Viewing Transformations

- How do we transform the 3D world to the 2D window?
- Concepts:
  - World Coordinates
  - View (or window) VOLUME
    - Need 3rd dimension later to get occlusions right
  - Viewing Coordinates
    - 3D viewing coordinates
- Separate Issues
  - Visibility (what’s in front)
  - Clipping (what is outside of the view volume)

Orthographic Projection

- Projection = transformation that reduces dimension
- Orthographic = flatten the world onto the film plane

Canonical View Volume

- -1 to 1 (zero centered)
- XY is screen (y-up)
- Z is towards viewer (right handed coordinates)
  - Negative Z is into screen
- For this reason, some people like left-handed
Orthographic Projection

- Rotate / Translate / Scale View volume
  - Can map any volume to view volume
- Sometimes pick skews
- Things far away are just as big
  - No perspective
- Easy – and we can make measurements
  - Useful for technical drawings
  - Looks weird for real stuff
    - Far away objects too big

Perspective Projection

- Farther objects get smaller
- Eye (or focal) point
- Image plane
- View frustum (truncated pyramid)
- Two ways to look at it:
  - Project world onto image plane
  - Transform world into rectangular view volume (that is then orthographically projected)

Perspective

- Eye point
- Film plane
- Frustum
  - Simplification
    - Film plane centered with respect to eye
    - Site down negative Z axis
      - Can transform world to fit

Basic Perspective

- Similar Triangles
  - Warning = using d for focal length (like book)
    - F will be "far plane"
  - Project world onto image plane
    - Transform world into rectangular view volume (that is then orthographically projected)

Use Homogeneous coordinates!

- Use divide by w to get perspective divide
- Issues with simple version:
  - Font / back of viewing volume
  - Need to keep some of Z in Z (not flatten)

\[
\begin{bmatrix}
    x' \\
    y' \\
    z' \\
    w'
\end{bmatrix} = \begin{bmatrix}
    1 & 0 & 0 & 0 \\
    0 & 1 & 0 & 0 \\
    0 & 0 & 1 & 0 \\
    0 & 0 & 1 & 1
\end{bmatrix}\begin{bmatrix}
    x \\
    y \\
    z \\
    w
\end{bmatrix} = \begin{bmatrix}
    x/z \\
    y/z \\
    z/z = 1 \\
    1
\end{bmatrix}
\]

The real perspective matrix

- N = near distance, F = far distance
- Z = n put on front plane, z=f put on far plane

\[
P = \begin{bmatrix}
    1 & 0 & 0 & 0 \\
    0 & 1 & 0 & 0 \\
    0 & 0 & n+f/n & 0 \\
    0 & 0 & -n & 0
\end{bmatrix}
\]
Shirley’s Perspective Matrix

• After we do the divide, we get an unusual thing for $z$ – it does preserve the order and keeps $n & f$

$$P_x = P\begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} x'z \\ y'z \\ n + f - \frac{fn}{z} \\ 1 \end{bmatrix}$$

Camera Model

• The “window coordinate” system is all we really know
• In a sense, it is the camera coordinate system
• Easiest to think about it as a camera taking a picture of the work
• Transform world coordinates into camera coordinates
  – Or, think about it the other way…

How to describe cameras?

• Rotate and translate (and scale) the world to be in view
• The camera is a physical object (that can be rotated and translated in the world)
• Easier ways to specify cameras
  – Lookfrom/at/vup