and rotationally and translationally swept parts) and the conversion of these parts to a MOVIE.BYU compatible format.

Several other related problems were encountered before the final model was completed. The first arose from a limitation in UTILITY - the inability to perform rotations or pivots while merging geometry data. A pivot (local rotation) of the space station was required to align the space station with the space shuttle model. Related to this was the problem resulting from the inability to save transformed geometry data in Version 4.0 of MOVIE.BYU. This meant that the pivot was required each time the model was displayed.

Another problem related to pivots with the MOVIE.BYU software was its inability to process multiple pivot points for a single part. The resupply operation depicted in the DOCKING AND RESUPPLY OPERATION movie required the shuttle doors to open -

pivot about their own hinge lines. Once the doors were pivoted, the entire shuttle model could not then be pivoted, for example, about an exterior point to align the shuttle with the space station model. The dual problems of multiple pivot points and saving transformed geometry data were solved with the development of the "geometry generator" program which will be discussed in a later section.

STORYBOARD PREPARATION

Three-dimensional animation by computer involves three steps. The animator must first obtain or create a data base describing the scene to be simulated. Spatial transformations must then be applied to the scene to produce the animation. Finally, the images are displayed using hidden surface and other display techniques for visual realism. These steps, however, are prefaced by the preparation of a "storyboard." A storyboard is an illustrated script - a sequence of pictures outlining the action to be displayed. This storyboard keys the visual aspects of the animation to the script.

A storyboard is constructed by the animator from a sequence of key frames, each defining precisely the sequence and appearance of actions to be shown in the movie. Note that computer costs and production time constraints are both factors to consider when preparing a storyboard. Once the storyboard has been created, the process of "filling in" the spaces between the key frames, or "inbetweening" can begin. (7,8)

PRIMARY KEY FRAME GENERATION

Rigid body motions may be accomplished through pivots, translations, rotations, or explodes (local translations), or through any combination of these actions. Commands are provided in the DISPLAY program for this purpose, and are used to orient the model to the desired view. For each animation sequence, vector images of the initial and final frames - the primary key frames - should be prepared. This ensures that the commands chosen produce the desired effect.

Although the DISPLAY program has facilities for performing the rigid body motions, the user interface results in a procedure based on "trial and error". The local and global transformation parameters are entered from a keyboard and then the model is displayed. This procedure is repeated until the proper view is obtained. A more attractive interface would provide the animator with the "real time" manipulation of the vector image controlled via a collection of interactive input devices. The output from such a procedure would be the resulting transformation parameters.

Once a satisfactory set of vector images is complete, the production of computer generated raster images representing the solid model can begin. At this point, each key frame has been rotated or translated to the desired orientation and viewed as a vector image on a vector device such as a TEKTRONIX terminal.

Each key frame will be generated as a continuous tone picture via the same sequence of steps using the MOVIE.BYU DISPLAY program. The first step that will be addressed is selection of a light source and its associated parameters for the various parts of the model. The light source may be located at the eye of the observer, at infinity, or at some user-specified position in 3-space. In addition, the regular light exponent and the highlight intensity and exponent may be specified for each part in the model. These exponents define the power to which the cosine is raised as a factor of the displayed intensity, either between the light source vector and the normal to the element in the case of the regular light exponent or between the reflected light and the direction to the observer in the case of the highlight exponent. These options are defined with the LIGHT command provided in DISPLAY. [Note that light must be specified if a continuous tone picture is desired. Highlights are optional].

The same light source vector may be used in more than one animation sequence. This is the case, for example, if the intent is to simulate observer rather than object motion. The key frames for these sequences should be previewed to ensure that the parameters selected are suitable throughout.

The next step in the creation of a continuous tone picture is the definition of the colors to be assigned to the subjects in the picture. The decision to produce a color versus black and white film must be made at this time. Color can add realism to the image but adds to production time.

Whether the decision is black and white or color, color parameters must be defined for the background and the various parts of the model. If a black and white display is selected, the background intensity and the intensity of each part are specified. If color is chosen, the background and part color component intensities are entered. Definition of these parameters is accomplished with the COLOR command provided in DISPLAY.

