Lecture 2 of 41

Viewing 1 of 4:
Overview, Projections

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Where We Are

Lecture Outline

- Reading for Last Class: Sections 2.1, 2.2.1 – 2.2.2, Eberly 2*
- Reading for Today: Sections 2.2.3 – 2.2.4, 2.8 Eberly 2*
- Reading for Next Class: Section 2.3 (esp. 2.3.4), Foley et al. Slides
- Last Time: Math Foundations, Matrix Transformations
  - Precalculus review: parametric equations of lines
  - Vector spaces and affine spaces
  - Linear systems, linear independence, bases, orthonormality
  - Cumulative Transformation Matrices (CTMs)
    - Translation
    - Rotation
    - Scaling
- Today: Basic Viewing Principles
  - Projections: definitions, history
  - Perspective: optical principles, terminology
- Next Class: Viewing and Normalizing Transformations (VT/NT)

Background:
Basic Linear Algebra for CG

- Reference: Appendix A.1 – A.4, Foley et al
  - A.1 Vector Spaces and Affine Spaces
    - Equations of lines, planes
    - Vector subspaces and affine subspaces
  - A.2 Standard Constructions in Vector Spaces
    - Linear independence and spans
    - Coordinate systems and bases
  - A.3 Dot Products and Distances
    - Dot product in R^n
    - Norms in R^n
  - A.4 Matrices
    - Binary matrix operations: basic arithmetic
    - Unary matrix operations: transpose and inverse
  - Application: Transformations and Change of Coordinate Systems

Readings:
Today: Sections 2.2.3 – 2.2.4, Eberly
Next class: Section 2.3 (esp. 2.3.4), FVFH slides
Computers & Information Sciences, KSU
Public mirror web site: http://www.kddresearch.org/Courses/CIS636

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Reading for Today: Sections 2.2.3 – 2.2.4, Eberly 2
Reading for Last Class: Sections 2.1, 2.2.1 – 2.2.2, Eberly 2

- T: Translation (see http://en.wikipedia.org/wiki/Translation_matrix)
  - Given
    - Point to be moved – e.g., vertex of polygon or polyhedron
    - Displacement vector (also represented as point)
  - Return: new, displaced (translated) point of rigid body

- R: Rotation (see http://en.wikipedia.org/wiki/Rotation_matrix)
  - Given
    - Point to be rotated about axis
  - Axis of rotation
    - Degrees to be rotated
  - Return: new, displaced (rotated) point of rigid body

- S: Scaling (see http://en.wikipedia.org/wiki/Scaling_matrix)
  - Given
    - Set of points centered at origin
  - Scaling factor
  - Return: new, displaced (scaled) point


Next Class: Viewing and Normalizing Transformations (VT/NT)
Review: Lab 0

- **Warm-Up Lab**
  - Account set-up
  - Linux environment
  - Simple OpenGL exercise
- **Basic Account Set-Up**
  - See http://support.cis.ksu.edu to understand KSU Department of CIS setup
  - Make sure your CIS department account is set up
  - If not, use SelfServ: https://selfserv.cis.ksu.edu/selfserv/requestAccount
- **Linux Environment**
  - Make sure your CIS department account is set up
  - Learn how to navigate, set your shell (see KSOL, http://unixhelp.ed.ac.uk)
  - Lab 1 and first homeworks will ask you to render to local XWindows server
- **Simple OpenGL exercise**
  - Watch OpenGL Primer Part 1 as needed
  - Follow intro tutorials on “NeHe” (http://nehe.gamedev.net) as instructed
  - Turn in: source code, screenshot as instructed in Lab 0 handout

Projections From 3-D to 2-D: Orthographic & Perspective

- **Orthographic Projections**
  - Plan view (orthographic projection) from perspective. 2000 BCE, earliest known technical drawing in existence
  - Greek influence in late 1st century BC (perspective)
  - Roman architect Vitruvius wrote specifications of and used orthogonal (orthographic) perspective. Architecture (reproduced in 1649). The original illustrations for these writings have been lost.

