Parallel Image Generation for a 3D Display

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ABSTRACT

Two viewing models for a three dimensional display are presented and a simple parallel processing scheme is outlined.

1 Introduction

Two dimensional (2D) images produced by conventional displays lack two cues which are important for the perception of the third dimension. These are the disparity between the two images seen by the viewer's eyes and the change of image as the viewer's head moves. A number of attempts have been made at providing the missing cues, see [Hodg87] and [Coll87], but the techniques that have been proposed in the past are either hard (hence slow) to produce by computation (e.g. hologram), have a poor image quality (e.g. varifocal mirror) or are inconvenient to use (e.g. stereo glasses must be worn). A technique which promises to overcome the above drawbacks is being developed by one of us (see [Trav89]).

2 3D Display: Logical Operation

When an observer looks at a solid object, what he effectively receives are two 2D pictures formed on the back of his retina. His perception is of a 3D object consistent with these two views. As he moves round the object, these two pictures change. The aim of the display described here is to project a group of pictures in such a way that whatever his position the observer will see the same pictures as if he were looking at the original object.

Imagine photographing a series of views of a solid object from a series of positions at successive incremental angles to the central axis and all in the horizontal plane. These P views are transferred one by one to a display where each is briefly presented. Simultaneously an optical apparatus on the front of the display controls the optical output in such a way that the picture displayed is visible from a single (but variable) direction - the action of this apparatus can be likened to a set of vertical parallel shutters.

During the sequential display of pictures of the solid object the shutters are rotated at such a rate that each picture on the display is visible at the same angle from the central axis as that subtended by the camera when it took the original photograph. The optical apparatus used to perform the shuttering operation is in fact fairly fast, and the series of pictures can be repeated sufficiently quickly to eliminate the effects of flicker.

The result is a display showing a static parallax image similar to those found in laterally multiplexed (or "stereographic") holograms.

3 The Viewing Models

The 3D display provides a 3D view of a static 3D model; each of the P images of the 3D model is stored in a different frame buffer and is produced using a modified graphics output pipeline which we have constructed. Each of the P images of the 3D model is produced from a different viewpoint. The P viewpoints lie on the horizontal line which is parallel to the screen plane and which is contained in the horizontal plane through the screen centre, see figure 2 or 5. The angle between the line segments joining adjacent viewpoints to the screen centre is constant and there is an equal number of viewpoints in each of the two halfspaces defined by the vertical plane through the screen centre. The direction of view is defined by the directed line segment from a viewpoint to the screen centre; in the case of parallel projections this line segment defines the direction of projection.

Two alternative projections were tried. These are ***parallel oblique*** and ***perspective oblique*** and they place diffe[illegible] requirements on the 3D display hardware as will be shown. I[illegible]re 1 all shutters are shown rotated to the same angle from w[illegible] it is clear that, at the viewpoint shown, the eye will see through some range of shutters only. The picture seen will thus be a composite of several images presented to the screen viewed through a number of different shutter positions. If the shutters were numerous and the view angles closely defined, the images which should be presented on the screen are parallel oblique projections. A different case shown in figure 4, allows the shutters to take up individually different angles so that the viewer can see the whole of a single image at each viewing position. In this case we want perspective oblique projections.

The geometry of the parallel oblique projection is shown in figures 2 and 3. The eye coordinates (x_e, y_e, z_e) of a point will be transformed into the following screen space coordinates:

$$x_s = x_e / sin\Theta$$

$$y_s = (d - d_1) \cdot y_e / z_e$$

where $d_1 = x_s \cdot cos\Theta$. Notice the absence of d in the equation for x_s. With parallel oblique projections, horizontal parallax will be correctly maintained if the viewer moves further from, or nearer to the screen. The y coordinates are perspectively projected and the combined effect is that there is a projection axis (the horizontal X_{eye} axis of figure 3) rather than a projection point.

When this approach is used, some objects may show a jagged appearance because the finite number of images (P) will be calculated for discrete changes in the projection angle Θ and a particular view will consist of a number of vertical strips from different images. For example, for a typical 20 degree field of view the viewer would see parts of 10 of the total number of images if these were spaced by 2 degrees.

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In the case of the perspective oblique projection the geometry is as shown in figures 5 and 6. A simple calculation shows that the eye coordinates (x_e, y_e, z_e) of a point will be mapped onto the following screen space coordinates:

$$x_s = d \cdot x_e / (z_e \cdot sin\Theta + x_e \cdot cos\Theta)$$

$$y_s = (d - d_1) \cdot y_e / z_e$$

where $d_1 = x_s \cdot cos\Theta$.

4 Parallel Image Generation

Updating each of the P frame buffers is a matter of performing the operations of the graphics output pipeline on the object data base using new viewing (and perhaps modelling and lighting) parameters. These operations are computationally expensive. Using Phong shading it takes several seconds to perform the above operations on a data base consisting of a few thousand polygons on a T800 floating point transputer [INMO88]. Fortunately the computation of each of the P images is completely independent of the others and they can therefore all be computed in parallel using P processors in the time it takes to compute a single image.

