Outline

- 3D viewing process:
  - Coordinate systems
- View specification:
  - Camera parameters
- View volume:
  - Clipping planes

3D Viewing Process

- Object coordinates
- Camera coordinates
- Clip coordinates
- Screen coordinates
- Raster coordinates
- World coordinates
- 3D transformation (model)
- 3D transformation (viewing)
- Camera coordinates
- 3D projection
- View clipping
- Perspective transformation (model)
- Perspective transformation (viewing)
- 2D transformation (viewport)
- Perspective division
- Clip coordinates

Object Coordinate System

- The local 3D coordinate system used for modeling individual objects
  - Contains the raw coordinates used for specifying the objects' shapes
  - Different objects may be defined under different measuring units

World Coordinate System

- The global 3D coordinate system used for modeling the virtual world (the scene to be rendered)
  - Objects defined in object coordinates are positioned into the virtual world through scaling, translation, & rotation

Camera Coordinate System

- The coordinate system that place the viewer at the origin with the view direction aligned with the Z axis
  - Normally set as a left hand system, with camera looking at the positive Z direction
  - Also called eye or view-reference coordinate system
Clip Coordinate System
- A homogenous coordinate system as the result of projection
- Obtained by multiplying camera coordinates with the projection matrix & clipping away objects out of the view volume
- All coordinates have limited range due to clipping

Screen Coordinate System
- A Cartesian coordinate system
- Results of perspective division on clipping coordinates
- All visible objects are projected into the interval: [-1,1]
- Independent to the rendering resolution
- Also called normalized device coordinate system

Raster Coordinate System
- The coordinate system defined based on the viewport used for display
- Mapped from the screen coordinates through scaling & translation
- Normally Y axis points downward
- Also called device or window coordinate system

View Specification Approaches
- Define transformation matrices directly:
  - Use a set of rotation & translation steps to convert from world to camera coordinates
  - Use perspective or parallel projection to convert from camera to screen coordinates
- Advantage:
  - Easy to implement
  - Define a virtual camera in the 3D scene:
    - Control the world-to-camera conversion using the camera’s external parameters
    - Control the camera-to-screen conversion using the camera’s internal parameters
- Advantage:
  - More user friendly

External Parameters
- Position:
  - Center of projection: COP
- Orientation:
  - View direction: V
  - Up direction: U
- The camera coordinate system:
  - \( Z' = V \)
  - \( X' = V \times U \)
  - \( Y' = X' \times V \)

Peudocode for Camera Setup
- void setupCamera(Vector pos, Vector view, Vector up){
  - Vector dx, dy, dz;
  - Matrix mat = new Matrix();
  - dx = view.normalize();
  - dy = dx.cross(up); // y = x \times z (left-hand system)
  - // generate the transformation matrix mat
  - mat.d00 = dx.x; mat.d10 = dx.y; mat.d20 = dx.z;
  - mat.d01 = dy.x; mat.d11 = dy.y; mat.d21 = dy.z;
  - mat.d02 = dz.x; mat.d12 = dz.y; mat.d22 = dz.z;
  - mat.d33 = 1;
  - mat.translate(- pos);
}
Internal Parameters

- Focal length:
  - Distance between the COP & the projection plane: \( f \)
  - Standard lens is 50mm
- Image (film) size:
  - Width & height: \( 2w \times 2h \)
  - 36x24 for 35mm film
- Field of view:
  - Angle: \( \theta_h, \theta_v \)
  - \( \tan(\theta_v/2) = w/f \)

3D Projection Defined

\[
P = \begin{bmatrix} 1/s & 0 & 0 & 0 \\ 0 & 1/s & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1/f & 0 \end{bmatrix}
\]

- Parameter \( s \) is the maximal dimension of image plane
  \( s = \max(w, h) \)

Clipping

- Points on the \( z=0 \) plane cannot be projected
  - The weight is zero after projection
  - Mapped to infinity
  - Have to eliminate the portion of scene that is behind the viewpoint before projection
  - To cut computational cost, we can also eliminate all objects that are outside the viewing volume

Clipping Planes

- Back clipping plane:
  - Also called far clipping plane or yon plane
  - Sometime at infinite
  - Remove objects too far, whose projections are too small
- Front clipping plane:
  - Near clipping plane or hither plane
  - Remove objects that are behind or too close to the COP

View Volume

- Definition:
  - The portion of the world that projects into the normalized window on the projection plane
  - Perspective projection
  - Truncated pyramid
  - Parallel projection
  - Parallelepiped

Clipping Planes (Cont’d)

- Surrounding planes:
  - Defined by the four edges of the image
  - Clipping with these planes is performed in clip coordinates by comparing \((x,y,z)\) with \( \pm w \)