COMPUTER-GENERATED ANIMATION FOR ANALYSIS AND DESIGN

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SUMMARY

Computer-generated animation and its application to engineering problems has received considerable attention recently. The development of computer-generated animation techniques is reviewed and some examples of the current state of the art are described and/or presented.

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INTRODUCTION

The area of computer-generated animation as a tool for engineering analysis and design has been under development for a considerable number of years. In this paper, an attempt is made to describe some of the salient features of the development of computer animation techniques. This is accomplished by examining some of the history of the development, by exploring the types of animation techniques in general use and by examining the motivation of individuals desiring to use animation in their engineering work.

A number of the ways in which computer-generated animation can be used will be examined in relationship to the suitability for the engineering task at hand. There have been developed a number of techniques for producing animation with computers and each of these will be explored and evaluated in terms of their suitability for use in engineering analysis and design. Finally, a number of the application areas in which computer graphics has been used in a beneficial manner will be described and illustrated.

HISTORY AND BACKGROUND

Since the introduction of automatic plotting equipment in a computing environment, there has been considerable interest in producing animated films from computer programs. Some of the earliest work was done by Ken Knowlton and his group at Bell Labs, references 1,2,3,4. This Bell Labs work emphasized the use of computer-produced animated movies for the explanation of difficult concepts such as simulation of control systems, simulation of force, mass and motion interaction and other physics concepts. Among the workers with Ken Knowlton was A. Michael Noll, whose work expressed considerable interest in using animated computer-generated graphics to illustrate concepts which are difficult to visualize without the additional coordinate of motion, references 5,6 & 7. Since the early Bell Labs work, a number of researchers have worked on systems development for simplifying computer-generated animation for the end user. Notable among these researchers were Anderson, references 8 & 9, who developed a language for aiding the user in describing the parameters of his particular animation in an easy-to-use manner, Phillips, reference 10, who reported on an animation system which made use of a low-cost remote storage tube terminal and others, references 11 & 12, whose general work was aimed at automating the animation processes in the computer. Most of this work has been concerned with producing animations for demonstrating physical phenomena in the educational environment. At the present time, many engineering groups have access to computer-controlled plotting equipment which allows them to generate and use animations in design and analysis procedures. Further discussion of some of these uses will occur in later sections of this paper.

WHY ANIMATION?

The adage, that "one picture is worth a thousand words", can be extended to "a time sequence of pictures is worth much more than a single picture." Many times, the ability to transmit a concept or feature is enhanced by generating a time sequence of views of the phenomenon and displaying it in that fashion. In addition, as described by Noll, there are some things which are just impossible to visualize in the three-dimensional world, particularly those items which contain more than three dimensions. Consequently, if one can make use of time as representative of the additional variables, animation can be used to illustrate the salient features of the additional variables. In the particular situation of highway alignment design, it becomes very important to be able to view the proposed design of a dynamic situation so that the human response can be evaluated and used in modifying the design parameters. In this manner safety and usability are enhanced. In the case of vibratory response of items, such as structures, the response phenomena quite often is easier to see if the vibration is animated rather than if mode shapes only are plotted. The visualization of mode shapes for vibration problems is generally enhanced by a dynamic simulation as opposed to looking at only static mode plots. The rapid assimilation of large volumes of data can be made through the use of animation. Quite often animation will allow you to pick out the critical data and get right to the heart of the problem.

TYPES OF DISPLAY DEVICES

There are a number of different types of animation which can be produced by computer techniques. The two broadest categories are animations using line or vector drawings and animations using raster scan representations. In the case of line drawings, the animation generally is generated on a Cathode Ray Tube, (CRT), device which has a grid of addressable points on the screen surface plus some vector capability for drawing lines between points on the screen. Complex views can be generated and displayed on the CRT, and through a variety of techniques, animations can be generated. In the case of the raster scan type graphics device, scan lines are used for displaying the information on a CRT. The displays produced are similar in appearance to that of a standard television set, although for high quality work, the number of scan lines generally exceeds that of a typical television screen. Both the line type device and the raster scan type device can generate color displays. This ability to provide color can often be an important consideration in the computer-generated animation. Raster scan graphics has been used with color to do very realistic simulations of environments under computer control and some examples of this type simulation can be seen in the presentations of Greenberg and Evans.

TECHNIQUES FOR COMPUTER PRODUCTION

There are four basic ways in which computer-generated animation can be obtained. These are

1. Through the use of photography of sequential hard copy,
2. Through the use of photography of sequential views displayed on a CRT,
3. From the direct writing on microfilm,
4. Through direct animation on the CRT.

Some of the earliest work on computer-generated animation made use of drawing sequential views with a line type plotter and then photographing these views sequentially to produce animation, (Reference 13). This technique is, of course, quite expensive since the cost to produce hard copy is high and the amount of human intervention and labor involved in performing the animation is significant. This technique has all but disappeared from use today. The second technique for producing animation is by use of direct photography of a picture generated on a CRT device. There are a number of ways of performing this operation and perhaps the most successful one is that used in many of the microfilm recorders. In this case the display buffer is dumped a single time to the CRT, generating a moving dot on the screen of the CRT with the camera lens open. When the display buffer is completely empty, the film is advanced to the next frame and you are ready to produce the next picture. This technique has often been used successfully to produce raster scan type photograph by having the raster scan only a single time with the shutter open. Some very successful work along this line was also done by Phillips at the University of Michigan (see reference 10) in which he used a storage tube type CRT and an ordinary 16-millimeter camera on which he photographed the generated display. There have also been many attempts to photograph a refresh type CRT to produce animation. There are problems associated with this method created by the refresh nature of the display CRT. In general, CRT's used for direct viewing, have a short life phosphor which is made visible by bombardment from the electron beam. Continuous visibility is obtained by periodically refreshing the display by dumping the display code from buffered memory through the electron-beam gun. Most direct-view CRT's are refreshed at from 30 to 60 times per second and, in general, the refresh rate is variable depending upon the number of line segments displayed. This variation of refresh rate creates problems of exposure control when attempting