- **Types of Projection**
  - Perspective
- **Projection in Computer Graphics**

Drawing as Projection

- Painting based on mythical tale as told by Piny the Elder: Corinthian man traces shadow of departing lover

[Image: Detail from The Invention of Drawing, 1930]

Adapted from slides © 1997 – 2010 van Dam et al., Brown University

Early Examples of Perspective

- Greek influence in late 1st century BC (perspective)
- Roman architect Vitruvius wrote specifications of and used orthogonal (orthographic) perspective. Architecture (reproduced in 1649). The original illustrations for these writings have been lost.

[Image: Roman architecture]

Adapted from slides © 1997 – 2010 van Dam et al., Brown University

Key Features of Linear Perspective

- Lines converge (1, 2, or 3 axes) to vanishing point
- Objects farther away are more foreshortened (i.e., smaller) than closer ones
- Example: perspective cube

[Image: Perspective cube]

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Early Perspective: Ad Hoc

- Ways of seeing three-dimensional space: shading suggests rounded, volumetric forms; converging lines suggest spatial depth of room
- Not systematic—lines do not converge to single vanishing point

[Image: Early perspective]

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Historical Setting for Invention of Perspective

- The Renaissance: new emphasis on importance of individual viewpoint and world interpretation, power of observation—particularly of nature (astronomy, anatomy, botany, etc.)
- Masuccio
- Donatello
- Leonardo
- Newton
- Universe as clockwork: intellectual rebuilding of universe along mechanical lines

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Brunelleschi and Vermeer

- Brunelleschi invented systematic method of determining perspective projections (early 1400s). Evidence that he created demonstration panels, with specific viewing constraints for complete accuracy of reproduction. Note the perspective is accurate only from one POV (see Last Supper)
- Vermeer created perspective boxes where picture, when viewed through viewing hole, had correct perspective
- Vermeer on the web:
  - http://www.yesno.org/artists/mysteries_in_the_masters/
  - http://www.veurne.verbier.3hm.com/
  - http://www.math.ucsd.edu/courses/math.html

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Stork vs. Hockney

- In artistic rivalry, David Hockney proposed that many Renaissance artists, including Vermeer, might have been aided by camera obscura while painting their masterpieces, raising a question about the accuracy of their work.

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Visual Pyramid and Similar Triangles [1]

- Projected image is easy to calculate based on
  - height of object (A)
  - distance from eye to object (CB)
  - distance from eye to picture (projection) plane (CD)
  - and using relationship CB : CD as AB : ED

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Visual Pyramid and Similar Triangles [2]

- The general case: the object we’re considering is not parallel to the picture plane
- AB is component of A at a plane parallel to the picture plane

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Dürer
- Concept of similar triangles described both geometrically and mechanically in widely read treatise by Albrecht Dürer (1471-1528)
- Refer to chapter 3 of the book for more information

Las Meninas (1656)
By Diego Velázquez
- Point of view influences content and meaning of what is seen
- Are royal couple in mirror about to enter room? Or is their image a reflection of painting on far left?
- Analyses through computer reconstruction of the painted space

Las Meninas is a mirror reflection
- From canvas in foreground, not reflection of actual people (Kamp p. 117-118)

Las Meninas
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Robert Campin
The Annunciation Triptych (c. 1425)

Piero della Francesca
The Resurrection (1460)
- Perspective can be used in unusual ways to control perception
- Use of two viewpoints concentrates viewer’s attention alternately on Christ and sarcophagus

Piero della Francesca
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Leonardo da Vinci
The Last Supper (1495)
- Perspective plays very large role in this painting

Geometrical Construction
Of Projections
- From Vredeman de Vries’s Perspective, 1593
- 2-point perspective—two vanishing points

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Planar Geometric Projection

- Projectors are straight lines, like the strings in Dürer’s “Artist Drawing a Lute”.
- Projection surface is plane (picture plane, projection plane)

- This drawing itself is perspective projection
- What other types of projections do you know?
  - isometric