The computation resolution for the Watkin's algorithm (9) which computes the visible segments also controls the realism and quality of a continuous tone picture. This variable is defined in the SCOPE command in DISPLAY and is picture dependent. In the application described here, a value of 1024 was used throughout, although the maximum value for the raster devices available was 512. A value of 1024 causes an averaging technique to be implemented which reduces the effect of aliasing. While the cost difference associated with the additional computations required in averaging was negligible in this application, it may be a consideration if a more complicated model were used.

Various shading commands are also provided in DISPLAY to allow the user to vary the color intensity across an element. Gouraud shading, which assumes linear variation in the light intensity between any two points on the element boundaries, is used to compute all color intensities except at the element corners. Three different types of shading - flat, smooth, and uniform - may be selected by the user, each of which has been implemented in DISPLAY as a variation of the Gouraud algorithm. Uniform shading defines all color intensities at the element corners to be the same value. Flat shading varies the light intensity across an element, but generally, the intensities will not match at the element boundaries. Smooth shading provides curved surface simulation by having the light intensity match at element boundaries, causing the boundaries to disappear.

ANIMATION

A continuous tone picture should be previewed for all primary key frames before proceeding to the next stage in the movie-making process, which is the generation of secondary key frames - the first step in the actual animation of the model. Secondary key frames serve to "fill-in" the gaps between the initial and final primary key frames in a sequence by defining the rigid body motions to be performed along the way.

DISPLAY's ANIMATE command allows the user to specify animation parameters for a sequence of frames which represent the desired motion. The user may specify any number of frames, for example, or which frames are to be displayed, or whether the animation steps are to be smooth or uniform. Customarily, when previewing secondary key frames, only a quarter of the actual number of frames to be generated are displayed. Additionally, the previewing is of vector images instead of continuous tone pictures since they are not only faster and cheaper to generate but are quite sufficient for this purpose.

While many types of motion can be accomplished with the MOVIE.BYU software, there are some restrictions. A program referred to as the "command file generator" was written to provide application specific capabilities which could not be provided by DISPLAY. These capabilities are outlined in the following paragraphs.

Light source calculations in DISPLAY are based on the location of the observer. Consequently, light source motions are not possible. This capability was included in the command file generator. Additionally, the ability to define initial/final translation and explosion values, order independent rotations, accelerating/decelerating motion, and the animation of a shift of the viewing window in the plane of the display device were included.

A second processor known as the "geometry generator" was written to allow multiple pivot points for each part, which were especially critical to completion of the arm sequences depicted during the resupply operation as illustrated in figure 3. The geometry generator reads a geometry file in MOVIE.BYU compatible format, provides an interactive display for performing multiple pivots, and outputs the transformed MOVIE geometry file. The initial and final geometry files are then input to the UTILITY program which creates a displacement file defining the linear distance between matching points on each file. The initial geometry file and the displacement file are input to DISPLAY where the ANIMATE command performs the linear steps necessary to generate the sequence.

One problem with this technique is that the resulting motions are linear in nature. Curved motions that are mapped to linear motions cause the shape of a part to become distorted. This problem is reduced by subdividing curved motions into nearly linear segments and generating displacement files between these segments.

