# Perspective Projections, OpenGL Viewing, 3D Clipping

CS116A
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# Outline

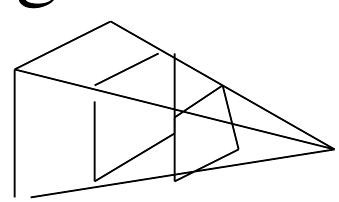
- Perspective projections
- OpenGL Viewing
- 3D Clipping

# Vanishing Points for Perspective Projections

- A point is a perspective scene where all lines not parallel to the view plane intersect is called a **vanishing point**
- When the set of lines is parallel to one of the axes then vanishing point is called a **principle vanishing point**.
- Can have 1, 2, 3 vanishing points and we can control this by the position of the projection plane

# View Volume

- We can create a view volume by specifying a rectangular clipping window on the view plane.
- Bounding planes are now not parallel. Get a shape called a pyramid of vision and  can truncate this by specifying near and far planes to get a frustrum.



# Perspective Projection Transformation Matrix

- Want to use our equations for xp, yp and zp of last day to get a matrix.
- Need to use homogeneous coordinates:
- Let xp = xh/h, and yp =yh/h where h =zprp-z.
- Here xh and yh are obtained from x and y as
- xh = x(zprp -zvp) + xprp(zvp -z)
- yh = y(zprp - zvp) +yprp(zvp -z).

# Matrix

- Now can map (x,y,z, 1) to the projected point in homogeneous coordinates (xh,yh,zh,1) with the matrix:

$$\begin{bmatrix} zprp - zvp & 0 & -xprp & xprp*zprp \\ 0 & zprp-zvp & -yprp & yprp*zprp \\ 0 & 0 & sz & tz \\ 0 & 0 & -1 & zprp \end{bmatrix}$$

- Here sz and tz are scaling and translation factors to go to normalized cube

# Symmetric Perspective Projection Frustrum

- The line from the projection reference point through the center of the clipping window, and through the view volume, is called the centerline.
- If this is perpendicular to the view plane then we have a **symmetric frustrum.**
- In this case, can say have a field of view angle. Have zprp -zvp = width*cot(theta/2)/2*aspect

# Normalized Perspective-Projection Transformation Coordinates

- To get into our normalized cube we have already done a scaling in z axis. To get the x and y coordinates in range need to apply a scaling.

$$\begin{bmatrix} sx & 0 & 0 & 0 \\ 0 & sy & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

- The equations for these scalling are sx = 2/xwmax -xwmin, similar for y. sz = znear+zfar/znear-zfar

and tz = 2*znear*zfar/(znear-zfar)

# 3D Screen Coordinates

- We now want to map info to screen coordinates.
- However, still want to keep z-info around (now normalized between 0 and -1), so it can be used in surface removal, etc.
- Map to viewport is thus kept as 3D and given by:

$$\begin{bmatrix} xvmax - xvmin/2 & 0 & 0 & xvmax + xvmin/2 \\ 0 & yvmax - yvmin/2 & 0 & yvmax + yvmin/2 \\ 0 & 0 & 1/2 & 1/2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

# OpenGl 3D Viewing Functions

- To specify where in world coordinates to look at a  scene need to enter view matrix mode:

  glMatrixMode(GL_MODELVIEW);

- Then can do:

  gluLookAt(x0, y0, z0, xref, yref, zref, Vx, Vy, Vz);

- The last three are the direction of view-up.

# OpenGL Orthogonal Projection Function

- Must be in projection mode to set up projection matrices. So do:

  glMatrixMode(GL_PROJECTION);
- To set up an orthogonal projection can do:

  glOrtho(xwmin, xwmax, ywmin, ywmax, dnear, dfar);

  each parameter is a double.
- Near plane is also the view plane.
- If dfar is 55 then point with z value < -55 clipped.
- Default parameters are -1 or 1 for each of the parameters listed above.
- No OpenGL function for oblique projections

# OpenGl Symmetric Perspective-Projection Function

- The GLU function:

  gluPerspective(theta, aspect, dnear, dfar);

  with each parameter a double sets up a symmetric, perspective projection.
- The angle can be between 0 and 180.
- The aspect specifies the width/height rations

# OpenGL General Perspective Projection Function

- To specify a perspective projection can use:
  glFrustrum(xwmin, xwmax, ywmin, ywmax,dnear, dfar);
- Numbers are double precision floats.
- Near and far clipping distances must be positive.
- The first four parameters say the coordinates of the clipping window on near plane.
- The clipping window can be specified anywhere on the near plane. So if xwmin = -xwmax and ywmin = - ywmax then get symmetric frustrum.
- If do not invoke projection command get orthogonal projection.

