Stereo viewing on the Evans and Sutherland PS350/PS330

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Viewing three-dimensional objects in stereo is an indispensable tool in molecular graphics. This paper presents a simple and elegant technique to incorporate stereo in application programs for the Evans and Sutherland PS350 and PS330 equipped with liquid-crystal glasses (Leeds shutters and similar devices). The method makes proper use of the hardware and is not subject to the difficulties encountered with other approaches. We use the time the scope's electron beams need to draw lines for synchronizing with the shutters. Left and right views are alternated in every refresh cycle, rather than requiring at least two. The technique retains the advantages of the PS350 refresh buffer and optimizes the frame-update rate on both machines.

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The European Molecular Biology Laboratory has been operating an Evans and Sutherland[1] Picture System 350 (PS350) since the autumn of 1986. The equipment features Millenium[2] electro-optic liquid-crystal stereo shutters,[3] also sold by Evans and Sutherland. The apparatus is known as Leeds shutters. We have installed a number of major molecular graphics programs on the PS350. To our surprise, while all of the programs presumably drive the stereo shutters, none of them did this on the PS350 with useful performance for anything but very small models. Study of the PS350 and PS330 hardware architectures revealed the underlying reasons. Consequently, we developed a technique that properly uses the equipment and yields optimized stereo performance. Because we have no immediate access to a PS330, the method was tested by R. E. Hubbard[4] for this machine.

In addition to having informed the manufacturer, Evans and Sutherland, about the technique, we believe this paper may help frustrated programmers and annoyed users who are trying to cope with similar hardware configurations.

The shutters are associated with a controller that offers several possible triggering mechanisms. The method usually chosen uses two optical pickups for synchronization[3] and requires no hardware changes or additions. A small trigger object is displayed to initiate the left view (i.e., to open the left shutter while closing the right one). This left trigger is followed by the object properly transformed for viewing with the left eye. Subsequently, the right trigger is displayed (i.e., open the right shutter while closing the left one), again followed by the object, this time properly transformed for viewing with the right eye. This alternating image stereo technique, called tachystoscopic stereo,[3] has the indisputable advantage that the entire screen size and resolution are available for display of the three-dimensional (3D) objects, as opposed to side-by-side stereo.

A BASIC DIFFERENCE BETWEEN PS350 AND PS330

To understand the requirements for a properly functioning electro-optic shutter stereo, it is important to understand a basic hardware difference between the PS330 and the PS350 and the terms frame-update rate and frame-refresh rate. The frame-update rate represents the speed at which the Picture System's Arithmetic Control Processor (ACP), followed by the Pipeline Subsystem (PLS), can transform the vector endpoints of a new viewing frame and present it, in the case of the PS330, to the Line Generator Subsystem (LGS) for display on the monitors, or, in the case of the PS350, to a refresh buffer memory for storage, from which it is subsequently continuously refreshed by the LGS. For the PS350, a frame-refresh rate then applies; this is the rate at which a complete pretransformed frame can be read from the refresh buffer by the LGS and output to the scopes. In the PS330, the machine's architecture forces the refresh rate to be equal to the update rate. Each newly refreshed frame is retransformed via the ACP/PLS subsystems. The result is a poor display that flickers excessively when dealing with complex objects.

THE PROBLEM WITH THE PS330

In all the programs we have installed, the alternating displays had been synchronized with the shutters by using the SET RATE command of the Picture System, which allows control of the duration of on and off phases, respectively, in numbers of frame updates. These phases can be sensed and used to generate left and right triggers and views synchronously with shutter operation. The phase states are governed by the ACP/PLS subsystem. In this method, the stereo views, left and right, are updated as two different, independent frames output to the LGS in alternating manner.

