Stereographics

And, even longer than that in stills

Binocular Vision

The Cyclops Model

The Vertical Parallax Problem
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 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 persuade 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:

```c
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.

```
void Frustum2( float left, float right, float bottom, float top, float near, float far )
{
  if( far != 0.0 )
    glFrustum( left, right, bottom, top, near, far );
  else
    if( far < 0.0 )
      { 
        near *= ( far/near );
        right *= ( far/near );
        bottom *= ( far/near );
        top *= ( far/near );
      }
    glFrustum( left, right, bottom, top, near, far );
}
```

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

```c
Frustum2( -10., 10., -10., 10., .1, 100. );
```

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.

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.

```
void Frustum2( float left, float right, float bottom, float top, float near, float far )
{
  if( far != 0.0 )
    glFrustum( left, right, bottom, top, near, far );
  else
    if( far < 0.0 )
      { 
        near *= ( far/near );
        right *= ( far/near );
        bottom *= ( far/near );
        top *= ( far/near );
      }
    glFrustum( left, right, bottom, top, near, far );
}
```

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

```c
Frustum2( -10., 10., -10., 10., .1, 100. );
```

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 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.

The OpenGL call can be used in place of gluPerspective:

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

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.
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.

Cyclops eye:

- $L_{Ip} = -Z_{0p} \cdot \tan(\frac{\phi}{2})$
- $R_{Ip} = Z_{0p} \cdot \tan(\frac{\phi}{2})$
- $B_{Ip} = -Z_{0p} \cdot \tan(\frac{\phi}{2})$
- $T_{Ip} = Z_{0p} \cdot \tan(\frac{\phi}{2})$

Left eye:

- $R_{Ip} = Z_{0p} \cdot \tan(\frac{\phi}{2}) + E$
- $L_{Ip} = -Z_{0p} \cdot \tan(\frac{\phi}{2}) + E$

Right eye:

- $R_{Ip} = Z_{0p} \cdot \tan(\frac{\phi}{2}) - E$
- $L_{Ip} = -Z_{0p} \cdot \tan(\frac{\phi}{2}) - E$

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.

### Code Snippet

```c
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);
}
```

### Diagram

- **Parallel viewing stereo**
- **Cross-eye viewing stereo**

### Notes

- Oftentimes, Stereographics Images are printed like this so that both Parallel and Cross-eyed Viewing will Work
- Acquiring Stereo Photos Yourself
- Print this page and cut out the left two images
- Place to mount this bar to a tripod
- Place to mount two cameras
Acquiring Stereo Photos Yourself

Two lenses

Acquiring Stereo Video

ESPN's 3D camera

Panasonic's 3D Camcorder

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():

```
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:

```
glutFullScreen(  );
```

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

```
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 );
```

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 >>
}
```

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

```
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 >>
}
```

Separating the Left and Right-eye Views – Shutterglasses

Uses an 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

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

Separating the Left and Right-eye Views – VR Headsets

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

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 shaders to get the correct fisheye lens distortion
Separating the Left and Right-eye Views

Left-Right 3DTV
Shutterglasses

Top-Bottom 3DTV
Shutterglasses

Interlaced 3DTV
Shutterglasses

Red-Cyan Anaglyphs

Encoding Stereo in a Single Image – ChromaDepth™
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: \[ E = Z_0p \cdot \tan\left(\frac{1}{4^\circ}\right) \]
• 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 \( Z_0p = Z_{far} \) 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 the scene is likely to have. Perceptually, it is often better to set \( Z_0p = Z_{near} \) 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.
• Intensity depth cueing (gFLog) nicely enhances the stereo illusion.
• If you are using texture mapping, be sure to use GL_LINEAR, not GL_NEAREST, for the texture filtering.

From what you now know, real stereo images have to be generated from the original data – they cannot be as effectively retro-generated from a mono image, at least not without a lot of work.

Beware the multiple plane effect!

Watch out for a lot of monoscopic movies being “re-released” in stereo!