HIGHWAY DESIGN ANIMATION

The one area in which I have had the most experience with producing animation of actual designs has been the attempt to visually simulate a proposed highway design. In the development of a highway design, many diverse parameter effects must be evaluated as they interrelate to one another. Generally, the placement of a highway route is dependent upon study of economists, political scientists, traffic engineers, and planning and location engineers. Therefore, it is increasingly necessary to evaluate more thoroughly the interrelationship between physical design parameters and ecological and environmental consequences. Evaluation by the driver and the designer of various design alignments is also necessary to obtain the best response to all these problems.

Being able to drive a proposed highway allows the eliminating of blind spots, dangerous hilltop curves and confusing intersections and exits ramps. Better signing is also made possible. I will show some sixteen millimeter motion picture films which were generated from existing highway design data basis and made over the period of time in which the present highway animating system was developed.

In September 1968, the Washington Federal Highway Administration Office of Research and Development proposed a 18-month joint effort with the Federal Highway Administration Denver Office to produce software for the production of perspective views of proposed highway designs. Plans were made to make use of the computer hardware capability at the University of Colorado. In particular, use of the graphics capability including an interactive graphics console and a 35 millimeter microfilm recorder was planned. In September 1969, the first result of the work was shown at the 11th Annual Highway Engineering Exchange Program (HEEP) meeting in Washington, D.C. A three-minute sixteen-millimeter animation film of an actual project under design in the Denver office was shown. This film was produced from a birds eye location of 15.24 m (50 ft) above the ground. This was done since the removal of hidden portions of the views had not yet been accomplished. In March 1970, some success was obtained in implementing an algorithm for removal of the hidden portion of the views and an animation was produced from a driver's-eye location. This development is represented by the second portion of the film which also includes a portion of actual photography of the completed highway. Both of these previously described animations were produced by photographing single frames of a refresh graphics display device and taking a number of single frames so as to produce the animation effect. As our work progressed on the perspective animation system, we developed software for producing animations directly on the 35-millimeter microfilm recorder. Consequently, the third piece of animation on the film is one of a State of California Highway Department design of a proposed road in the Six Rivers National Forest in northern California and was produced by generating single frames of equally spaced views on the 35-millimeter microfilm. The 35-millimeter microfilm was then reduced to 16-millimeter film through the use of an optical printer. This resulted in a master copy on 16-millimeter film which could then be used in the optical printing process to expose multiple frames of each of the original frames and to add color and overlays with titles and credits. It should be emphasized that all of the titles and credits were also produced on the same microfilm recorder. In 1972, the U.S. Bureau of Reclamation was involved in the design of a new water carrying canal in California and requested to photograph such a device directly, leading to variations in intensity due to different portions of the film seeing a different number of refreshes. Similar type problems can occur in the case of raster scan devices. Additional problems may occur in the case of color devices in obtaining color saturation. Consequently, most of the direct photography work with CRT's is done with an open shutter and a single dumping of the display buffer for a single view. If the view is to be displayed in color then each color is dumped sequentially with the proper filter so as to generate maximum color saturation.

The direct writing microfilm device works by having a defected light beam impinge directly on a sensitized film. The result is essentially identical to the photography type microfilming technique.

The last type of animation technique mentioned is that of direct animation on the CRT and perhaps this is the one which many of us have been aiming towards from the beginning. Unfortunately, in many engineering design problems, the amount of computation involved in producing a animated sequence is still too much to allow for real-time display of the results. As the animating portions of CRT display devices are becoming implemented more often in hardware, this problem appears to be lessening. At the present time, one can find hardware implementations for rotations, scaling, perspective transformations, intensity queuing, and in some cases, hidden line removal. All of these implementations have made it easier to get to a real-time animated display directly on the CRT device.

APPLICATIONS

Some of the earliest proposed animation systems were used to draw stick like cartoons or for the production of animated art work. More recently, there has been considerable interest in using raster scan color graphics to produce animated television commercials. A primary interest of this group is the use of computer-generated graphical animations in the area of simulations. There is a wide range of applications in this simulation area, ranging from simulating the response and behavior of a structure or engineering design under some time varying situation all the way to attempting to simulate the real surrounding areas as is the case for pilot and driver training simulations. The examples of work which I will show with the film clips are really concerned with attempting to combine the two types of simulation - that of superposition of an engineering design on the surrounding real world and an evaluation of this simulation both from an engineering design and an aesthetic point of view.

High quality computer-generated animations have been produced at a wide variety of installations, including the University of Utah, Cornell University, General Electric Syracuse, National Center for Atmospheric Research, Sandia Labs, and Livermore, just to mention a few.

that we produce an animation of this project so that they could evaluate the effects of the proposed design on the surrounding terrain. The fourth portion of the film which you will see contains this animation of flying over the proposed canal. This piece of animation was produced with the identical technique used for the US 199 animation in California with the exception that some of the colors added with the optical printing process are different.

The fifth and final film portion is a copy of an animated sequence of a highway design produced for the State of New York Department of Transportation by General Electric Syracuse on their raster scan color graphics system.

CONCLUSIONS

The use of computer-generated animations to aid in engineering analysis and design appears to have a bright future. The developments of faster computational hardware, along with the incorporation of many graphical display features into hardware point to increasing ability to provide real-time animations directly on CRT screens. Meanwhile, many important engineering problem solutions will be aided by using microfilm recorder techniques to produce animations.

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