CS 430/536
Computer Graphics I

3D Viewing
Week 6, Lecture 12

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Overview

• 3D Viewing
• 3D Projective Geometry
• Mapping 3D worlds to 2D screens
• Introduction and discussion of homework #4

Lecture Credits: Most pictures are from Foley/VanDam; Additional and extensive thanks also goes to those credited on individual slides
Recall the 2D Problem

• Objects exist in a 2D WCS
• Objects clipped/transformed to viewport
• Viewport transformed and drawn on 2D screen
From 3D Virtual World to 2D Screen

• Not unlike The Allegory of the Cave (Plato’s “Republic”, Book VII)
• Viewers see a 2D shadow of 3D world
• How do we create this shadow?
• How do we make it as realistic as possible?
History of Linear Perspective

• Renaissance artists
  – Alberti (1435)
  – Della Francesca (1470)
  – Da Vinci (1490)
  – Pélerin (1505)
  – Dürer (1525)

Dürer: Measurement Instruction with Compass and Straight Edge

The 3D Problem: Using a Synthetic Camera

- Think of 3D viewing as taking a photo:
  - Select *Projection*
  - Specify *viewing parameters*
  - *Clip* objects in 3D
  - *Project* the results onto the display and draw
The 3D Problem: (Slightly) Alternate Approach

- Think of 3D viewing as taking a photo:
  - Select *Projection*
  - Specify *viewing parameters*
  - Perform trivial *accept/reject test* in 3D
  - *Project* the results onto the image plane
  - *Clip* lines to world window
  - Transform to viewport and draw
Creating a 3D View: Parameterizing the Camera

Basic Ideas:

• Camera has
  – location
  – lens (focal length)
  – projection type

• World has
  – lights
  – colors
  – objects (visible and hidden surfaces)
Planar Geometric Projections

- Projections onto Planes
  - Consider the line $AB$
- Perspective Projection
  - a single viewing location
  - similar to a photograph
- Parallel Projection
  - viewing location at $\infty$
  - good for capturing shape and dimensions
Perspective Projections

- Idea: lines not parallel to projection plane converge to a *vanishing point* (VP)
- Lines extending to axis VPs are parallel to either x, y or z axes
- Projections characterized by # of axes cut by the projection plane
Perspective Projections: Example

- One-point perspective
- z axis vanishing point
- Projection plane cuts only the z axis
Perspective Projection (Titanic)
Perspective Projections: Example

- Two-point perspective, cutting x and z
- Used commonly in CAD
- Three-point projections are not much different
Parallel Projections

- Two types, depending on *projection direction vector* and *projection plane normal*
- Orthographic Projections
  - both vectors are the same
  - front-, top-, plan-, and side-elevation projections
- Oblique Projections
  - vectors are different
Mercury Spacecraft
Axonometric Orthographic Projections

- Projections to planes not normal to principle coordinate axes, i.e. showing several faces
- The *Isometric* Projection
  - very common
  - projection plane at equal angles to each of the coordinate axes
  - 8 of them, one in each octant
Mercury Spacecraft

THREE AXIS HAND CONTROL

Palm Pivot

Wrist Pivot
Oblique Projections

- Projection direction and Projection plane normal differ
- Preserves certain angles and distances
- Good for use in illustration and measurement
Oblique Projections

- Cavalier - all lines (including receding lines) are made to their true length

- Cabinet - receding lines are shortened by one-half their true length to approximate perspective foreshortening
Oblique Projections are Good for Illustrations
Projection Relationships

- As the distance to the projection point moves toward infinity, the two projection families unify:
  - Projection plane
  - Direction to center of projection
  - Distance to CoP
Specification of 3D Views

- Projection Plane == View Plane
  - defined as a view reference point (VRP) and a view plane normal (VPN)
  - View up vector (VUP) defines “up” on the plane (so we can orient axes on to the plane)
Specification of 3D Views

• View plane window min/max are specified wrt viewing reference coordinates (VRC)
  – axis 1 (of VRC): VPN (the $n$ axis)
  – axis 2: VUP projected onto view plane ($v$ axis)
  – axis 3: perpendicular to $n$ & $v$, for RH CS ($u$ axis)
  – $CW$: center of window
Aiming the Projection

- Defined by:
  - Projection Reference Point (PRP)
  - Projection type
  - PRP is defined in with View Reference Coordinates (VRC)
  - Result: a semi-infinite viewing pyramid or view parallelepiped

- Perspective
  - CoP = PRP

- Parallel
  - DoP = CW - PRP
Defining the View Volume

- What portion of the world do we view?
  - where do we start?
  - how far back to go?
- View Volume
  - front clipping plane
  - back clipping plane
- For perspective, things far away gets smaller
From View Volume to Screen

