Stereographics

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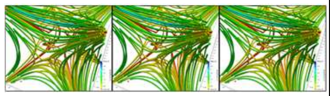
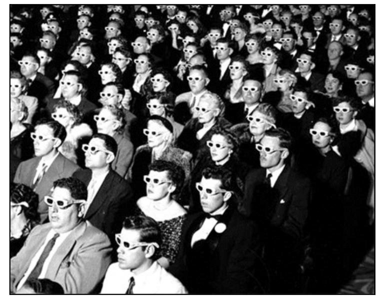


Stereovision is not new – It's been in common use in the movies since the 1950s



Life Magazine

Hard to believe that people used to dress like this to go see a movie…

And, even longer than that in stills

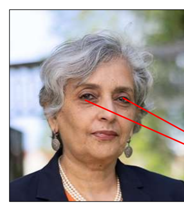
Newport Maritime Museum

Portland Art Museum's Ansel Adams Exhibit

Binocular Vision

In everyday living, part of our perception of depth comes from the slight difference in how our two eyes see the world around us. This is known as *binocular vision*.

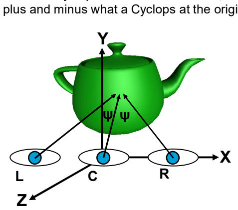
We care about this, and are discussing it, because stereo computer graphics can be a great help in de-cluttering a complex 3D scene. It can also enhance the feeling of being immersed in a movie.



OSU's 16th President Dr. Jayathi Murthy

The Cyclops Model

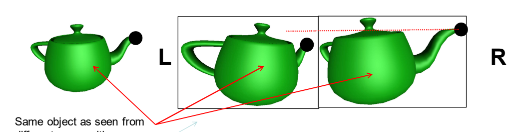
In the world of computer graphics, the two eye views can be reconstructed using standard projection mathematics. The simplest approach is the *Cyclops Model*. In this model, the left and right eye views are obtained by rotating the scene plus and minus what a Cyclops at the origin would see



The left eye view is obtained by rotating the scene an angle +ψ about the Y axis. The right eye view is obtained by rotating the scene an angle -ψ about the Y axis. In practice, if you wanted to do this (and you don't), a good value of ψ would be 1-4°.

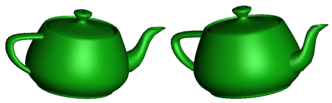
The Vertical Parallax Problem

This seems too simple, and in fact, it is. This works OK if you are doing orthographic projections, but if you use perspective, you will achieve a nasty phenomenon called ***vertical parallax***, as illustrated below:

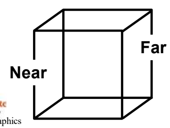


The fact that the perspective shortening causes the black-dot point to have different vertical positions in the left and right eye views makes it very difficult for the eyes to converge the two images. For perspective projections, we need a better way.

The Vertical Parallax Problem



Why not just keep using orthographic projections? Mathematically this is fine, but in practice, the two depth cues, stereo and no-perspective, fight each other. This will bring on an optical illusion. A good example of this is a simple cube, drawn below using an orthographic projection:



Because of the use of stereographics, the *binocular cues* will say that the Near face is closer to the viewer than the Far face is.

However, our *visual experience* reminds us that the only way a far object can appear the same size as a near object is if it is, in fact, larger. Thus, your visual system will perceive the Far face as being larger than the Near face, when in fact they are the same size.

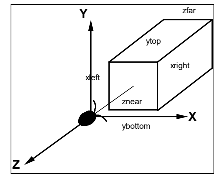
Diversion #1 – Specifying the Viewing Frustum

The OpenGL **glFrustum** call can be used to ask for a perspective projection in place of the **gluPerspective** call:

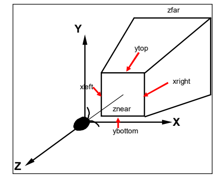
glFrustum(left, right, bottom, top, near, far);

This is meant to look a lot like the **glOrtho( )** call.

