CS 430/536
Computer Graphics I

3D Viewing

Week 6, Lecture 12

David Breen, William Regli and Maxim Peysakhov
Geometric and Intelligent Computing Laboratory
Department of Computer Science
Drexel University
http://gicl.cs.drexel.edu

Overview

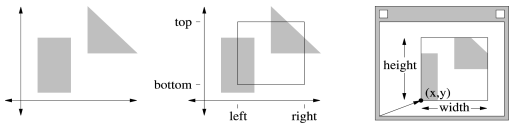
- 3D Viewing
- 3D Projective Geometry
- Mapping 3D worlds to 2D screens
- Introduction and discussion of homework #4

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

Pics/Math courtesy of Dave Mount @ UMD-CP 1994 Foley/VanDam/Finer/Huges/Phillips ICG

Recall the 2D Problem

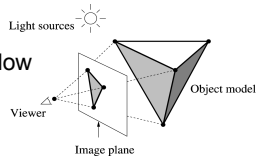
- Objects exist in a 2D WCS
- Objects clipped/transformed to viewport
- Viewport transformed and drawn on 2D screen



Pics/Math courtesy of Dave Mount @ UMD-CP

From 3D Virtual World to 2D Screen

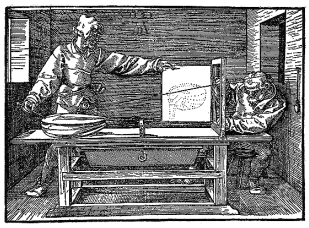
- Not unlike The Allegory of the Cave (Plato's "Republic", Book VII)
- Viewers see a 2D shadow of 3D world
- How do we create this shadow?
- How do we make it as realistic as possible?



Pics/Math courtesy of Dave Mount @ UMD-CP

History of Linear Perspective

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

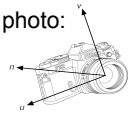


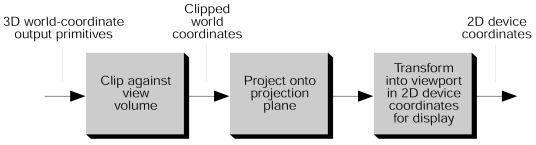
Dürer: Measurement Instruction with Compass and Straight Edge

http://www.handprint.com/HP/WCL/tech10.html

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

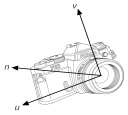




1994 Foley/VanDam/Finer/Huges/Phillips ICG

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



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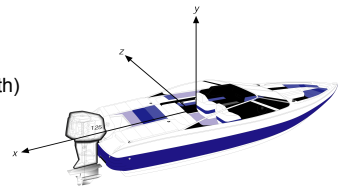
Creating a 3D View: Parameterizing the Camera

Basic Ideas:

- Camera has
  - location
  - lens (focal length)
  - projection type
- World has
  - lights
  - colors
  - objects (visible and hidden surfaces)



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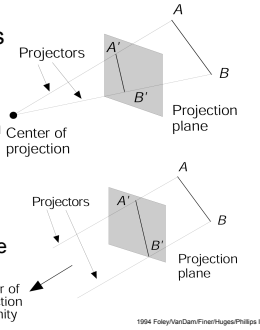
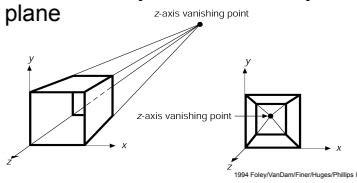
Planar Geometric Projections

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



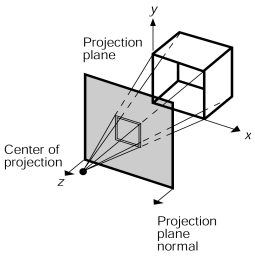
Perspective Projections

- 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



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Perspective Projection (Titanic)

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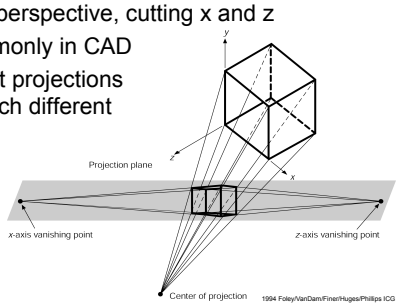
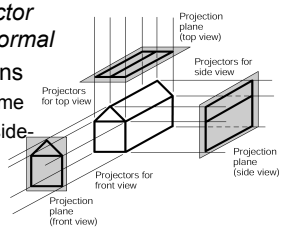
Perspective Projections: Example