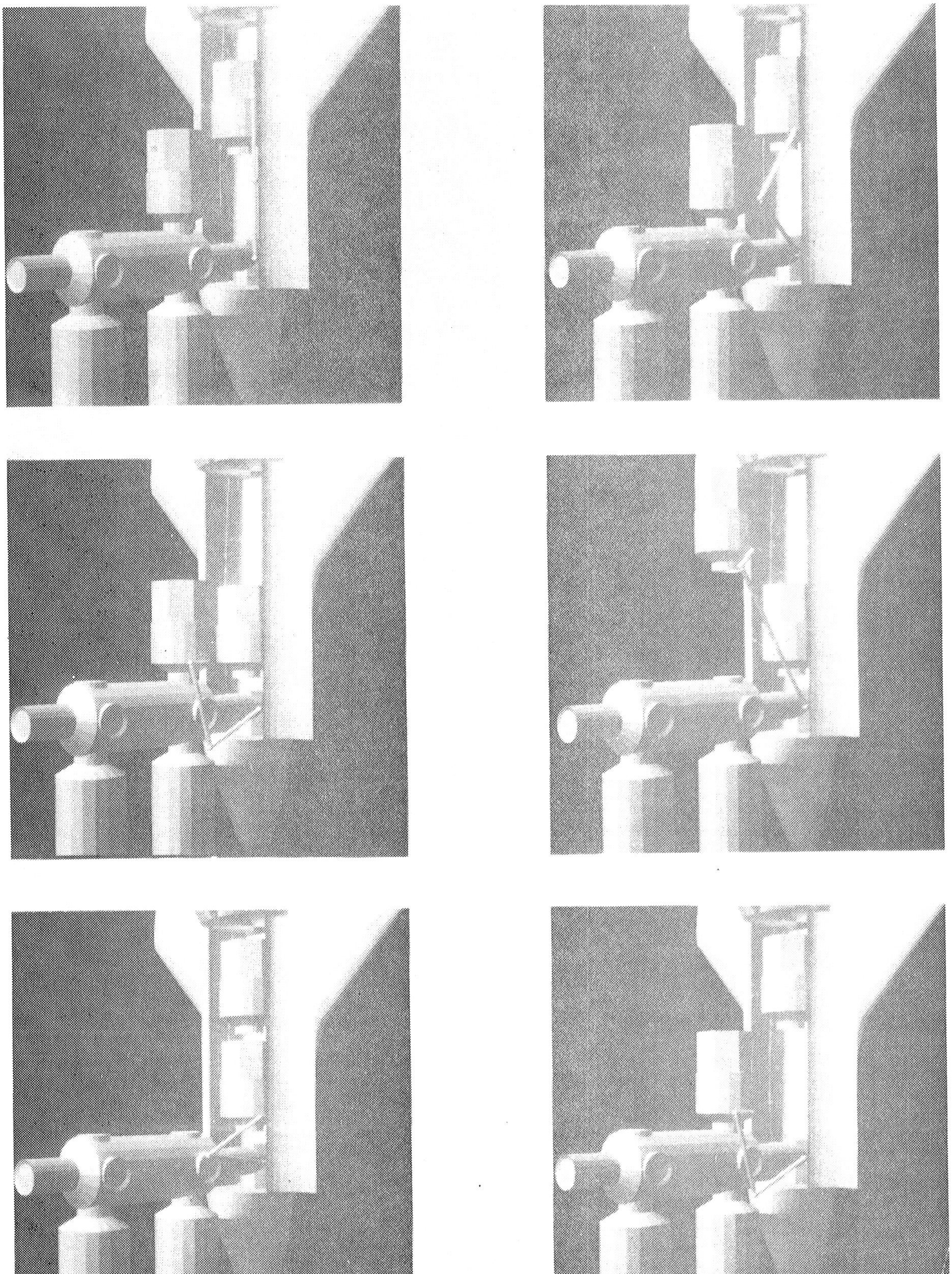

FIGURE 3: RASTER IMAGES DEPICTING RESUPPLY OPERATION

Once the animation sequences have been previewed and deemed acceptable, each frame represented by a raster image is recorded on magnetic tape. The LaRC implementation of MOVIE.BYU (version 4.0) provides a TAPE device in the SCOPE command of DISPLAY which writes each image to a user-specified magnetic tape in a format compatible with the Digital Display/Film Writer System. Currently, the Digital Display/Film Writer System is an off-line system which can only read data previously recorded on magnetic tape.

TITLE GENERATION

MOVIE.BYU provides an easy to use, interactive title generation program, referred to as TITLE, which creates the geometry representing two- and three-dimensional character strings. This geometry is in a format compatible with that which DISPLAY expects.

The format or layout of a title frame should be decided upon before TITLE is executed, since the user is prompted for not only the alphanumeric character strings, but also the height, width, depth, and spacing of the individual characters. In addition, the x-, y-, and z- coordinates of the lower left edge of each line of text must be specified. The titles should be fairly large in size and clearly legible.

Scrolling titles were generated during the experimental stages of movie-production for this application. Static title frames were later generated and found to be more visually appealing by the audience. This was partly attributed to the fact that the title frames were filmed at 12 frames per second which caused the sensation of "jerkiness" as the titles scrolled, making them difficult to read. Three-dimensional titles were also prepared during the experimental stage of movie-making, but were found to be difficult to read and more time-consuming to generate.

When deciding how to film the title frames, it is necessary to consider the amount of text on each frame. By selecting the length of time, as measured in seconds, that each frame is to be displayed, it is easy to compute the number of movie frames to film as noted in the following section.