# OpenGL Viewports and Display Windows

- Finally setting the size of the viewport that projected points will appear in is specified in the same way as in the 2D case:

  glViewport(xvmin, yvmin, xvmax, yvmax);

# 3D Clipping

- As in the 2D case, in the 3D there are advantages to having normalized cube before clipping:
  - All device independent transformations are carried out before applying any clipping.
  - Each clip plane is parallel to one of the 3 axes regardless of the original shape of the view volume so can be optimized.
- Common choice of cubes are the **unit cube** which has extents between 0 and 1 and the **symmetric cube** has extents between -1 and 1.

# Clipping in 3D Homogeneous Coordinates

- In homogeneous coordinates (x,y,z) gets converted to (x,y,z, 1).
- After all our transformations and projections might have (x_h, y_h, z_h, h) where h is not 1. (Might happen because of perspective transformation).
- If divided away the factor h, would lose precision, so this is why want to do clipping in homogeneous coordinates

# 3D Regions Codes

- The concept of region code used in Cohen-Sutherland clipping can be extended to 3D. Need to use a 6 bit number now for all the regions:
  – bit 6- far, bit 5 - near, bit 4 - top, bit 3-bottom, bit 2 -right, bit 1 -left
- Conditions for setting bit same as in 2D case but now have 2 extra bits to set for each point.

# Assigning Bit Values

- Suppose we have a point $(x,y,z,h)$. Then

  bit 1 =1 if $h+x <0$

  bit 2 =1 if $h-x < 0$

  bit 3 =1 if $h+y <0$

  bit 4 = 1 if $h-y <0$

  bit 5 = 1 if $h+z <0$

  bit 6 = 1 if $h-z <0$

# 3D Point and Line Clipping

- A point is within the view volume if its region code is 000000. So this gives us an easy way to clip points.
- For lines, we can clip the whole line if when we AND the endpoint codes we get a 1 in the same bit position. We can accept the whole line if when we OR the codes we get 000000.
- Otherwise, we need to analyze the part of the line that needs to be saved.

# More line clipping

- Suppose the endpoint of our line are: P1=(x1,y1,z1,h1) and P2=(x2,y2,z2,h2).
- Can write points on line segment with P= P1+ (P2-P1)u for u between 0 and 1.
- Look for bits in the region code that are not the same. Know boundary crossed, and also in which coordinates. For example, maybe x.
- Then can solve for u to find point of intersection.
- If for instance crosed xmax = 1. Then know intersection point x/h must equal 1. So get: u=x1-h/((x1-h1) - (x2-h2))

# 3D Polygon Clipping

- Say want to intersect a tetrahedron with our view volume.
- First check if its coordinate extents lie completely within the view volume or if its coordinates lie completely outside one of the clipping boundaries.
- If not, go through each edge in the object, clip and to obtain a new vertex lists, edge lists for the clipped object.
- Then might have to add new faces to our face list
- If object is made of triangle strips process easier as can then use Sutherland-Hodgman

# 3D Curve Clipping

- First check if the coordinate extents of curved object are completely inside the view volume.
- Then check if object is completely outside any one of the six clipping planes.
- If this accept/reject test fails, then we locate intesections with clipping plane.
- This involves solving simultaneous surface and clipping plane equations.
- This can be hard so polygon patches are often used to approximate curved surfaces

# Arbitrary Clipping Planes

- Might also want  to clip to arbitrary planes.
- Might be  used for cross-sectional view.
- Can specify a plane with $Ax+By+Cz+D=0$
- Objects behind the plane, for instance point $(x,y,z)$ with $Ax+By+Cz+D<0$ are the ones that are usually clipped.

# OpenGL Optional Clipping Planes

- One can specify additional clipping planes for a scene than those of the view volume with:

```
glDouble planeCoeffs[] ={1.0, 2.0, 3.0, 4.0};
   //A=1, B,=2, C=3, D =4
glClipPlane(GL_CLIP_PLANE0, planeCoeffs);
```

- To use this plane can use glEnable(GL_CLIP_PLANE0); and glDisable to stop using
- There are also planes 1,2… Tod find out how many use: glGetIntegerv(GL_MAX_CLIP_PLANES, numPlanes);