In the glFrustum case, the values of **left**, **right**, **bottom**, and **top** are now the boundaries of the viewing volume on the **face of the near clipping plane**. **near** and **far** are the same as used in glOrtho and gluPerspective.



glOrtho(xl, xr, yb, yt, zn, zf);



glFrustum(xl, xr, yb, yt, zn, zf);

Diversion #1 – Specifying the Viewing Frustum

glFrustum(left, right, bottom, top, near, far);

But rather than having to specify the left, right, bottom, and top limits at the face of the near clipping plane (which is what **glFrustum** expects), let's setup a way to specify those limits at some convenient distance in front of us. (This is derived using similar triangles.)

```
void
FrustumZ( float left, float right, float bottom, float top, float znear,   float zfar,   float zproj )
{
        if( zproj != 0.0 )
        {
                left     *= ( znear/zproj );
                right    *= ( znear/zproj );
                bottom   *= ( znear/zproj );
                top      *= ( znear/zproj );
        }

        glFrustum( left, right, bottom, top, znear, zfar );
}
```

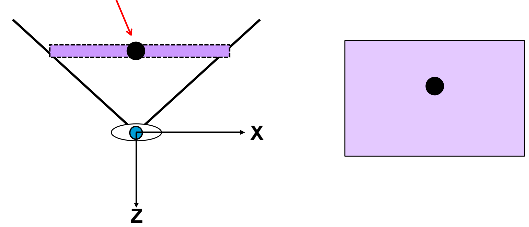
A convenient distance in front of the eye to set the left, right, bottom, and top values

So, if you wanted to view a car from 30 feet away, you could say:

FrustumZ(-10., 10., -10., 10., .1, 100., 30.);

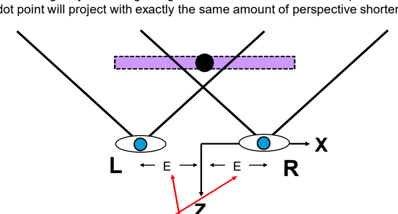
Diversion #2 – Where does a 3D Point Map to in a 2D Window?

Take an arbitrary 3D point in the viewing volume. Place a plane parallel to the near and far clipping planes at its Z value (i.e., depth in the frustum). The location of the point on that plane shows proportionally where the 3D point will be perspective-mapped from left to right in the 2D window.



Two Side-by-side Perspective Viewing Volumes

The best stereographics work is done with perspective projections. To avoid the vertical parallax problem, we keep both the left and right eyes looking straight ahead so that, in the vertical parallax example shown before, the block-dot point will project with exactly the same amount of perspective shortening.



The left eye view is obtained by translating the eye by -E in the X direction, which is actually accomplished by translating the scene by +E instead. Similarly, the right eye view is obtained by translating the scene by -E in the X direction.

Two Side-by-side Perspective Viewing Volumes

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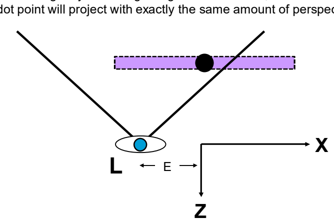

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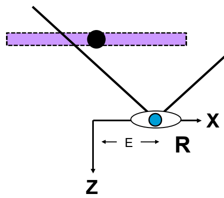
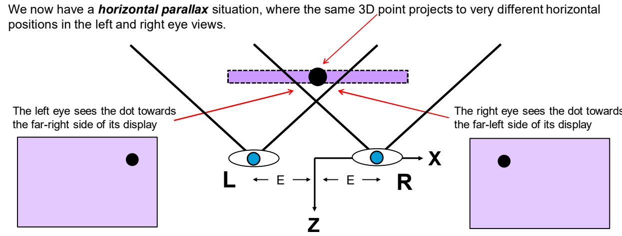


Two Side-by-side Perspective Viewing Volumes

We now have a ***horizontal parallax*** situation, where the same 3D point projects to very different horizontal positions in the left and right eye views.