To this effect, we propose the close-coupling of P T800 transputers with each of the P frame buffers. This can be achieved by using Video Random Access Memory (VRAM) for the part of the memory of each transputer corresponding to the frame buffer. Each transputer must also have sufficient memory to store the entire object data base plus a copy of the graphics output pipeline code. The transputers must be connected in a sensible manner (e.g. tree) to allow the broadcasting of the viewing parameters. These parameters consist of 3 vectors: *from*, the viewpoint, *at*, the screen centre and *up*, the view up vector. These can be augmented to include lighting and modelling parameters. In any case these parameters only occupy a few tens of bytes and can be broadcast very rapidly through the 10Mbit/sec transputer links. Each transputer must vary the value of the *from* parameter according to the view angle Θ for which it is responsible. Notice that no local communication between the transputers is required.

5 Further Work

We intend to simulate the effect of parallel oblique projections when used in conjunction with parallel shutters, by appropriately merging vertical strips from each of the P different parallel projections, in order to produce the image that would be visible from a particular viewpoint.

Animators have been looking into techniques for exploiting frame-to-frame coherence for some time. A substantial effort has been directed at reducing the computational cost of hidden surface elimination [Hubs82] and some recent approximate techniques are aimed at reducing the cost of ray-tracing animation sequences [Badt88]. However the P projected images of the 3D display offer more scope for exploiting incremental techniques than the frames of an animation for two reasons: first there is a regular difference between the viewpoints of the P images of the 3D display, and second the relative positions of the objects in the model are the same for all P images (i.e. the modelling transformations are the same for all P projections). However, incremental techniques may not be very useful when the P images are computed in parallel because data dependencies between the computations of adjacent images will be introduced.

6 Conclusions

We have presented two viewing models for an experimental three dimensional display. The parallel oblique projections may produce a jagged effect when P is small but will correctly maintain the horizontal parallax effect for a range of distances between screen and viewer. With the aid of parallel processing the time required to change the 3D image will be comparable with the time taken to alter the image on a conventional display.

Acknowledgement

We would like to thank Michael Hearn whose rendering program we modified in order to produce the oblique projections of the teapot and the simulation.

References

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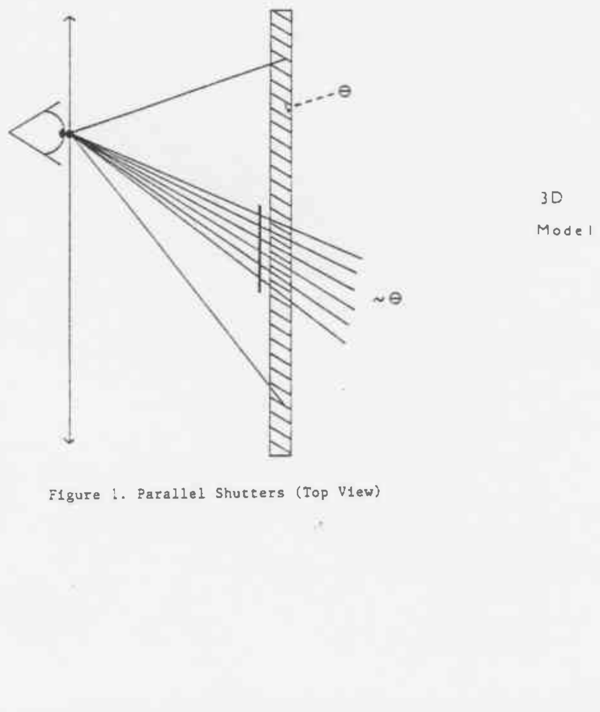

Figure 1. Parallel Shutters (Top View)