It should be noted that MOVIE's title generation software is only one means of producing movie titles. Software may be written, for example, which takes advantage of the character fonts available with either the LRCGOSF (10) or NCAR (11) routines. In addition, titles may be prepared locally on the Dicomed. The MOVIE software provides advantages over the other techniques in that the software already exists and is easy to use.

FILMING

The filming of the individual frames of a motion picture is directed by personnel from the Analysis and Computation Division (ACD). This process involves the display of each movie frame on the digital display system and the subsequent filming of each frame with a camera linked to the system.

The LaRC Digital Display/Film Writer System consists of a 512 x 512 color raster display, a DICOMED D-47 film recorder, a local processor with alphanumeric terminal, and a tape drive. Commands to the system are entered at the alphanumeric terminal which allow the user to display, modify, and output images. The motion picture camera used to film the individual frames is linked electronically to the system and is controlled by the Digital Display System software. The motion picture camera is placed approximately six feet from the display surface and then the image is framed and focused. The actual set-up of the camera, including film loading, is handled by personnel from ACD.

At this point an important decision must be made concerning frame replication. The generation of a single movie frame is an expensive operation with respect to resources utilized. For example, to generate a one-minute movie filmed at the standard rate of 24 frames per second, 1440 frames must be generated. When each data frame is replicated twice to produce 12 movie frames per second, it has been observed that the sensation of "jerkiness" is minimal. The same one-minute film would require only 720 frames in this case. This replication of data frames is economically efficient when possible. Replication factors of above two can lead to noticeable jerkiness but may be acceptable for certain sequences, such as small movements of a model, in a motion picture.

The optimal replication factor for a particular sequence, however, cannot easily be determined with the current available technology. Some type of animation preview capability would prove useful for this purpose.

PROCESSING/DEVELOPMENT

Film processing is the final step in the movie production process. LaRC Photo/Graphics Branch personnel process the film and perform the necessary editing operations, including splicing. This procedure is extremely critical in that movies may be produced in several stages and these separate stages will need to be edited into one complete motion picture.

HARDWARE PROBLEMS/PROPOSED SOLUTIONS

The current method for creating key frames begins with a conceptual image of the model's orientation. Estimates of the numerical transformation values required to obtain the orientation are then entered, and finally the computer-generated image is displayed. If the computer-generated image does not represent the conceptual image, the process is repeated with new values until the images match. The problems with this process include the determination of absolute numerical values by an "educated guess" method, and the subsequent display time delay to verify that the guess was indeed correct.

Both problems may be solved by an interactive display system which performs dynamic motions, such as the Evans and Sutherland Multi-Picture System. This system includes valuators which could be programmed to perform rotations and translations, thereby replacing numerical estimates with incremental changes of a dial. With the dynamic motion capability, the transformed model could be regenerated at near real-time speeds, depending on the complexity of the model. Once the final orientation of the model had been achieved, a processor could convert the transformation matrices, created through manipulation of the valuators, to MOVIE.BYU commands, thus completing the automation of a previously cumbersome process.

The process of recording images on magnetic tape and displaying the images on a CRT monitor for subsequent filming creates four problems. The first problem is the "processing speed", i.e. the amount of time required to generate an "image" and store the "image" on tape. The second problem is the large amount of resources necesssary from CPU time and memory to disc and tape space. The third problem concerns the absence of a facility to preview the animation sequences at film speeds prior to filming and, finally, filming from a monitor rather than recording directly on film. The solutions to these problems may lie in the new video disc recording technology which provides read and write capabilities with a dedicated computer and/or graphics workstation. Since an entire movie could be stored on one video disc, the storage problem would be eliminated. A processor could be written to control the order and rate at which images are displayed, thereby ensuring smooth motions and proper interfaces between sequences prior to committing them to film. A link between the video disc recorder and a film recorder such as the DICOMED D-47 would eliminate the possibility of external light reflections from the monitor's screen.

There is a need for an economical method for using or simulating a 24-bit frame buffer. Currently, MOVIE.BYU uses 24-bits of color but the DICOMED can only handle 8-bits so the 24-bits are mapped into 8-bits with a corresponding reduction in color clarity. One means of obtaining 24-bits of color is to write out each image three times to tape for the red, green, and blue color tables. This method increases the amount of processing and storage several times, plus the movie processing command on the DICOMED would be rendered useless. An alternate method would be to use a system such as the DeAnza which is 24-bit color compatible.