- Consider a unit cube in *normalized projection coordinates (NPC)*
- Transform view volume to a rectangular solid in NPC
  - $z_{\text{max}}$ plane: front clip plane
  - $z_{\text{min}}$ plane: back clip plane
  - etc. for $x$ and $y$
  - this is the **3D Viewport**
- Transformation via the View Mapping Matrix
  - The $z=1$ face is mapped to the display
  - Display by discarding the $z$ coordinate and drawing as in 2D
Parameter Summary

• Viewing Parameters:
  – VRP (WC)
  – VPN (WC)
  – VUP (WC)
  – PRP (VRC)
  – \( \{u,v\}_{\text{min}}, \{u,v\}_{\text{max}} \)
  – CW (VRC)
  – F & B (VRC)
  – projection type

• What the parameters mean:
  – View Reference Point
  – View Plane Normal
  – View Up Vector
  – Projection Reference Point
  – Window extent
  – Center of Window
  – Front and Back clipping planes
  – perspective/parallel
Parameterizing Projections

- Viewing Parameters:
  - VRP (WC)
  - VPN (WC)
  - VUP (WC)
  - PRP (VRC)
  - window (VRC)
  - projection type

- What the parameters mean:
  - View Reference Point
  - View Plane Normal
  - View Up Vector
  - Projection Reference Point
  - Size of the 2D window
  - perspective/parallel

*the* film
*hold camera*
*aim*
*Zoom*
Examples of 3D Viewing: Preliminaries

- Dimensions and location of a simple house
- Two-point perspective projection of the house
Examples of 3D Viewing: Preliminaries

- Default viewing specification
  - $x,y,z$ coincides with $u,v,n$
  - Window bounds from 0 to 1
Examples of 3D Viewing: Preliminaries

- Default parallel projection view volume
  - cuboidal
Examples of 3D Viewing: Preliminaries

- Default perspective projection view volume
  - pyramid-like
Parameterizing Projections: Example

- Viewing Parameters:
  - VRP(WC) (0,0,0)
  - VPN(WC) (0,0,1)
  - VUP(WC) (0,1,0)
  - PRP(VRC) (.5,.5,1.0)
  - window(VRC) (0,1,0,1)
  - projection parallel
  - DOP(VRC) (0,0,-1)
Perspective Projections: Example

- Parameters:
  - VRP(WC) (0,0,0)
  - VPN(WC) (0,0,1)
  - VUP(WC) (0,1,0)
  - PRP(VRC) (8,6,84)
  - window(VRC) (-50,50,-50,50)
  - projection perspective
Perspective Projections: Example (centering)

- Parameters:
  - VRP(WC) $(0,0,54)$
  - VPN(WC) $(0,0,1)$
  - VUP(WC) $(0,1,0)$
  - PRP(VRC) $(8,6,30)$
  - window(VRC) $(-1,17,-1,17)$
  - projection perspective
Perspective Projections: Example (centering 2)

- Parameters:
  - VRP(WC) (8,6,54)
  - VPN(WC) (0,0,1)
  - VUP(WC) (0,1,0)
  - PRP(VRC) (0,0,30)
  - window(VRC) (-9,9,-7,11)
  - projection perspective
Finite View Volumes: Example

- Parameters:
  - VRP(WC) (0,0,54)
  - VPN(WC) (0,0,1)
  - VUP(WC) (0,1,0)
  - PRP(VRC) (8,6,30)
  - window(VRC) (-1,17,-1,17)
  - projection perspective
  - F(VRC) +1
  - B(VRC) -23
Perspective Projections: Example

- Parameters:
  - VRP(WC) (16,0,54)
  - VPN(WC) (0,0,1)
  - VUP(WC) (0,1,0)
  - PRP(VRC) (20,25,20)
  - window(VRC) (-20,20,-5,35)
  - projection perspective
Perspective Projections: Example

- Parameters:
  - VRP(WC) (16,0,54)
  - VPN(WC) (1,0,1)
  - VUP(WC) (0,1,0)
  - PRP(VRC) (0,25, 20\sqrt{2})
  - window(VRC) (-20,20,-5,35)
  - projection perspective
Perspective Projections: Example (cont.)

- Showing the object relative to the view plane, w/ overhead view
Perspective Projections: Example (rotating VUP)

- Same parameters as before
- VUP rotated away from y by 10°
Parallel Projections: Example

- Parameters:
  - VRP(WC) (0,0,0)
  - VPN(WC) (0,0,1)
  - VUP(WC) (0,1,0)
  - PRP(VRC) (8,8,100)
  - window(VRC) (-1,17,-1,17)
  - projection parallel
Programming assignment 4

- Read SMF file
- Implement parallel projection
- Implement perspective projection
- Output projected and clipped polygon edges