Stereo viewing on the PC/AT with EGA graphics

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Tachystoscopic stereo can be used to greatly enhance the performance and usability of low-cost molecular graphics systems. Here, a simple way to connect and control three-dimensional liquid-crystal glasses from a PC/AT with EGA graphics capabilities is described. The method makes elegant use of the screen's vertical retrace for synchronization purposes, allowing left and right views to be alternated every refresh cycle.

Keywords: tachystoscopic stereo, personal computer, molecular graphics

INTRODUCTION

Viewing three-dimensional (3D) objects in stereo has proved to be extremely useful in molecular graphics and several major molecular graphics packages have been set up to make use of this technique.[1] In this paper, a method is presented to allow the inclusion of 3D viewing in low-cost systems. We discuss the principle of tachystoscopy,[2,3] the connection and synchronization of SEGA 3D liquid-crystal glasses[4] to a PC/AT with EGA graphics. Simple algorithms for stationary and rotating 3D images are also presented before giving a final appraisal of the approach.

TACHYSTOSCOPY

Tachystoscopy is a method of generating stereo images by the rapid interchange of two perspectives of an object: a "left" view that is visible only to the left eye and a "right" view that is visible only to the right eye. This process is particularly suitable for use with computers as the left- and right-eye views can be precalculated, stored and then alternately displayed on a monitor. It is important that each view be visible only to the appropriate eye; otherwise the stereo image may flicker or not be resolvable. Additionally, the frequency of view swapping must be sufficient (40–60 Hz) to ensure a smooth stereo image. Harris and his coworkers have discussed[2,3] how liquid-crystal glasses can be used to obscure the "wrong" eye's vision while the other view is being displayed.

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Received 12 June 1990; accepted 4 September 1990

The left- and right-eye views consist of two-dimensional projections of an object in three dimensions. The projections are separated by an angular displacement of about 0.1 radians, corresponding to the angle made between a focus point on the object and the left and right eyes of the viewer. Different types of projections (parallel, isometric or perspective) affect the perspective depth of the stereo image.

CONNECTION

The SEGA 3D glasses may be attached to a SEGA video game system using an associated controller unit. By tapping into the controller's circuitry and modifying it slightly, it is possible to use the controller to drive the glasses as required. A block diagram of the controller circuit is given in Figure 1, illustrating the modifications required.

Five changes to the controller circuit are necessary: The first two require that a positive 5-V power line and a ground line be connected to the circuit. Next, the trace connecting pin 5 of IC_3 to IC_2 must be cut. An easy place to do this is on the back face of the board, as illustrated in Figure 2. The fourth modification is to connect pin 1 of IC_3 to the capacitor C_1. Lastly, a toggle line must be attached; this line is driven by the software and provides a transistor–transistor logic (TTL) signal to pin 5 of IC_3. Communication between the software and the toggle line is achieved via one of the data bits on a parallel port on the PC/AT. The software should outport a signal to the parallel port each time the lenses are required to be toggled. A low output should shut the left lens and open the right one while a high output should do the opposite. If the lenses are toggled 180° out of phase with the views on the monitor, so that the views are visible to the "opposite" eye, a depth reversed image will result.

The positive and ground lines may be taken from an external DC source; alternatively, they may be tapped off the PC/AT's power supply via the parallel port card. The latter method has the advantage that no external power source is necessary, but the drawback that the parallel port card becomes dedicated and should not be used with other devices.

SYNCHRONIZATION

The refresh cycle of a typical raster device involves a number of scan lines equal to the height resolution of the screen, as indicated in Figure 3. The screen is momentarily blanked

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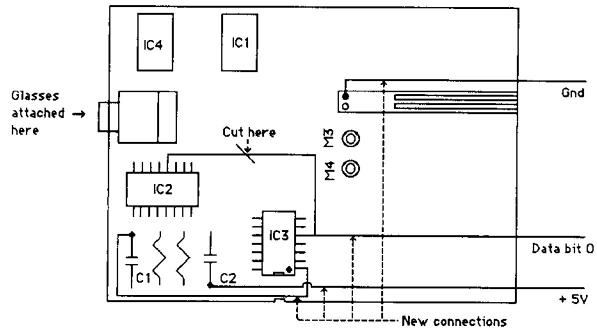

Figure 1. Block diagram of the SEGA 3D glasses controller circuit. The required modifications are indicated by the dashed lines

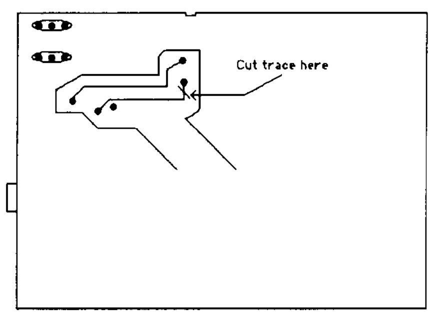

Figure 2. Rear side of the controller circuit. The trace should be cut as indicated

