Viewing in 3D

Overview

- 3D Viewing Pipeline/Coordinate Systems
- Camera Specification and Transform
- View Volume
3D Viewing/Rendering Pipeline

- MC: Modeling Transform
- WC: Viewing Transform
- VC: Projection Transform
- PC: Normalization Transform & Clipping
- NC: Viewport Transform
- DC: Draw Call
Synthetic Camera Model

- Pin-hole camera model (all objects in perfect focus)
- A convenient, flexible approach to specifying viewing parameters.
- Allows operations such as fly-by, swivel, zoom and head-tilt through 3D environments.
- All specification in a viewing (camera or eye) coordinate system.
Camera Specification (simplified)

**In World Coordinates**

- View Point (viewer position or center of projection with view direction $\vec{N}$)
- View coordinate system defined with respect to view point.

**In View Coordinates**

- View plane onto which objects are projected to form a 2D image.
- View frustum (volume) which defines the field of view.
Alternative Specification

- *Window*, using field of view angles \((\theta_u, \theta_v)\) and \(d\), the distance to the projection plane.
Where is up?
A view reference point
A view plane normal vector
The view plane
A view up vector
A window in uv coordinates
This way up!
A viewing example
A viewing example
An example of 3D viewing
The Viewing Transformation

$M_{wv}$ maps

\[
\begin{bmatrix}
0, 0, 0 \\
\vec{X}, \vec{Y}, \vec{Z}
\end{bmatrix} \Rightarrow \begin{bmatrix}
\vec{X}, \vec{Y}, \vec{Z} \\
\vec{U}, \vec{V}, \vec{N}
\end{bmatrix}
\]

Hence

\[
\begin{align*}
\vec{U}^T &= \vec{M} \vec{X}^T = \text{left column of } \vec{M} \\
\vec{V}^T &= \vec{M} \vec{Y}^T = \text{middle column of } \vec{M} \\
\vec{N}^T &= \vec{M} \vec{Z}^T = \text{right column of } \vec{M}
\end{align*}
\]
The Viewing Transformation

\[ M = \begin{bmatrix} \vec{U}^T & \vec{V}^T & \vec{N}^T \end{bmatrix} = \begin{bmatrix} u_x & v_x & n_x \\ u_y & v_y & n_y \\ u_z & v_z & n_z \end{bmatrix} \]

\( M \) is the rotation matrix that transforms \((\vec{X}, \vec{Y}, \vec{Z})\) to \((\vec{U}, \vec{V}, \vec{N})\).
The Viewing Transformation

\[ \vec{P} = \vec{M} \vec{Q} + \vec{r} \]
\[ \vec{Q} = (a, b, c) = \vec{M}^{-1} (\vec{P} - \vec{r}) \]
\[ = \vec{M}^T (\vec{P} - \vec{r}) \]
\[ = \vec{M}^T \vec{P} - \vec{M}^T \vec{r} \]

If \( \vec{P} = (0, 0, 0) \) then

\[ \vec{M}_{wv} = \vec{R} \cdot \vec{T} \]

\[ \vec{M}_{wv} = \begin{bmatrix} u_x & u_y & u_z & 0 \\ v_x & v_y & v_z & 0 \\ n_x & n_y & n_z & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & -r_x \\ 0 & 1 & 0 & -r_y \\ 0 & 0 & 1 & -r_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \]
Determining View Parameters

- Specify view point and view direction $\vec{N}'$ in world coordinates (e.g., point camera at origin or center of scene)
- Normalize $\vec{N}$ to unit length
  \[ \vec{N} = \frac{\vec{N}'}{|\vec{N}'|} \]
- Specify “$\vec{UP}$” vector. Normalize to unit length
  \[ \vec{V}' = \frac{\vec{UP}}{|\vec{UP}|} \]
- Calculate $\vec{U}$ and $\vec{V}$
  \[ \vec{U} = \vec{N} \times \vec{V}', \quad \vec{V} = \vec{U} \times \vec{N} \]
View Volume

- The volume of 3D space that is projected and displayed.
- Volume defined by a 2D window on the projection plane and front and back clipping planes (hither/yon, near/far).
- View volume is specified in camera coordinates.
- View volume is a truncated frustum.