SOFTWARE PROBLEMS

As with "hardware", resources are again a problem; particularly the CP time slice. A single user system may be better. Several software problems and deficiences were noted during the production of the docking and resupply movie. Problems, such as the lack of efficient geometric data manipulation software, have been discussed previously and will not be repeated here.

There were several problems encountered in the use of MOVIE.BYU to generate the images for the motion picture. First, it was observed that there were white, or nearly white, pixels distributed randomly along the "edges" of the model. These pixels did not appear consistently in every frame and hence, when displayed on film, produced annoying "flashes" at those pixel locations. The cause of this problem has not yet been determined.

Another problem is that of large model size. As model size increases so do the time and resources required to produce the picture. It will be necessary to examine techniques for reducing the time needed to produce a MOVIE.BYU-generated image.

While MOVIE.BYU produces somewhat visually realistic images, it was observed that additional modeling techniques for the production of even more realistic images could be valuable. The ability to model multiple light sources, shadows, and the mapping of textures over a surface were mentioned as possible options.

Problems with image aliasing were observed early in the production of the motion picture. The computation resolution was increased from 512 x 512 to 1024 x 1024. The resulting image was then averaged to produce a 512 x 512 display image to reduce the effects of aliasing. This, of course, increased the computation time required to generate each image. Therefore, there is a definite need for software which allows the generation of a high-resolution image (=>1024) with anti-aliasing of the image.

Along with better display, preview, and animation-assistance equipment, there is a definite need for efficient software for these systems. Constant regeneration of the models used in the production of this movie led to the use of large amounts of time and resources. The capability to interactively animate a given model would aid in better utilization of time and resources.

CONCLUSIONS

During the production of the movie and the post-production period of analysis, several problem areas in the procedure were identified. Recommendations for alleviating these problems are presented here. It is important to note that many of the existing problems in producing a motion picture can be remedied or eliminated, in some instances, through more than one solution.

Since resource use is related directly to the complexity of the input geometric model, there exists a need for techniques which allow the user to "optimize" the input model--that is, reduce the total number of nodes and elements considered in computation. Such techniques include, for example, the use of a back face cull algorithm, whenever possible, and reduction in the level of detail in the model when "parts" of the model are of inconsequential viewing size.

In addition to model optimization, it is necessary to reduce the time and resources needed to develop correct animation sequences. One such answer to this problem may be the use of interactive systems such as the Evans and Sutherland Multi-Picture System and its accompanying software to model animation sequences dynamically, rather than resorting to the present technique of trial and error on a storage tube device. With its interactive power, the Multi-Picture System and similar devices would save the movie maker a great deal of time and effort.

One step in the motion picture production effort is the generation of the actual frame of the movie which, as stated previously, consumes a great deal of resources. As observed during the production of this movie, generation of a sequence of twenty movie frames during prime working hours slowed all system activity greatly. Hence, it was recommended that the generation of movie sequences be postponed until non-prime hours. This would be feasible if "batch" jobs submitted to the PRIME system could request tape mounts from within the submitted job (command) file, which at present, is not permitted. It may be necessary, if motion picture film is used more and more frequently as an output medium, to dedicate a computer to the production of motion pictures.

When movie sequences are generated, the major information is written, at present, to magnetic tape. If many sequences are generated, a large number of magnetic tapes could be required, thereby amplifying the current problem of shortages of external magnetic tape reels. Further study should be undertaken which examines the possibility of compresssing the image information on magnetic tape such that more images may be placed on a single tape. Experimentation with techniques to accomplish this are taking place currently.

Additionally, it has been noted that the time needed to generate a movie sequence may be quite lengthy, and since the MOVIE.BYU software writes each scanline of an image to magnetic tape, a tape drive is monopolized for as long as four to six hours, thereby locking out any other potential tape users. One alternative would be to write image information to disk storage, and then at a later time, transfer all the image information to magnetic tape. The limitation that exists here is the lack of large volumes of disk storage on the PRIME computer. Therefore, it may be necessary to consider either writing movie frames directly to film, or to use some other storage media, such as video discs. If the frames are written directly to film, a potential problem exists. If the film is defective, or a high quality copy of the film is desired, all frames of the movie must be regenerated.