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

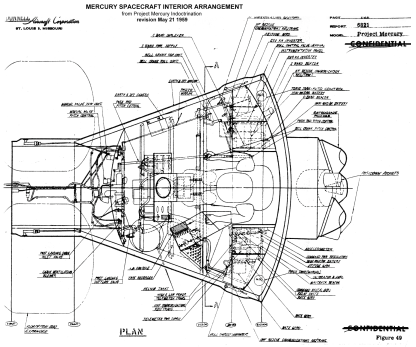


Parallel Projections

- 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

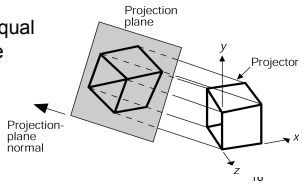


Mercury Spacecraft



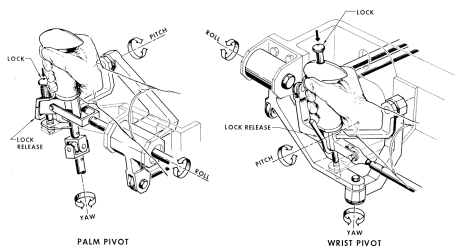
Axonometric Orthographic Projections

- 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



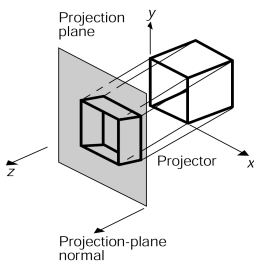
Mercury Spacecraft

THREE AXIS HAND CONTROL



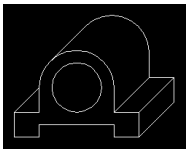
Oblique Projections

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

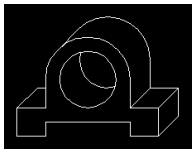


Oblique Projections

- 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 fore-shortening



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Oblique Projections are Good for Illustrations

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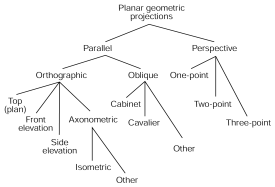
Projection Relationships



- 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

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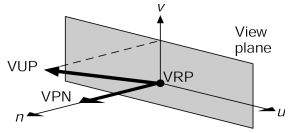
Specification of 3D Views

- 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)



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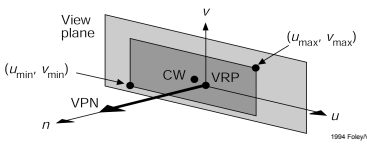
Specification of 3D Views

- 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



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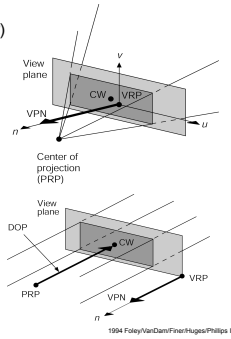
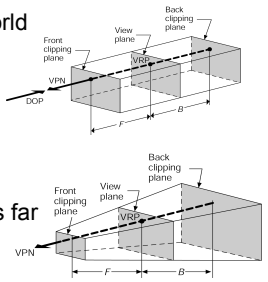
Aiming the Projection

- 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



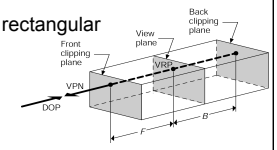
Defining the View Volume

- 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-max plane: front clip plane
  - z-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

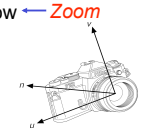


Parameter Summary

- Viewing Parameters:
  - VRP (WC)
  - VPN (WC)
  - VUP (WC)
  - PRP (VRC)
  - $\{u,v\}_{min}$, $\{u,v\}_{max}$
  - 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

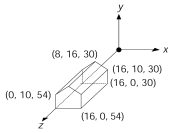
Parameterizing Projections

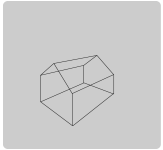
- Viewing Parameters:
  - VRP (WC)
  - VPN (WC)
  - VUP (WC)
  - PRP (VRC)
  - window (VRC)
  - projection type
- What the parameters mean:
  - View Reference Point — *the film*
  - View Plane Normal — *the film*
  - View Up Vector — *hold camera*
  - Projection Reference Point — *aim*
  - Size of the 2D window — *Zoom*
  - perspective/parallel



Examples of 3D Viewing: Preliminaries

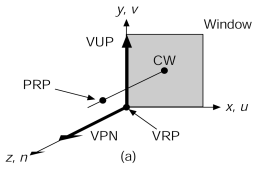
- Dimensions and location of a simple house
- Two-point perspective projection of the house





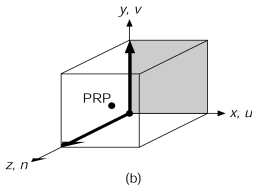
Examples of 3D Viewing: Preliminaries

- Default viewing specification
  - x,y,z coincides with u,v,n
  - Window bounds from 0 to 1



