COMPUTER ANIMATION IN DISTANCE TEACHING

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ABSTRACT

Television plays an important role in the distance teaching methods of the Open University. The use of computer animation has greatly enhanced the teaching process. Computer images are created using a graphics package based on the SIGGRAPH "Core" system and viewed on a range of colour raster terminals. Previewing animation sequences has been simplified by developing an interactive animation system. Completed sequences are recorded direct to videotape using a system developed jointly by the BBC and the Open University. They are subsequently edited into television programmes for transmission by the BBC.

INTRODUCTION

The Open University is an independent self-governing distance-teaching institution which awards its own degrees and certificates. Students do not attend a campus, but learn at home and in their own time from specially written booklets, recommended text books, radio and television broadcasts and other audio-visual material. There are about 65,000 undergraduates at various stages of their degree studies and another 23,000 people taking single courses. At present, there are 131 undergraduate courses covering a wide range of disciplines.

Television programmes are made in partnership with a special unit of the BBC. Some 35 hours of television are broadcast each week over the BBC network. The BBC OU Production Centre is probably the largest and best-equipped educational audio-visual centre anywhere in the world.

Computer animation has proved to be particularly effective in the television programmes produced for the Mathematics and Science faculties of the university. Some forty minutes of computer generated animation has been used in nine half-hour programmes produced for the second-level course "Probability and Statistics". The sequences range from animating simple histograms to 3-D representations of bivariate normal distributions. It has been found that the teaching of many facets of statistics is made simpler by the use of computer animation to illustrate specific points. Other effective applications have been found in physical chemistry, physics and molecular biology.

A particularly interesting sequence in molecular biology resulted in the first solid modelling animation of a Lysozyme enzyme. Co-ordinates of the molecules were generated on a Cray 1 and converted by the IBM UK Scientific Center to solid graphic images. These were then previewed and recorded using the animation system described in this paper.

THE CAVITY ANIMATION SYSTEM

The Cavity system is based on four design objectives:

1. A previewing environment is available which allows the user to view any frame in the sequence easily;

2. Computer images can be modified without having to resort to time-consuming compilations and loading of source code;

3. Single and multiple fairings are available to allow changes to position, angles, colours and other parameters in a visually smooth fashion;

4. Sequences can be recorded direct to video-tape and meet the requirements of BBC videotape standards. The computer controls the operation of the videotape machine (VTR) and the whole recording process once begun, requires no manual intervention.

It should be noted that as many of the animation sequences are illustrating scientific topics, the primary means of control is by numerical model. A fully interactive graphics editor has been developed and integrated into the Cavity system for work requiring manual input.

ANIMATION SOFTWARE

The animation system is made up of the following software components:

1. A Graphics Package

The graphics package is a full implementation of the SIGGRAPH "Core" system written in FORTRAN 77. The package includes additional routines to allow such facilities as anti-aliasing, hidden line removal, RGB and HLS colour models.

2. Animation Control File (ACF)

The ACF is a text file which controls which routines will be called to form the images associated with each frame of the animation sequence. The file contains commands which initialise and change entries in a database. Parameters associated with graphics images may be linearly changed to specified values over a specified number of frames. These changes may also be done using several fairing techniques. The system can also cope with large numbers of overlapping changes. Commands are also available to define and enable or disable boolean variables.

3. User Routines

The user routines are written by the programmer/animator. They produce images by calling routines in the graphics package or obtaining picture segments from metafiles. The routines are generally controlled by boolean variables defined in the ACF and enabled for the relevant frames.

4. The Database

The database is held in memory and is modified either by commands in the ACF or as a result of actions in the user routines. It holds key variables which change during the animation sequence as well as those modified during development of the sequence. Variables can be boolean, integer, real and arrays of these types and may have names of up to 30 characters.

5. Videotape Control Routines

These routines control the recording process. Appropriate commands are sent from the computer to the VTR to control normal VTR functions such as pre-roll and cue actions. The commands pass through the Cavity convertor box, described later. The VTR also sends data back to the computer through the convertor box, reporting on its status.

6. Animation Package (ANIMAT)

The animation package consists of a set of routines which allow the user to preview individual frames of an animation. The user keys in commands at the terminal and ANIMAT uses the specifications in the ACF together with routines in the graphics package to produce the images.

The user can step forward or backward through the sequence or jump to any specified frame. Images can be altered by using a second terminal to edit the ACF file. The UPDATE command will make the necessary changes to the database and redisplay the relevant frame.

When an animation is completed, ANIMAT is used to initiate the recording process and control the VTR with the videotape control routines.