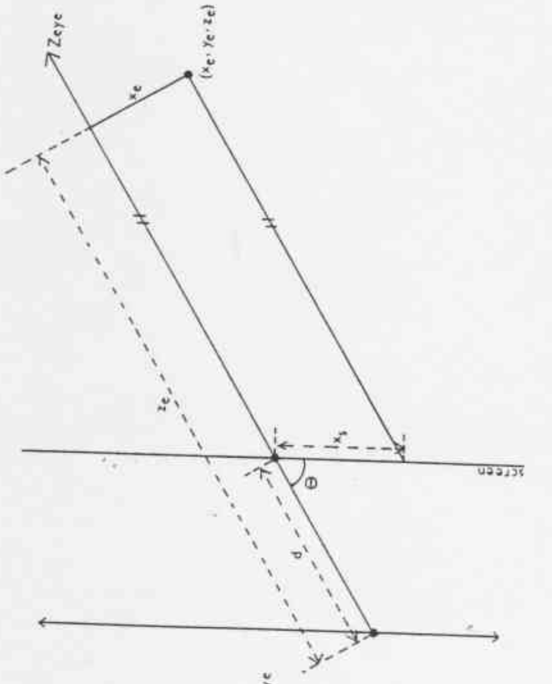

Figure 2. Parallel Oblique Projection; Geometry of x_s

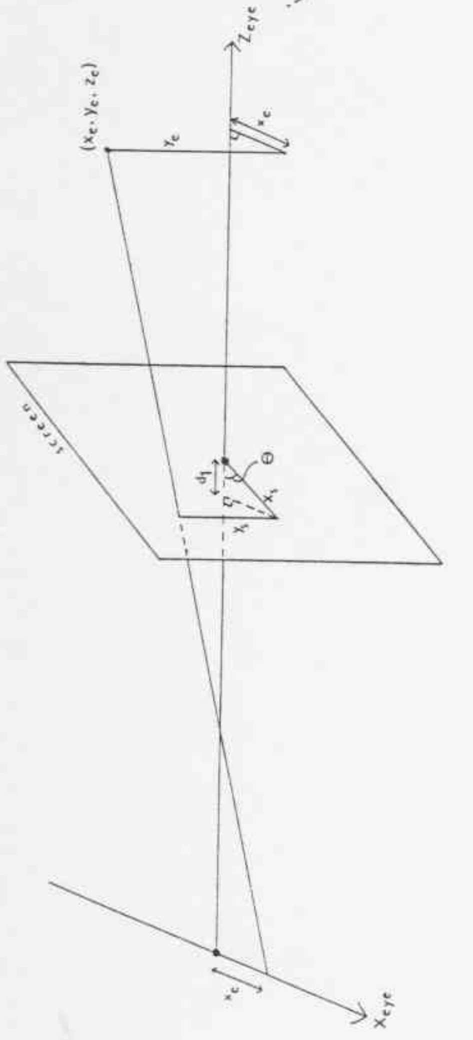

Figure 3. Parallel Oblique Projection; Geometry of y_s

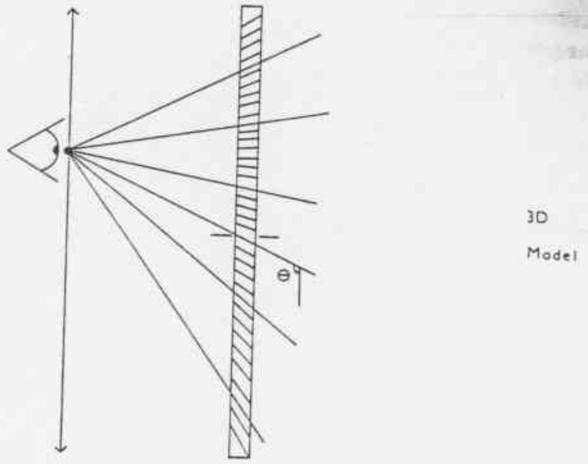

Figure 4. Perspective Shutters (Top View)

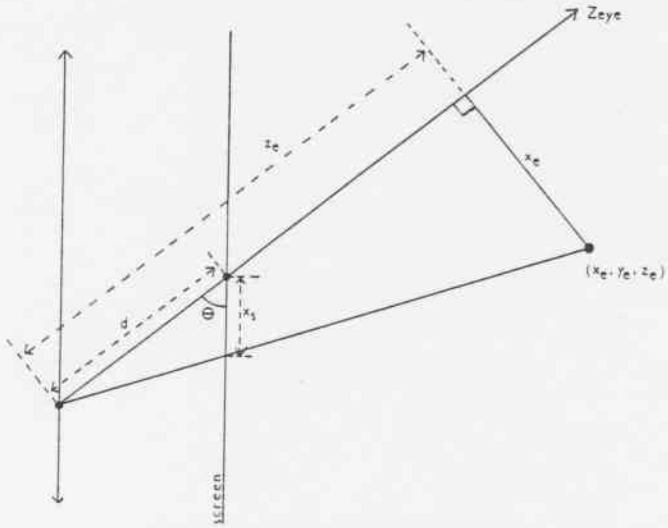

Figure 5. Perspective Oblique Projection: Geometry of x_s

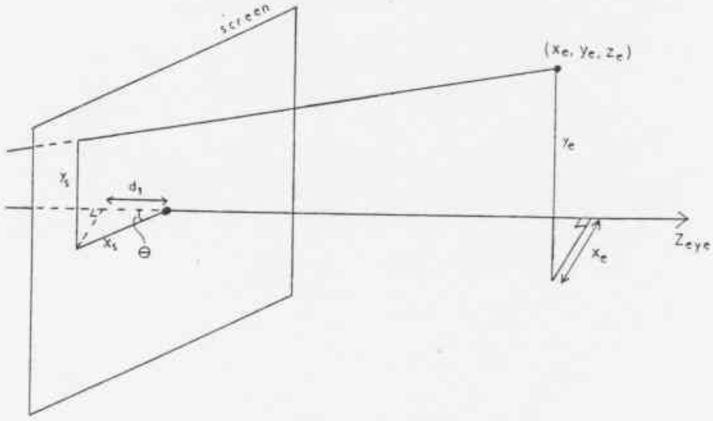

Figure 6. Perspective Oblique Projection: Geometry of y_s