Visualization

"Generate an *image* of a *3D scene* simulating a *virtual camera*"

- Scene Description
  - Geometric Models
- Camera Description
  - Viewing Specification
- Illumination Description
  - Lights and Materials

Rendering Tasks

- Viewing

  determine which objects contribute to each pixel

  - Transformation
  - Enumeration
  - Visibility

- Illumination

  compute the color of all pixels

  - Shading
  - Interpolation

- Different Ways to Organize Tasks

Rendering Geometry

- Homogeneous Geometry
  - One Type of Primitive
  - Convert to Common Primitive
- Examples:
  - Polygons
  - Cubic Patches
  - Quadrics
- Heterogeneous Geometry
  - Many Types of Primitives
  - Primitive Dependent Operations
  - Common Interface

Viewing Operations

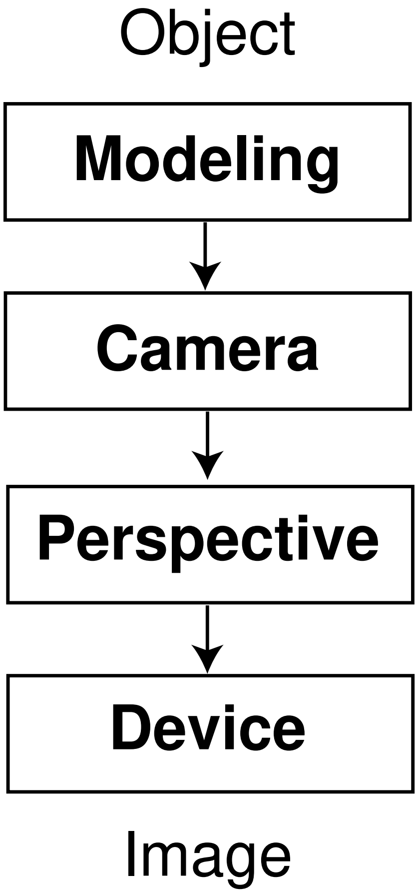
- Camera Transformation
- Clipping

  Projection
- Rasterization

  Visibility

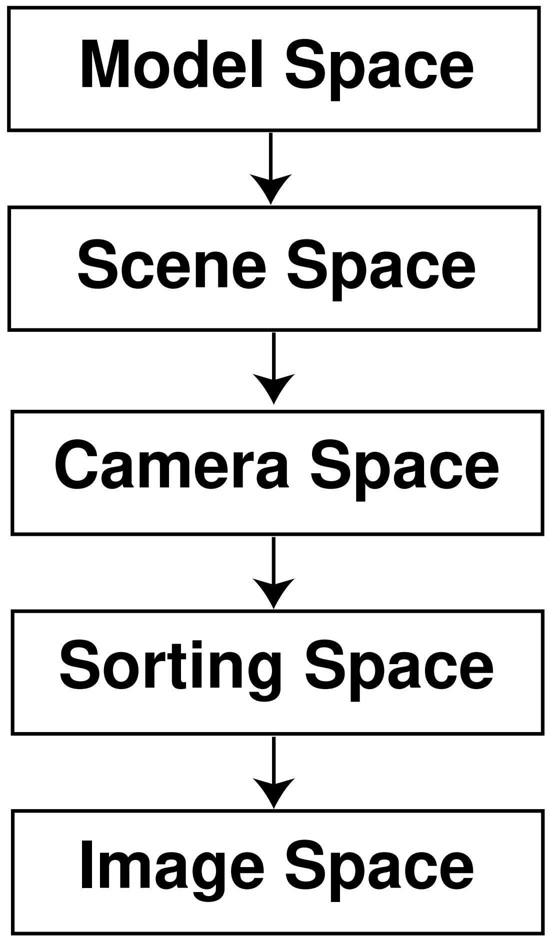
Viewing Pipeline

"Sequence of transformations mapping
3D objets to viewport"



Reference Spaces

"Objects are transformed to coordinate systems where viewing operations are performed"



Model Space

- Characteristics
  - Object Coordinate System
  - Origin: Center of Object
  - Principal Axis (Object)
  - Normalized
- Operation
  - Modeling Ops

Scene Space

- Characteristics
  - Global Coordinate System
  - All Objects
  - Application Units
- Operation
  - Shading

Camera Space

- Characteristics
  - Camera Coordinate System
  - XY Plane: Image Plane
  - Z Axis: View Direction
  - Normalized Fustrum
- Operation
  - Clipping

Sorting Space

- Characteristics
  - Sorting Coordinate System
  - Viewpoint at Infinity
  - Preserve Linear Structures
- Operation
  - Visibility Computation