7. Graphics Environment

The programmer/animator can set up an environment which adds a range of graphics commands to the operating system of the computer. The only source code which need be altered when developing a sequence is in the user routines. The user then specifies which output devices are to be used and invokes the ANIMATE command followed by the file containing the user routines. All relevant graphics routines, output device specific routines and VTR control routines will automatically be loaded together.

ANIMATION HARDWARE

Animation sequences are currently being developed on a DEC 2060. All communications are over serial RS232 lines at 9600 BAUD. The following input/output devices are available for development work:

1. AED 767
2. SIGMA 5000 GOC
3. TEKTRONIX 4012
4. DEC GIGI VK100
5. DEC VT241
6. Pericom 7800
7. BBC Micro
8. CALCOMP31 Plotter
9. Altek Datatab Digitizer
10. GTCO Digi-Pad 5 Digitizer.

The recording process uses:

1. AMPEX 1" VPR2
2. Newbury 7000 VDU
3. Cavity convertor box
4. Michael Cox Coder
5. Sony 5860 P U-matic recorder.

Final development work is done on the AED 767, which has a resolution of 767 x 585, compatible with British television requirements. The eight memory planes of the device offer a suitable colour table, easily modified by the programmer/animator.

THE CAVITY CONVERTOR BOX

This device was designed and built by John Franklin and Alan Francis of the BBC Open University Production Centre. Data from the DEC 2060 is sent to a frame store in the BBC Production Centre. Control codes are separated from the graphical data which is assembled into RGB signals. The RGB signals are locked to station sync pulses and fed to the Michael Cox coder to produce a PAL encoded video signal. This signal is then routed to the video input of the VTR.

Some of the control codes command the internal functions of the frame store, while others control the motion of the VTR. The latter are gated to a downstream output of the frame store and fed to the Cavity Convertor. The Convertor is built around a Z80 microprocessor and updates timecodes and cues and records as appropriate. It also keeps the VTR and computer in step by telling the computer when each video recording operation is complete.

PRODUCTION OF A SEQUENCE

The decision to use a computer animation sequence in a programme is generally taken by the BBC producer. Discussions are then held with the course team of academics writing the course to assess the teaching potential of the sequence. Once approved by the academics, a storyboard of the sequence is developed in conjunction with a graphic designer from the BBC.

At this stage the programmer/animator becomes involved and decisions are taken with regard to the type of images required and how best to animate them. After the sequence is approved by BBC resources and planning, a detailed storyboard is produced.

The programmer/animator then writes the user routines necessary to generate the images and the associated ACF file to set and control variables used in specific frames. One command in the graphics environment loads all the required modules together and the sequence is edited and previewed on a colour raster terminal. In some sequences, the graphics editor might be used to draw certain images. These are stored in metafiles and accessed from the user routines. Alternatively, a frame generated by the user routines may be stored in a metafile, accessed by the graphics editor and modified as required. Parts of the sequence may be recorded directly onto the Sony U-matic recorder to give some picture of the movement involved in the sequence. When all the images for the sequence are being generated correctly, frame numbers in the ACF are adjusted to synchronise the sequence with its accompanying commentary.

Recording of sequences takes place on two nights each week, although additional sessions are made available as required. The recording process is initiated by a VT editor, operation is entirely automatic and takes place overnight.

The time taken to record a sequence is generally dependent on the complexity of the images being drawn. Inevitably, the VTR has to wait for the computer to complete the frame before recording it. Recording sessions typically last for twelve or thirteen hours if no hardware malfunctions occur.

EXAMPLES OF AN ANIMATION SEQUENCE

Three animation sequences were commissioned for a programme in the course "Probability and Statistics". The sequences were used to illustrate concepts which would have been difficult with traditional graphics techniques. The programme deals with the bivariate normal distribution. Bivariate distributions are probability distributions for two random variables. The distributions of each variable alone when obtained from the joint distribution of the variable is called the marginal distribution.

As an example, consider the heights of fathers and their adult sons in a large population. These are continuous random variables, both of which can be regarded as being normally distributed. They are not independant, since tall fathers tend to have tall sons, so to describe their joint distribution to look at say, the average heights of sons of six-feet tall fathers, requires a continuous bivariate distribution whose marginals are normal.

The bivariate normal distribution has an explicit mathematical representation which, when plotted, results in a 3-D contour. Once the image is drawn, it is easily manipulated using the animation package. The image is rotated, split into independant segments which can move freely. By changing parameters in the mathematical description of the distribution, the whole surface can be animated. Hidden line removal is used where appropriate and limited shading enhances the final image.

