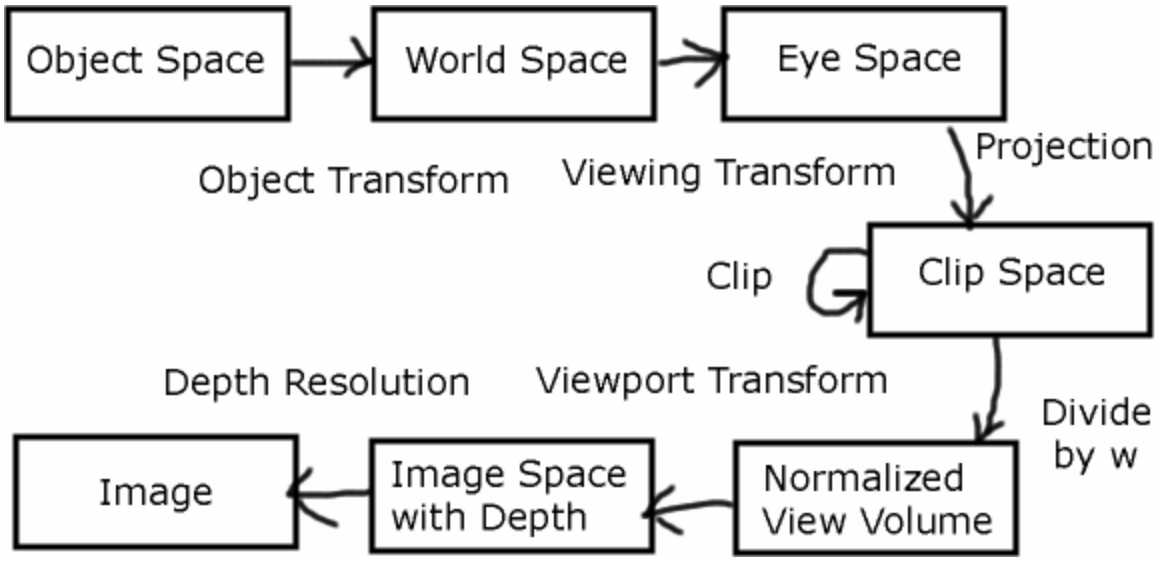
CSC 418/2504 Computer Graphics
Tutorial 5 Notes, October 15, 17

Review of the Graphics Pipeline
3D Clipping
OpenGL Pipeline

The Graphics Pipeline



Object Transformation Matrix (review, see tutorial 3 and class notes):
series of rotations, scales, shears, and translations as a single matrix

Camera Transform (review, see tutorial 3 and class notes):
inverse of the matrix that brings camera to its world space position, followed by a z reflection, since the camera has a left handed coordinate system. This is equivalent to translation and followed by a change of basis to the camera's space.

Projection (review, see tutorial 3 and class notes):
warps viewing frustum to a rectangular volume
Orthographic: scale in three dimensions
Perspective: depth dependent scale for x and y,
nonlinear change in z

end result for visible points: $x \in [-w, w]$
$y \in [-w, w]$
$z \in [0, w]$

Clipping: clip all polygons to rectangular view volume
straightforward extension of 2D clipping (see next section)

Divide by w: change to normalized view volume
$x \in [-1,1]$
$y \in [-1,1]$
$z \in [0,1]$

Viewport Transform: translation and scale to fit window

Resolve Visibility (see class notes and tutorial 2):
z-buffer, polygon scan conversion, bsp tree, etc.

3D Clipping:

Why not before projection?
If projection is orthographic, it would require clipping by axis aligned planes, no additional expense.
If projection is perspective, it would require clipping by arbitrary planes in space, more expensive
Choose after projection for general efficiency.

Why not after divide by w?
After this operation, points behind us are reflected through eye; many can become unintentionally visible.
Consider the visible eye space point $\mathbf{p}_V = [-x, -y, 1, 1]^T$ and the eye space point $\mathbf{p}_B = [x, y, -1, 1]^T$, behind us, along with the simple perspective projection matrix:

$$\mathbf{M} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1/d & 0 \end{bmatrix}$$

After projection

$$\mathbf{p}_V' = [-x, -y, 1, 1/d]^T$$
$$\mathbf{p}_B' = [x, y, -1, -1/d]^T$$

After divide by w, we have the same point:

$$\mathbf{p}_{\mathbf{V}}' = [-xd, -yd, d, 1]^{\mathbf{T}}$$

$$\mathbf{p}_{\mathbf{B}}' = [-xd, -yd, d,]^{\mathbf{T}}$$

Extension of 2D Clipping:

Bitwise labeling of points: Extend to six bits. Additional two represent $z < 0$ and $z > w$. Use the same rejection and acceptance tests.

Clip against six axis-aligned planes instead of 4:

$$x = -w, x = +w, y = -w, y = w, z = 0, z = +w$$

OpenGL Pipeline:

Modelview Matrix: object transform and eye space transform, see tutorial 3 notes for OpenGL commands
Projection Matrix: projection only, see tutorial 3 notes.
Clipping: internal to OpenGL
Divide by w: internal to OpenGL
Viewport Transform: calculated internally based on call to glViewport
Visibility Resolution: internal, typically z-buffer