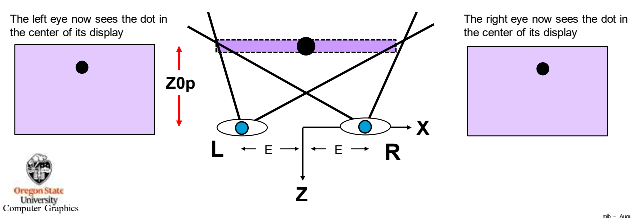


Note that this is a *situation*, not a *problem*. The difference in the left and right eye views requires at least *some* horizontal parallax in order to work for stereographics. You can convince yourself of this by alternately opening and closing your left and right eyes. We just need a good way to *control* the horizontal parallax to keep it convergeable by your eyes.

Two Side-by-side Non-symmetric Perspective Viewing Volumes

We do this by moving the sides of each eye's viewing volume to match the left and right boundaries of the cyclops-eye's viewing volume. We also define a distance in front of the eye, ***z0p***, to the ***plane of zero parallax***. This is where our 3D dot now projects to the ***same location for each eye's display.***

To the viewer, the plane of zero parallax will be the glass monitor screen and objects in front of it will appear to live in the air in front of the glass screen and objects behind this plane will appear to live inside the monitor.

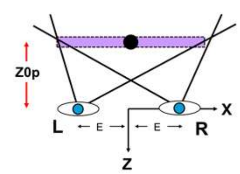


Two Side-by-side *Non-symmetric* Perspective Viewing Volumes

Use the Cyclops's left and right boundaries as the left and right boundaries for each eye, even though the scene has been translated. In the left eye view, the boundaries must then be shifted by +E to match the +E shift in the scene. In the right eye view, the boundaries must be shifted by -E to match the -E shift in the scene.

Looking from the Cyclops eye at the origin, determine the left, right, bottom, and top boundaries of the viewing window on the plane of zero parallax as would be used in a call to glFrustum( ). These can be determined by knowing Z0p and the original field-of-view angle Φ:

Left eye viewing volume:
$L0p = -Z0p * \tan(\phi/2) + E$
$R0p = Z0p * \tan(\phi/2) + E$



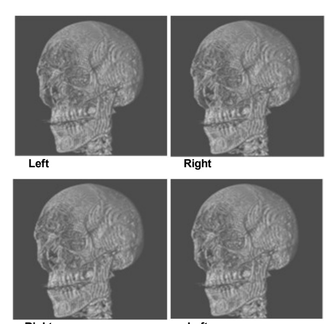
Right eye viewing volume:
$L0p = -Z0p * \tan(\phi/2) - E$
$R0p = Z0p * \tan(\phi/2) - E$


```
void
Stereopersp( float fovy, float aspect, float znear, float zfar, float z0p, float eye )
{
	float left, right;	// x boundaries on z0p
	float bottom, top;	// y boundaries on z0p
	float tanfovy;		// tangent of y fov angle

	// tangent of the y field-of-view angle:

	tanfovy = tan( fovy * (M_PI / 180.) / 2. );

	// top and bottom boundaries:

	top = z0p * tanfovy;
	bottom = -top;

	// left and right boundaries come from the aspect ratio:

	right = aspect * top;
	left = aspect * bottom;

	// take eye translation into account:

	left -= eye;
	right -= eye;

	// ask for a window in terms of the z0p plane:

	FrustumZ( left, right, bottom, top, znear, zfar, z0p );

	// translate the scene opposite the eye translation:

	glTranslatef( -eye, 0.0, 0.0 );
}
```


An Example

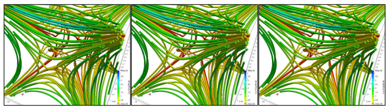
Parallel viewing stereo

Cross-eye viewing stereo



Oftentimes, Stereographics Images are printed like this so that both Parallel and Cross-eyed Viewing will Work

L R L



Print this page and cut out the left two images

Note to self: don't resize these images, as much as you are tempted to – they fit perfectly in ypur viewer as they are now.