The problem is that the ACP is clocked at the line frequency (50 Hz in Europe, 60 Hz in the USA). If the ACP/PLS needs just minimally longer than a clock cycle for a frame update, the next update can be started

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the subsequent clock pulse only. In this case, the effective rate is nearly cut in half. Worse still, the ACP/PLS throughput is strongly dependent on the complexity of the PS300 network and of the picture, as well as on clipping, which may differ between the two stereo views. This can result in dynamic timing variations. In view of the above, one must conclude that the phases are a hazardous means for synchronizing electro-optic shutters on a PS330.

THE PROBLEM WITH THE PS350

The PS350 alleviates the problem of low ACP/PLS frame-update rates for complex objects by storing the updated frames in a refresh buffer memory, from which they are refreshed by the LGS at much higher rates, typically at line frequency. However, this complicates phase synchronization of stereo views considerably beyond the problems already faced on the PS330. In fact, we contend that depending on the phases for PS350 stereo is utterly impossible.

The current view is refreshed independently of the operation of the ACP/PLS until the latter have completed a new frame update and the LGS has finished displaying the current frame from the refresh buffer. We may expect that, in many cases, the effective stereo performance of the PS350 is degraded to less than the already slowed performance of the PS330 when keeping in mind that the two stereo frames are updated and displayed as separate entities. Furthermore, because the refresh rate is independent of the update rate, which governs the phase states, the state changes are not synchronous to screen refresh most of the time when viewing anything but very small objects. The effect is that it cannot be guaranteed that each view, left and right, is refreshed exactly the same number of times for each stereo cycle. That, however, is necessary for the perception of a comprehensible 3D image. We often observed severe fluctuations even when looking at still pictures in stereo.

In view of the above, one would expect that any technique that attempts to control stereo by employing the ACP/PLS subsystems is likely to experience difficulties to synchronize, increased flickering, or both. We believe that, at least, the refresh rate would be reduced, thereby eliminating the advantage of the refresh buffer.

THE PROBLEM WITH THE SHUTTERS

To frustrate the programmer further, the stereo controller and glasses present additional complications. As of this writing, the controller's circuitry adds a delay to the trigger signal, and the glasses' response to being triggered may be delayed as well. To reach a stable state, say left shutter really opened and right shutter really closed, the apparatus needs a few milliseconds. In the usual triggering method, we observed cases where the left trigger actually triggers the right view, and *vice versa*. The mirroring of the stereo view can be reversed with the controller.

THE SOLUTION

We developed a stereo triggering technique that is safe and elegant in its simplicity. On the PS350 it bypasses all influences of the ACP/PLS frame update and, hence, need only cater for the delays due to stereo controller and glasses themselves. On the PS330, it yields marked improvement also.[4] For both machines, the problems stemming from the use of the on and off phrases are eliminated.

Instead of synchronizing to phases that are, predictably, "out of phase" most of the time for the PS350, and instead of using an approach that can at best degrade the performance of the PS330, we use the LGS and consequently the time the electron beams require to draw lines on the screen. Both views, left and right, are combined into a single display frame, each preceded by the proper trigger object. Between each trigger and the corresponding view, an object is displayed to "waste" the time the glasses need to settle. For a PS350 at the proper display speed for the usual color shadow mask (CSM) scope, 267 vectors displayed across the entire screen width provide the correct delay. More vectors will decrease display performance unnecessarily. When fewer are used, a number of initial vectors in the objects of interest will dim or become invisible altogether when viewed with the glasses. To avoid irritation by the synchronizing vectors actually appearing on the display (even zero intensity leaves them visible), we apply the observation that the LGS performs proper timing irrespective of which monitors are selected for output. Hence, all scopes are disabled for the synchronizing object.

For a PS330 only, it may be indicated to tune each program because of the dependence of the frame update rate on the complexity of networks. This can be achieved by reducing the number of synchronizing vectors until maximum display performance is reached while still yielding optimal stereo. Tuning should be done in the program mode exhibiting the least traversal overhead, i.e., displaying a single vector in the program's state that produces the fastest screen refresh.

