Stereographics

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

And, in stills, even longer than that

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.
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. Looking at everything from the top:

The left eye view is obtained by rotating the scene an angle +Ø about the Y axis. The right eye view is obtained by rotating the scene an angle -Ø about the Y axis. In practice, a good value of Ø is 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 points A and B 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.

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 is the Far face. However, our visual experience says 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 in place of `gluPerspective`:

```
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`. 
Diversion #1 – Specifying the Viewing Frustum

```c
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);
}
```

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

```c
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, points A and B will project with exactly the same amount of shortening.

Two Side-by-side Perspective Viewing Volumes

We do this by defining a distance in front of the eye, z0p, to the plane of zero parallax, where a 3D point projects to the same window location for each eye. To the viewer, the plane of zero parallax will be the glass 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. The plane of zero parallax is handled by:

1. Set the distance from the eyes to the plane of zero parallax based on the location of the geometry and the look you are trying to achieve.
2. 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 field-of-view angle Φ.
Two Side-by-side Non-symmetric Perspective Viewing Volumes

Cyclops eye:
\[ L_{0p} = -Z_{0p} \cdot \tan(\frac{\theta}{2}) \]
\[ R_{0p} = Z_{0p} \cdot \tan(\frac{\theta}{2}) \]
\[ B_{0p} = -Z_{0p} \cdot \tan(\frac{\theta}{2}) \]
\[ T_{0p} = Z_{0p} \cdot \tan(\frac{\theta}{2}) \]

Left eye:
\[ R_{0p} = Z_{0p} \cdot \tan(\frac{\theta}{2}) + E \]
\[ L_{0p} = -Z_{0p} \cdot \tan(\frac{\theta}{2}) + E \]

Right eye:
\[ R_{0p} = Z_{0p} \cdot \tan(\frac{\theta}{2}) - E \]
\[ L_{0p} = -Z_{0p} \cdot \tan(\frac{\theta}{2}) - E \]

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.

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 the viewer as they are now.

ESPN’s 3D camera
Panasonic’s 3D Camcorder

Acquiring Stereo Video

Quad-Buffered OpenGL

Remember double buffering, where you draw into the back buffer and display from the front buffer? OpenGL actually has two back buffers and two front buffers, one for each eye. So, draw the left eye view into GL_BACK_LEFT and the right eye view into GL_BACK_RIGHT. First you need to tell GLUT that you are doing stereo graphics. In InitGraphics():

```c
glutInitDisplayMode( GLUT_RGBA | GLUT_DOUBLE | GLUT_DEPTH | GLUT_STEREO );
```

Then go ahead and create the window as normal. After creating the window, you can also expand it to be the full screen with:

```c
glutFullScreen(  );
```

In Display(), you need to clear both buffers:

```c
glDrawBuffer( GL_BACK_LEFT );
glClear( GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT );
glDrawBuffer( GL_BACK_RIGHT );
glClear( GL_COLOR_BUFFER_BIT | GL_DEPTH_BUFFER_BIT );
```

In Display(), you also need to draw into both back buffers:

```c
for( int eye = 0; eye <= 1; eye++ )
{
glMatrixMode( GL_PROJECTION );glLoadIdentity();
if( eye == 0 )  // left eye view
{
    glDrawBuffer( GL_BACK_LEFT );
    Stereopersp( fovy, 1.0, znear, zfar, z0p, - eyesep );
}
else          // right eye view{
    glDrawBuffer( GL_BACK_RIGHT );
    Stereopersp( fovy, 1.0, znear, zfar, z0p,   eyesep );
}
    glMatrixMode( GL_MODELVIEW );
    glLoadIdentity(  );
    // draw the 3D scene >>
}
glutSwapBuffers(  ); // this goes outside the eye loop!
```
Separating the Left and Right-eye Views – Shutterglasses

Infrared transmitter to synchronize the left-right of the glasses to the left-right of the screen refresh.

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

Separating the Left and Right-eye Views – the Stereo Mirror

Two filters statically provide the polarization.

Separating the Left and Right-eye Views – Dual Projectors (“GeoWall”)
Separating the Left and Right-eye Views – Stereo Movie Projectors

For movies and sporting events

One filter dynamically provides the polarization (L-R-L-R-L-R per 1/24 sec frame)

Circularly polarized glasses

AMC Theater, Corvallis