Acquiring Stereo Photos Yourself: A Two-camera Mounting Bar

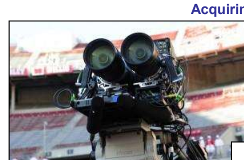
Places to mount this bar to a tripod

Places to mount two cameras

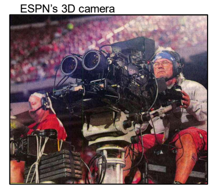
Acquiring Stereo Photos Yourself: A Digital Stereo Camera

Two lenses

Acquiring Stereo Video



ESPN's 3D camera

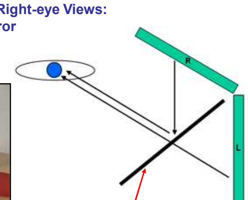


ESPN's 3D camera

Panasonic's 3D Camcorder

Separating the Left and Right-eye Views: The View-Master

Separating the Left and Right-eye Views: Stereo Mirror

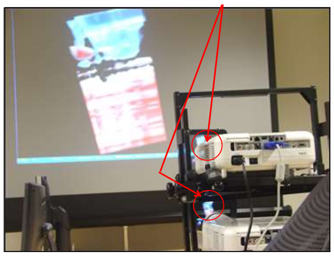


Half-silvered mirror

An interesting property of mirrors is that the reflection rotates the polarization by 90º so that the two images can be separated by polarized glasses.

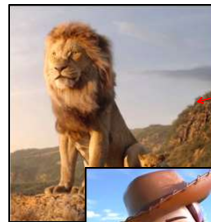
Separating the Left and Right-eye Views: Dual Projectors ("GeoWall")

Two filters statically provide the polarization



Separating the Left and Right-eye Views: Stereo Movie Projectors

For movies and sporting events



Separating the Left and Right-eye Views: Stereo Movie Projectors

AMC Theater, Corvallis

Circularly polarized glasses

One filter dynamically provides the polarization (L-R-L-R-L-R per $^{1}/_{24}$ sec frame).
These are the projectors and glasses that the Corvallis AMC movie theater uses.

Separating the Left and Right-eye Views: Head-mounted Goggles

Separating the Left and Right-eye Views: VR Headsets

Uses an accelerometer and a gyroscope to determine the head position and the head orientation

http://theriftarcade.com

Uses shaders to get the correct fisheye lens distortion

Separating the Left and Right-eye Views – View-Master Viewer for your Cell phone

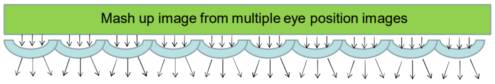
Uses the phone's gyroscope to know the head orientation

Uses a moving magnet and the phone's digital compass to perform a "left-click"

SideKick

Uses shaders to get the correct fisheye lens distortion

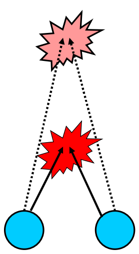
Separating the Left and Right-eye Views: Lenticular

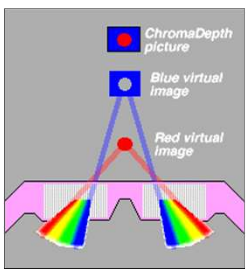


Stereographics Rules of Thumb

- Stereographics is especially good for de-cluttering wireframe displays.
- Use perspective, not orthographic, projections to avoid the optical illusion.
- Use an eye separation, E, of approximately: $E = Z0p * tan(1^\circ - 4^\circ)$
- Use the far clipping plane well. The stereo effects are enhanced when the scene is not complicated by a lot of tiny detail that is far away. The interactive response is improved too.
- Because you are drawing the scene twice, using display lists is especially important.
- It is fun to set Z0p = Zfar so that the image appears to be hanging out in the air in front of the monitor. However, in real life we rarely see anything hanging out in the air that has its sides clipped for no apparent reason, as your scene is likely to have. Perceptually, it is often better to set Z0p = Znear so that the entire scene looks like it is inside the monitor and that you are viewing it through a rectangular hole cut through the glass. This situation is common in everyday life, so we are used to seeing things that way. Personally, I like putting Z0p about 1/3 of the way through the scene.
- Intensity depth cueing (glFog) nicely enhances the stereo illusion. This also lets you bring the far clipping plane in closer.
- If you are using texture mapping, be sure to use GL_LINEAR, not GL_NEAREST, for the texture filtering.

Encoding Stereo in a Single Image – ChromaDepth™





http://cs.oregonstate.edu/~mjb/chromadepth

Encoding Stereo in a Single Image – ChromaDepth™