Image Space

- Characterisitcs
  - Device Coordinate System
  - Viewport
  - Discrete Resolution
  - Aspect Ratio
- Operation
  - Compositing

Viewing Specification

- View Point
- View Direction
- View Up
- View Distance
- Near Plane
- Far Plane
- Image Center
- Image Dimensions
- Projection Type

Camera Transformation A

- Translate View Point to Origin

$$A = \begin{pmatrix} I & 0 \\ -V & 1 \end{pmatrix}$$

Camera Transformation B

- Transform Axis xyz to uvn

$v = \frac{U-(U \cdot n)n}{|U-(U \cdot n)n|}$

$u = n \times v$

- Left Handed - Right Handed

$$B = \begin{pmatrix} u^T & v^T & n^t & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Camera Transformation C

- Align Image Center with z Axis

$$C = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ -c_u/d & -c_v/d & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Camera Transformation D

- Scale such that Far Face of View Pyramid is Unit Square at $z = 1$

$$C = \begin{pmatrix} d/(s_u f) & 0 & 0 & 0 \\ 0 & d/(s_v f) & 0 & 0 \\ 0 & 0 & 1/f & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Camera Transformation

$$N = ABCD$$

$$N = N_0 N_1$$

$$N_0 = \begin{pmatrix} u_x & v_x & n_x & 0 \\ u_y & v_y & n_y & 0 \\ u_z & v_z & n_z & 0 \\ -u.V_p & -v.V_p & -n.V_p & 1 \end{pmatrix}$$

$$N_1 = \begin{pmatrix} d/(s_u f) & 0 & 0 & 0 \\ 0 & d/(s_v f) & 0 & 0 \\ -c_u/(s_u f) & -c_v/(s_v f) & 1/f & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Perspective E

- Translate z_{min} to Origin

$$E = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & -z_{\text{min}} & 1 \end{pmatrix}$$

Perspective F

- Scale z_{min} to Unit Square

$$F = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1/(1 - z_{\mathsf{min}}) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Perspective G

- Perspective Transform

$$G = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & (1 - z_{min})/z_{min} \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Perspective Transformation

$$P = EFG$$

$$P = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1/(1-z_{\mathsf{min}}) & 1/z_{\mathsf{min}} \\ 0 & 0 & -z_{\mathsf{min}}/(1-z_{\mathsf{min}}) & 0 \end{pmatrix}$$

$$P = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1/(1-z_{\mathsf{min}}) & 1 \\ 0 & 0 & -z_{\mathsf{min}}/(1-z_{\mathsf{min}}) & 0 \end{pmatrix}$$

Device K

- Translation $(-1, -1, 0, 1)$ to Origin
- Scaling in x and y to Unit

$$K = \begin{pmatrix} 0.5 & 0 & 0 & 0 \\ 0 & 0.5 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0.5 & 0.5 & 0 & 1 \end{pmatrix}$$

Device L

- Mapping to Device Resolution

$$L = \begin{pmatrix} \Delta_X & 0 & 0 & 0 \\ 0 & \Delta_Y & 0 & 0 \\ 0 & 0 & \Delta_Z & 0 \\ X_{\text{min}} & Y_{\text{min}} & Z_{\text{min}} & 1 \end{pmatrix}$$

where

$$\Delta_i = (i_{max} - i_{min})$$

Device M

- Rounding

$$M = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0.5 & 0.5 & 0.5 & 1 \end{pmatrix}$$

floor(x, y, z)

Device Transformation

$$S = KLM$$

$$S = \begin{pmatrix} \Delta_x/2 & 0 & 0 & 0 \\ 0 & \Delta_y/2 & 0 & 0 \\ 0 & 0 & \Delta_z & 0 \\ (\nabla_x + 1)/2 & (\nabla_y + 1)/2 & Z_{min} + 0.5 & 1 \end{pmatrix}$$

where

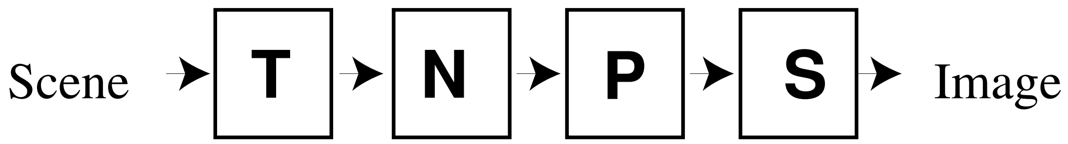
$$\Delta_i = (i_{max} - i_{min})$$

and

$$\nabla_i = (i_{max} + i_{min})$$

Transformation Computation

- Parametric Models



- Implicit Models