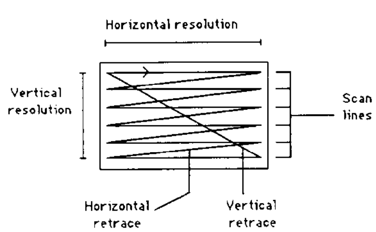

Figure 3. Scanning path of a typical raster device

after the completion of each scan line while the electron guns perform a horizontal retrace and reposition themselves at the start of the next scan line. The screen is blanked so that the diagonal motion of the guns will not be visible. Similarly, after the completion of the last scan line, the screen is again blanked while the guns perform a vertical retrace (VR), positioning themselves at the start of the first scan line. Because the VR occurs immediately after the completion of the last scan line (and hence after the completion of one image on the screen), it is convenient to use this event as a means of synchronizing the switching of lenses on the glasses with the display of alternating views on the screen.

It is necessary to poll Input Status Register 1 (ISRO) on the EGA graphics card to check if a VR has occurred.[5] When bit 3 is a logic low, video information is being displayed on the screen. When this bit is a logic high, a vertical retrace is occurring. The following sequence of events is a useful guide for achieving the correct synchronization:

Shut off right lens/open left lens
Display left image
Wait for a vertical retrace
Shut off left lens/open right lens
Display right image
Wait for a vertical retrace

At each occurrence of a VR, a signal is sent to the parallel port to instruct the controller to toggle the lenses on the glasses.

STATIONARY STEREO IMAGES

The EGA graphics can be operated in two modes using Turbo C: EGAHI and EGALO.[6] In the EGAHI mode two pages, with a resolution of 640×350 pixels, are accessible, but only one page is visible at any time. By assigning and predrawing the right-eye view of a 3D object on one page and the left-eye view on the other, a stereo image of the object can be generated with the following Turbo C code:

```
/* parallel port is at hex. address 378 */
while (True) {
   setvisualpage(1);                      /* Right view */
   while (! (inport(0×3DA) & 0×8));       /* Wait for a VR */
   outport(0×378,0);                      /* Close right eye */
   setvisualpage(0);                      /* Left view */
   while (! (inport(0×3DA) & 0×8));       /* Wait for a VR */
   outport(0×378,1);                      /* Close left eye */
   }
```

Thus, the left lens on the glasses is blanked by outputting a logic high to the parallel port before the right view is instigated. The contents of ISRO are then continually polled until bit 3 becomes set, indicating the occurrence of a VR. During the VR, the right lens is blanked while the left side becomes visible. A similar sequence of events holds for the left view. Each view (right or left) makes full use of the resolution available (640×350 pixels), resulting in a full-screen stereo image, rather than side-by-side stereo.

ROTATING STEREO IMAGES

The basic paradigm suggested here for rotating stereo images about a vertical axis involves the use of three frame buffers and the VR to signal an interrupt. In the EGALO mode, four pages of resolution 640×200 pixels are available. Three pages are used as frame buffers: one for the left-eye view, another for the right-eye view and a third for the next-view.

The left- and right-eye views of the first stereo image are precalculated and stored in two of the frame buffers. It is then displayed, using the VR to generate an interrupt at each refresh cycle. The interrupt updates the visible page, oscillating between the left- and right-eye views each cycle, and toggles the glasses.

Concurrent to the display of the first stereo image, the next-view is calculated and drawn into the next frame buffer. By equating the degree of rotation between stereo images with the degree of rotation between left- and right-eye views, the next-view can be used in conjunction with either of the previous left- or right-eye views (depending on the sense of rotation) to form the next stereo image. Thus for a clockwise rotation (right to left), the old right-eye view becomes the new left-eye view and the next-view becomes the new right-eye view for the new stereo image. The frame buffer for the old left-eye view is then used for the new next-view. The update of each of these views must be performed in a noninterruptable, critical region. Figure 4 illustrates this process.

The speed of rotation of the object, as seen in stereo on the screen, depends upon the time taken to calculate and draw the next frame. Generally, the more complicated the frame, the longer the time taken between stereo views. It should be noted that the required rotation times depend on the underlying graphics display system and not on the stereo system. Table 1 lists the rotation times required for different numbers of residues while viewing parts of a protein in stereo using the PASS display system.[7]