Therefore, the acquisition of a video disc-based record/playback system, such as a laser-optical memory disc recorder directly interfaced to the computer, would alleviate several problems encountered during the production of future motion pictures. A system of this kind would allow the user to transfer images from the computer directly to video disc, thereby eliminating the problems associated with transferring image information to magnetic tape or disk storage. Additionally, a video disc system would allow the movie maker to access individual movie frames in any desired sequence, and would provide a "preview" capability at a "real-time" rate. The latter would give the animator a better concept of the number of "inbetween" frames needed to produce a smooth rendering of the displayed motions. Finally, a video disc system would eliminate problems associated with transferring 16mm movies to the more convenient medium of videotape.

A display problem alluded to earlier was the loss of valuable color information when using the Digital Display/Film Writer system for output. To review, the MOVIE.BYU display software uses 24-bits of color information, while the Digital Display uses 8-bits, thereby reducing the number of displayable colors from over 16.7 million to 256. To produce visually realistic images, it is necessary to use as much of the color information as possible. One solution to this problem would be the use of the Gould DeAnza IP8500 Image Processing System as a movie production device in much the same fashion as the Digital Display System is used currently. Naturally, this would involve the installation of camera control software similar to that which resides on the Digital Display System.

Concerning visual realism, additional enhancements and/or modifications to the MOVIE.BYU display software, such as simulation of metallic surfaces, anti-aliasing techniques, and texture mapping, would lead to more realistic images in motion pictures. Currently, research is taking place regarding the incorporation of advanced visual realism algorithms into the MOVIE.BYU software.

Finally, a procedure should be developed by which an occasional movie maker could, along with the necessary image information, submit a 'job' to ACD personnel for the filming of a movie such as the one that has been described in this document. This could assure consistency in the production of motion pictures, and remove the one-time or infrequent user from problems encountered from a lack of knowledge of the filming equipment and procedures.

In conclusion, it is recognized that motion pictures, whether they be 16mm movie film or video disc-based, are becoming an increasingly more popular medium for presentation. Hence, every attempt should be made to optimize the procedures used to produce such output.

REFERENCES

1. Catmull, E.: "The Problems of Computer-Assisted Animation," COMPUTER GRAPHICS, Vol. 12, No. 3, 1978.

2. Christiansen, H.; and Stephenson, M.: MOVIE.BYU Training Manual. Brigham Young University, Department of Civil Engineering, 1982.

3. Crow, R.D.: "Shaded Computer Graphics in the Entertainment Industry," COMPUTER, March, 1978.

4. DeRyder, D.D.; Ferebee, M.J.; and McMillin, J.L.: "Interactive Geometry Modeling of Space Station Conceptual Designs," NASA CP-2272, 1983.

5. Gates, R.L.; and von Ofenheim, W.H.: "Application and Enhancements of MOVIE.BYU," NASA CP-2272, 1983.

6. Jones, K.H.; Randall, D.P.; Gates, R.L.; and von Ofenheim, W.H.: "The Solid Model Geometry Generator (SMGG)," NASA CP-2272, 1983.

7. "Langley Graphics System", COMPUTER PROGRAMMING MANUAL, Vol.IV., National Aeronautics and Space Administration, Langley Research Center, Hampton, Va.

8. Nazemetz, J.; Sage, K.; Gates, R.; and DeRyder, D.: "Geometric Modeling of Large Space Antenna Deployment," NASA CP-2272, 1983.

9. "NCAR Graphics Software", NCAR TECHNICAL NOTE, National Center for Atmospheric Research, Boulder, CO., February, 1978.

10. Watkins, G.S.: "A Real Time Visible Surface Algorithm," Department of Computer Science, University of Utah, UTEC-CSc-70-101, June, 1970.

11. Gentry, Arvel E.: "The Mark IV Supersonic-Hypersonic Arbitrary Body Program," AFFDL-TR-73-159, November 1973.

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LANGLEY TECHNICAL MONITORS: JOHN E. HOGGE AND DARLENE D. DERYDER

16. Abstract

This paper describes the process of producing computer generated 16mm movies using the MOVIE.BYU software package developed by Brigham Young University and the currently available hardware technology at the Langley Research Center. A general overview relates the procedures to a specific application. Details are provided which describe the data used, preparation of a storyboard, key frame generation, the actual animation, title generation, filming, and processing/developing the final product. Problems encountered in each of these areas are identified. Both hardware and software problems are discussed along with proposed solutions and recommendations.

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MOVIE.BYU, kinematics, storyboard, frame generation, animation, computer generated movies	unclassified - unlimited Subject Category 60

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