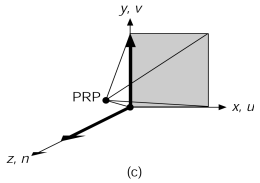
Examples of 3D Viewing: Preliminaries

- Default parallel projection view volume
  - cuboidal



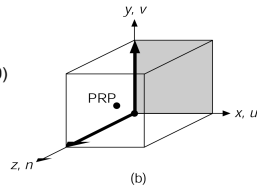
Examples of 3D Viewing: Preliminaries

- Default perspective projection view volume
  - pyramid-like



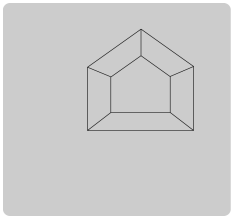
Parameterizing Projections: Example

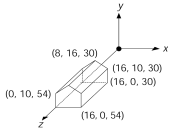
- Viewing Parameters:
  - VRP(WC) (0,0,0)
  - VPN(WC) (0,0,1)
  - VUP(WC) (0,1,0)
  - PRP(VRC) (.5,.5,1.0)
  - window(VRC) (0,1,0,1)
  - projection parallel
  - DOP(VRC) (0,0,-1)



Perspective Projections: Example

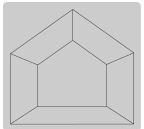
- Parameters:
  - VRP(WC) (0,0,0)
  - VPN(WC) (0,0,1)
  - VUP(WC) (0,1,0)
  - PRP(VRC) (8,6,84)
  - window(VRC) (-50,50,-50,50)
  - projection perspective

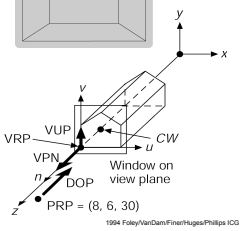




Perspective Projections: Example (centering)

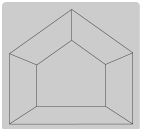
- Parameters:
  - VRP(WC) (0,0,54)
  - VPN(WC) (0,0,1)
  - VUP(WC) (0,1,0)
  - PRP(VRC) (8,6,30)
  - window(VRC) (-1,17,-1,17)
  - projection perspective

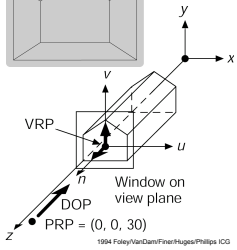


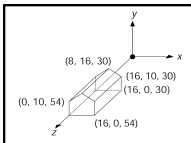


Perspective Projections: Example (centering 2)

- 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

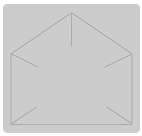


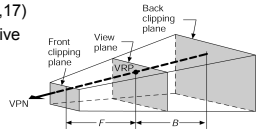




Finite View Volumes: Example

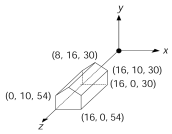
- Parameters:
  - VRP(WC) (0,0,54)
  - VPN(WC) (0,0,1)
  - VUP(WC) (0,1,0)
  - PRP(VRC) (8,6,30)
  - window(VRC) (-1,17,-1,17)
  - projection perspective
  - F(VRC) +1
  - B(VRC) -23

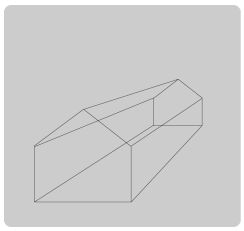




Perspective Projections: Example

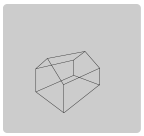
- Parameters:
  - VRP(WC) (16,0,54)
  - VPN(WC) (0,0,1)
  - VUP(WC) (0,1,0)
  - PRP(VRC) (20,25,20)
  - window(VRC) (-20,20,-5,35)
  - projection perspective

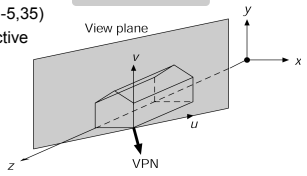




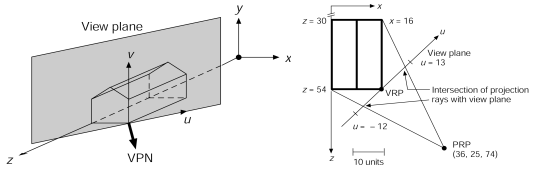
Perspective Projections: Example

- 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





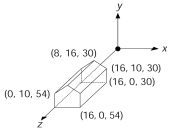
Perspective Projections: Example (cont.)

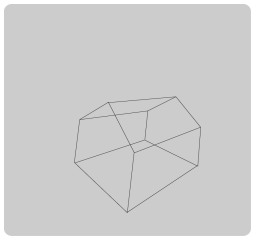


- Showing the object relative to the view plane, w/ overhead view

Perspective Projections: Example (rotating VUP)

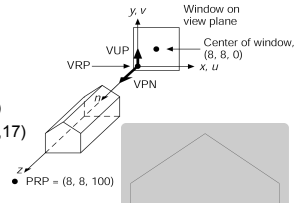
- Same parameters as before
- VUP rotated away from y by 10°

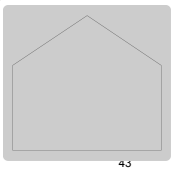




Parallel Projections: Example

- 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

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