Planar Geometric Projection

- Perspective: determined by Center of Projection (COP) (in our diagrams, the “eye”)
- Parallel: determined by Direction of Projection (DOP) (projectors are parallel—do not converge to “eye” or COP).
  Alternatively, COP is at 

Types of Projection

Logical Relationships Among Types of Projections

Multiview Orthographic

- Used for:
  - engineering drawings of machines, machine parts
  - working architectural drawings
- Pros:
  - accurate measurement possible
  - all views are at same scale
- Cons:
  - does not provide “realistic” view or sense of 3D form
  - Usually need multiple views to get a three-dimensional feeling for object

Axonometric Projections

- Same method as multiview orthographic projections, except projection plane not parallel to coordinate planes: parallel lines equally foreshortened
- Isometric: Angles between principal axes equal (120°). Scale ratio applied along each axis
- Dimetric: Angles between two of the principal axes
  - Different scales used along two of the axes
- Trimetric: Angles different between three principal axes; need three scale ratios
- Note: different names for different views, but all part of a continuum of possible viewpoints.

- In general, a projection is determined by where you place the projection plane relative to principal axes of object (relative angle and position), and what angle the projectors make with the projection plane.
Isometric Projection [1]

- Used for:
  - video game environments
  - virtual reality
  - architectural drawings
  - structural design
  - 3D modeling in real-time (Maya, AutoCAD, etc.)

- Pros:
  - does not need multiple views
  - unique isometric views of objects
  - measurements can be made to scale along principal axes

- Cons:
  - lack of foreshortening creates distorted appearance

Oblique Projections

- Projections at oblique angle to projection plane; view cameras have accordion housing, used for skyscrapers

- Pros:
  - presents exact shape of one face of an object (can take accurate measurements); better for larger objects that animate in complex environments
  - lens/foreground masking makes complete use of view
  - displays some of object's 3D appearance

- Cons:
  - objects can look distorted if careful choice not made about position of projection plane (e.g., circles become ellipses)
  - lack of foreshortening (not realistic-looking)

Examples of Oblique Projections

View Camera

Examples of Oblique Projections

Rules for placing projection plane for oblique views: projection plane should be chosen according to one or several of following:
- parallel to most irregular of principal faces, or to one which contains circular or curved surfaces
- parallel to largest principal face of object
- parallel to face of interest

Projection plane parallel to circular face

Projection plane not parallel to circular face

Source: http://users.usinternet.com/rniederman/star01.htm
Main Types of Oblique Projections

- **Cavalier**: Angle between projectors and projection plane is 45°. Perpendicular faces projected at full scale.
- **Cabinet**: Angle between projectors & projection plane: \( \arctan(2) = 63.43° \). Perpendicular faces projected at 50% scale.

Examples of Orthographic And Oblique Projections

Summary of Parallel Projections

Perspective Projections

Vanishing Points [1]

Vanishing Points [2]
Vanishing Points and The View Point [1]

- Perspective image is intersection of a plane with an infinite ray from object to eye (OP).
- Combining these 2 views:
  - Projection plane
  - Viewpoint

Vanishing Points and The View Point [2]

- Project parallel lines AB, CD on xy plane.
- Projectors from eye to AB and CD define two planes which meet in a line which contains the view point, or eye.
- This line does not intersect projection plane (XY), because parallel to it. Therefore there is no vanishing point.

Vanishing Points and The View Point [3]

- Lines AB and CD (this time with A and C behind the projection plane) projected on xy plane. AB and CD do not line up.
- Projectors from eye to AB and CD define two planes which meet in a line which contains the view point.
- This line does intersect projection plane.

Summary

- Taxonomy of Projections
  - Orthographic: top, front, side: axonometric (iso-di-, tri-metric)
  - Oblique: cabinet, cavalier
  - Perspective: one-, two-, three-point
- Kinds of Projections
  - Orthographic: “dead on”, i.e., (DOP || VPN)
  - Oblique: “at an angle”, i.e., (DOP || VPN)
- Parallel Projections
  - Orthographic: see above
  - Oblique: see above
- Perspective Projections
  - Orthographic: see above
  - Oblique: see above

Next Time:
Projection in Computer Graphics