The following scheme is applied. We emphasize again that it describes a single display frame:

(1) Display the left view trigger
(2) Wait for the stereo viewers to settle by displaying 267 full-screen-size vectors with all displays deselected
(3) Display the left-eye view
(4) Display the right view trigger
(5) Wait for the stereo viewers to settle, as under Step 2
(6) Display the right-eye view

This technique retains the advantages of the PS350 refresh buffer and, for the PS330 also, optimizes the frame-update rate. Right- and left-eye views are alternated in every frame-refresh cycle, as opposed to requiring at least two cycles. In the usual double-buffer mode of the PS350, a stereo frame is continuously refreshed and the glasses run synchronously while a new stereo frame is being updated and stored into the other half of the buffer. Delays are kept to the minimum, and, consequently, flicker is minimized. On the PS350 the necessary delay is a constant function of the shutters and entirely independent of the complexity or type of image being viewed.

The technique has one more advantage. The invisible object displayed for timing also provides an interval for the left-eye view to "fade away" before the right-eye view is displayed, and *vice versa*. Hence, ghosting produced by the persistence of the scope's phosphor is markedly reduced.

For the PS350, the disadvantage of the technique is a doubling of the required refresh buffer area. So far, however, that has never manifested itself on our installation by buffer overflows, even when large objects were viewed. The possibility of obtaining good stereo displays while using the high refresh rate of the PS350 for flicker-free performance far outweighs this potential drawback.

PS300 CODE

The following code is easy to include in most PS300 networks that provide for stereo imaging to synchronize the Leeds shutters. The structures **LEFT_VIEW** and **RIGHT_VIEW** are assumed to be available and properly transformed, including any necessary text size, window, and viewport settings.

{*Produce a trigger object:* Text Size *overrides any current character size; character spacing is zero. Use red for the trigger color — the red phosphor is fast, the pickups are sensitive to red. The resolution in time is enough for a single vector in 3D.*}

```
trigger := begin_structure
    text size 0.03;
    set characters screen_oriented/fixed;
    set color 120, 1;
    characters 0, 0 step 0, 0   '*+@#O*+@#O';
end_structure;
```

{*Translate trigger to positions for triggering left and right views. Note: Viewport is set here, but a previous viewport of different size may be active and nest. Such viewports should be applied to their objects only.*}

```
left_trigger := begin_structure
    viewport horizontal = -1:1 vertical = -1:1;
    window x = -1:1      y = -1:1;
    translate by 0.87, -0.985 then trigger;
end_structure;
```

```
right_trigger := begin_structure
      viewport horizontal = -1:1      vertical = -1:1;
    window x = -1:1      y = -1:1;
    translate by 0.97, -0.985 then trigger;
end_structure;
```

{*Produce the synchronizing object: A vector list of 267 contiguous vectors. Vector length: Entire screen width (cf. above about viewport requirements). Deselect all scopes; we don't want to see this. Clipping would affect timing, hence disable.*}

```
sync_obj := begin_structure
    set displays all off;
    set depth_clipping off;
    set picking off;
    viewport horizontal = -1:1      vertical = -1:1;
    window x = -1:1      y = -1:1;
    sync_vectors := vector_list n = 268
        -1.00,  1.00     1.00,  1.00
        -1.00,  0.99     1.00,  0.99
        -1.00,  0.98     1.00,  0.98
           ... ...          ... ...
           ... ...          ... ...
        -1.00, -0.33     1.00, -0.33
    ;
end_structure;
```

{*Set contrast to 0.25: We need brightness, yet retain some depth cuing.*}

```
lview := set contrast to 0.25 then LEFT_VIEW;
rview := set contrast to 0.25 then RIGHT_VIEW;
```

{*Collect all in a single stereo_frame.*}

```
stereo_frame := instance of left_trigger, sync_obj, lview,
                            right_trigger, sync_obj, rview;
```

{*Where needed, display this final stereo frame. The Delay Knob on the Millenium controller must be at minimum position, entirely counterclockwise.*}

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