Figure 2 shows studio models used in the television programme to represent heights of 1078 father-son pairs. The probability density function (p.d.f.) of a bivariate normal distribution is shown in Figure 3. The animation sequence had to realistically represent the studio model. Manipulation of the RGB colour model allowed the appropriate colours to be generated. The image was further enhanced with text labels which were orientated in 3-D space. Figure 4 shows the p.d.f. as drawn by the computer. In the animation sequence the p.d.f. is split into vertical cross-sections. This reveals that each section has the shape of a normal curve.

FUTURE DEVELOPMENTS

At present, the Cavity system uses the AED 767 as a frame store during the recording process. We are intending to install a PLUTO II graphics controller for future work. This is an 8088 based graphics processor with 1 Mbyte of frame buffer memory and complete compatability with the AED 767 with regards to colour table, resolution and performance. Another PLUTO II will be available for development work.

Recent applications have demanded more sophisticated images requiring hidden surface removal and shading algorithums. These have been implemented at the user routine level.

The acquisition of a VAX 11/785 has raised the possibility of moving the animation system to a machine with much faster transmission rates. The complexity of images now being produced requires an improvement on the current data transmission rate of 9600 BAUD.

CONCLUSIONS

The Cavity animation system allows BBC producers and graphic designers to work alongside programmer/analysts of the Open University in producing computer animation sequences. In the first two years of operation, the system has resulted in some two hours of computer animation. The system allows completed sequences to be recorded overnight, direct to videotape. No manual intervention is required in the recording process.

Animation sequences are intended as a teaching aid and not simply visual entertainment. To this end, care must be taken not to obsure the teaching point by creating images which are visualy distracting to the student.

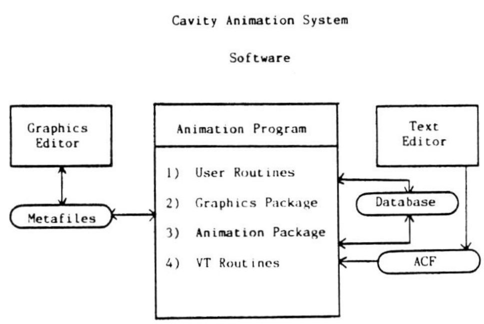

Figure 1

Figure 2

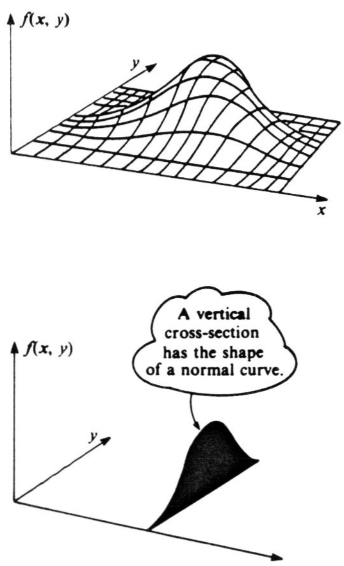

Figure 3

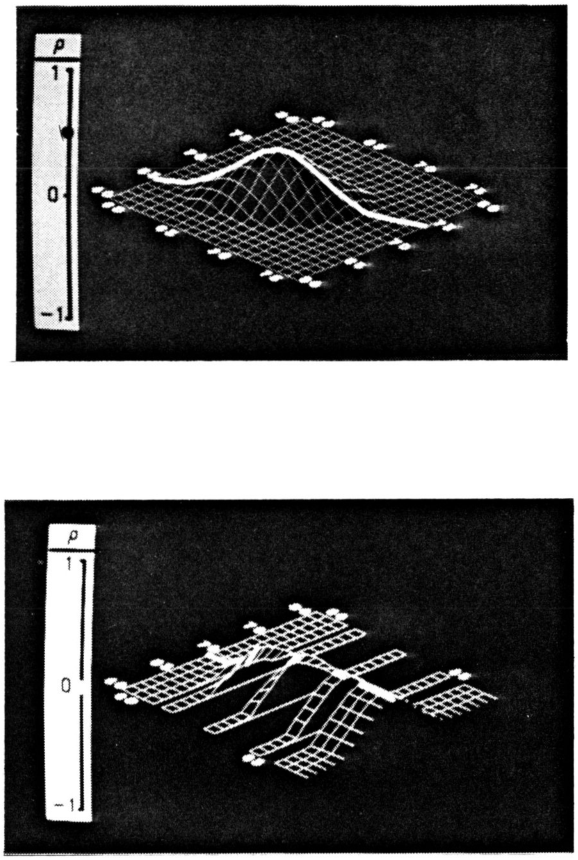

Figure 4