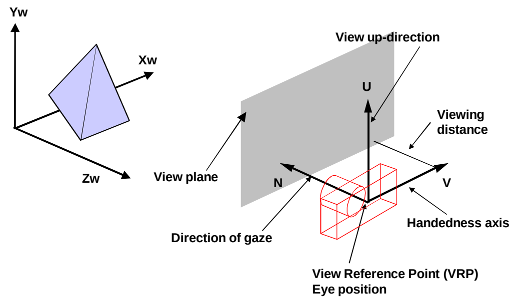
Implementing a virtual camera

Defining a camera
Implementing a virtual snapshot
- Coordinate system transformations
- Viewing projections

Practical exercise

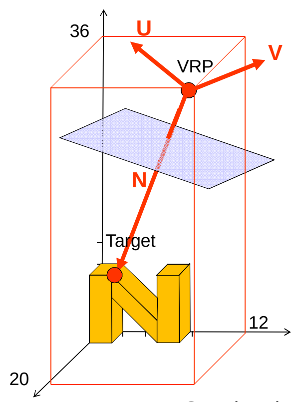
Virtual camera - definitions



Creating a view of the scene – an outline

1. Create vertex tables for an object in the World coordinate system.
2. Find the axes of the Viewing (camera) coordinate system, vectors **V**, **U** and **N** (from VRP and the Target point).
3. Find the transformations which change the coordinates of the object from the World system to the Viewing system. This is the same transformation which aligns the axes of the Viewing system (**V**,**U**,**N**) with the axes of the World system (**X**,**Y**,**Z**). Create the combined transformation matrix for these transformations.
4. Create the perspective projection matrix (from the viewing distance D) and combine with the matrix calculated in (3) above.
5. Transform all the object vertices through the combined matrix calculated in (4).
6. Calculate the homogeneous coordinates of the points transformed in (5), so that the last (fourth) coordinate for each point is 1. As a check see that the z coordinate of each point is equal to D, the viewing distance.
7. Plot the 2D points.

2. Define the camera coordinate system



See the class exercise “Big N”

2. The camera coordinate system

- Define N
  N=TP-VRP
- Define a temporary “up-vector”
  U_0=[0 1 0]
- Compute the handedness vector
  V=U_0 x N
- Compute the correct up-vector
  U=N x V

3. Coordinate system transformation

3.1.
Define a matrix to translate the centre of the Camera system to the centre of the World system

$$TM = \begin{bmatrix} 1 & 0 & 0 & -x_{VRP} \\ 0 & 1 & 0 & -y_{VRP} \\ 0 & 0 & 1 & -z_{VRP} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

3. Coordinate system transformation

3.2

Define a matrix to align the axes of the Camera system with the axes of the World system

$$R_{xyz} = \begin{bmatrix} \frac{V_x}{|\mathbf{V}|} & \frac{V_y}{|\mathbf{V}|} & \frac{V_z}{|\mathbf{V}|} & 0 \\ \frac{U_x}{|\mathbf{U}|} & \frac{U_y}{|\mathbf{U}|} & \frac{U_z}{|\mathbf{U}|} & 0 \\ \frac{N_x}{|\mathbf{N}|} & \frac{N_y}{|\mathbf{N}|} & \frac{N_z}{|\mathbf{N}|} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

3. Coordinate system transformation

3.3.

Define a matrix to convert from the right-handed World coordinate system to the left-handed Camera coordinate system (scaling by -1 w.r.t. X)

$$SM = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

4. Perspective projection

Define a perspective projection matrix with Centre of Projection (COP) at the centre of the coordinate system and the viewing plane at the distance D

$$P_{per} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1/D & 0 \end{bmatrix}$$

Perspective projections are covered in unit 10 ‘Viewing transformations’

5. Transform the object vertices

- Vertices defined in a N x 4 matrix P
- Compute the combined transformation matrix
  $CM = P_{per} * R_{xyz} * SM * TM$
- Apply the combined transformation matrix to the vertices
  P’ = CM * P

Composite transformations are covered in unit 9 ‘Composite transformations’

6. Homogeneous coordinates

- Perspective projection makes the vertices P’ non-homogeneous.
- Make them homogenous by dividing the coordinate vector of each vertex by its fourth (homogeneous) component

$$P' = \begin{bmatrix} x \\ y \\ z \\ h \end{bmatrix} \qquad P'' = \begin{bmatrix} x \\ y \\ z \\ h \end{bmatrix} / h = \begin{bmatrix} x/h \\ y/h \\ z/h \\ 1 \end{bmatrix}$$

7. Plot the 2D points

- The ‘z’ coordinate for all the homogeneous vertices should be equal D
- Plot the object in 2D, using only (x,y) coordinates of the homogenous vertices, and the object’s surface table