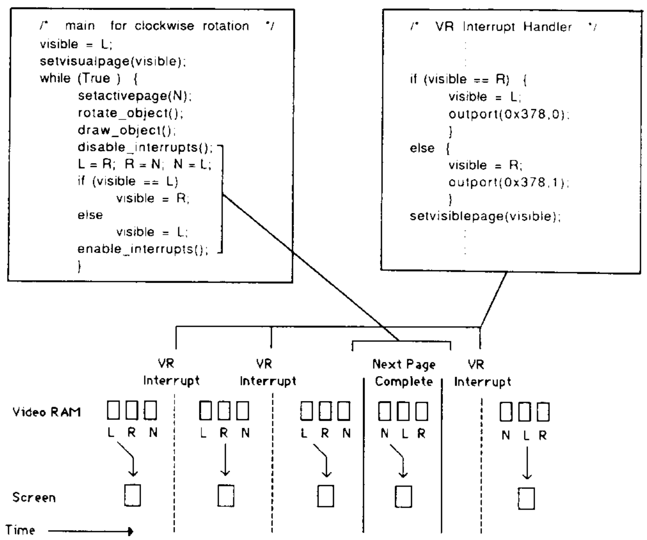

Figure 4. Basic method proposed for rotating stereo images. The main program, which calculates and draws the next frame, is interrupted each time a VR occurs. This toggles the visibility of the left and right frames in video RAM. The sense of rotation of the frames is opposite to that of the object

Table 1. Averaged rotation times required between stereo views for residues 1–100 of cytochrom c2, (entry 2C2C taken from the Brookhaven Protein Data Bank[10,11]). The underlying display program was PASS,[7] running on a 286AT clone with an 80287 floating-point coprocessor and a 16-Mhz cpu clock. Up to about 40 residues can be rotated in less than a second

Number of residues	Time for one stereo rotation step (sec)
1–10	0.28
1–20	0.51
1–30	0.75
1–40	1.00
1–50	1.30
1–60	1.56
1–70	1.85
1–80	2.15
1–90	2.33
1–100	2.63

ARBITRARY ROTATIONS ABOUT ANY AXIS

For continuous rotating stereo images, which allow a variable degree of rotation about any axis, one may use the same mechanism, with the addition of an extra frame buffer. Thus, the four pages available in the EGALO mode are used as frame buffers, and the new left- and right-eye views must be buffered before the next stereo image can be displayed. Clearly, this reduces the rotation speed by half, but also increases the flexibility of and control over rotations.

ROCKING STEREO IMAGES

An intermediate state exists between stationary stereo images and fully rotating images: rocking stereo images. By combining the ideas presented for stationary stereo images with those presented for rotating stereo images, it is possible to generate stereo images that rock over a small angle (about 18°) about a vertical axis. Using the four frame buffers in the EGALO mode, and equating the degree of rotation between stereo images with the degree of rotation between left- and right-eye views, three equally-spaced stereo images can be produced. By sequentially displaying these images in alternate directions (clockwise and anticlockwise) the effect of a rocking stereo image is achieved. Thus, a partial rotation can be generated without the use of a VR interrupt handler.

DISCUSSION

This method of full screen stereo viewing has the advantage of cost effectiveness over other methods that are available.[2] The configuration given here is for one viewer. Extra glasses are required for additional viewers; and these should be connected in the same way, only using a different data bit of the parallel port. If two glasses are connected to data bits 0 and 1, outporting a binary 0 (0000) would shut the same lens off on both glasses. Outporting a binary 3 (0011) would shut the other lenses off.

The modifications to the controller circuit are quite crude and provide little flexibility in the individual control of the left and right lenses. Once in use, there is no means to switch off both lenses on the glasses. If such versatility is required for a specific application, further modifications to the controller are necessary.

The SEGA glasses were selected solely on the basis of initial availability (the computer section of a local department store) and low cost (under $100 AUS). Although similar systems do exist,[8] we have not undertaken a comparison of their respective performance characteristics.

In our method, rotating and rocking stereo images require the use of the EGALO mode, which reduces the screen's resolution from 640×350 to 640×200 pixels. We find this loss of two-dimensional resolution to be more than compensated for by the combined effects of the rotation and introduced depth perception in the stereo image.

Algorithms for stationary stereo images are very simple to implement. Algorithms for rotating stereo images, on the other hand, are more complicated and typically require a VR interrupt handler.[9] Interrupt handlers of this nature tend to introduce specific video card dependencies, which can hamper portability. The principles discussed here are, however, universally applicable to any system that makes use of a graphics card that allows the VR interrupt to be trapped. It is worthwhile to note that the DOS operating system can have re-entrancy problems after making library routine calls from within an interrupt handler. To avoid this, the interrupt handler (Figure 4) should preserve the contents of all registers before making the outport and setvisiblepage calls. After these calls the registers should be restored.

CONCLUSION

A means of incorporating tachystoscopic stereo viewing to low-cost graphics systems has been presented. The method is simple, cost effective and produces clear, full screen stereo images. Stereo viewing is particularly applicable to molecular graphics because of the nature of the objects being viewed. Atomic structures are typically close packed. Viewing the 3D orientation of this packing may lead to an understanding of the packing mechanism.

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