University of British Columbia
CPSC 314 Computer Graphics
Jan-Apr 2007

Tamara Munzner

Viewing/Projections IV

Week 4, Fri Feb 2

http://www.ugrad.cs.ubc.ca/~cs314/Vjan2007

Reading for Today

- FCG Chapter 7 Viewing
- FCG Section 6.3.1 Windowing Transforms
- RB rest of Chap Viewing
- RB rest of App Homogeneous Coords

Reading for Next Time

- RB Chap Color
- FCG Sections 3.2-3.3
- FCG Chap 20 Color
- FCG Chap 21 Visual Perception

News

- my office hours reminder (in lab): today 11-12
- homework 1 due 3pm in box marked 314
  - same hallway as lab
- project 1 due 6pm, electronic handin
  - no hardcopy required
  - demo signup sheet going around again
    - Mon 1-12; Tue 10-12:30, 4-6; Wed 10-12, 2:30-4
    - arrive in lab 10 min before for your demo slot
    - be logged in and ready to go at your time
    - note to those developing in Windows/Mac
      - your program **must** compile and run on lab machines
      - test before the last minute, no changes after handin

Homework 1 News

- don't forget problem 11 (on back of page)
- Problem 3 is now extra credit
  - Write down the 4x4 matrix for shearing an object by 2 in y and 3 in z.

Correction (Transposed Before): 3D Shear

- shear in x
  - shear due to x along y and z axes
- shear in y
- shear in z
- general shear

$$\cancel{\begin{bmatrix}1 & sy & sz & 0\\0 & 1 & 0 & 0\\0 & 0 & 1 & 0\\0 & 0 & 0 & 1\end{bmatrix}} \quad xshear(hxy,hxz)=\begin{bmatrix}1 & 0 & 0 & 0\\hxy & 1 & 0 & 0\\hxz & 0 & 1 & 0\\0 & 0 & 0 & 1\end{bmatrix}$$

$$\cancel{\begin{bmatrix}1 & 0 & 0 & 0\\sx & 1 & sz & 0\\0 & 0 & 1 & 0\\0 & 0 & 0 & 1\end{bmatrix}} \quad yshear(hyx,hyz)=\begin{bmatrix}1 & hyx & 0 & 0\\0 & 1 & 0 & 0\\0 & hyz & 1 & 0\\0 & 0 & 0 & 1\end{bmatrix}$$

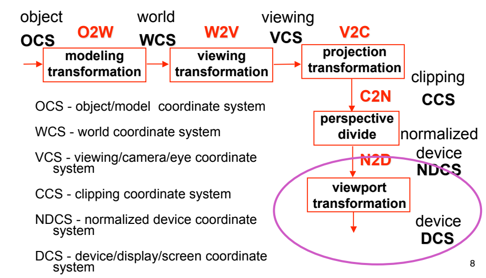
$$\cancel{\begin{bmatrix}1 & 0 & 0 & 0\\0 & 1 & 0 & 0\\sx & sy & 1 & 0\\0 & 0 & 0 & 1\end{bmatrix}} \quad zshear(hzx,hzy)=\begin{bmatrix}1 & 0 & hzx & 0\\0 & 1 & hzy & 0\\0 & 0 & 1 & 0\\0 & 0 & 0 & 1\end{bmatrix}$$

$$shear(hxy,hxz,hyx,hyz,hzx,hzy)=\begin{bmatrix}1 & hyx & hzx & 0\\hxy & 1 & hzy & 0\\hxz & hyz & 1 & 0\\0 & 0 & 0 & 1\end{bmatrix}$$

News

- midterm Friday Feb 9
  - closed book
  - no calculators
  - allowed to have one page of notes
    - handwritten, one side of 8.5x11" sheet
  - this room (DMP 301), 11-11:50
  - material covered
    - transformations, viewing/projection

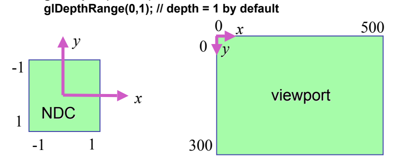
Projective Rendering Pipeline



NDC to Device Transformation

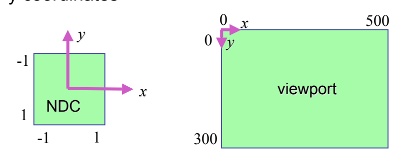
- map from NDC to pixel coordinates on display
  - NDC range is x = -1...1, y = -1...1, z = -1...1
  - typical display range: x = 0...500, y = 0...300
    - maximum is size of actual screen
    - z range max and default is (0, 1), use later for visibility

glViewport(0,0,w,h);
glDepthRange(0,1); // depth = 1 by default



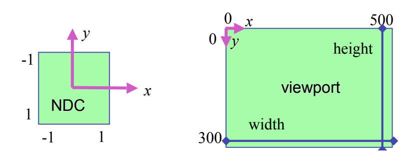
Origin Location

- yet more (possibly confusing) conventions
  - OpenGL origin: lower left
  - most window systems origin: upper left
- then must reflect in y
- when interpreting mouse position, have to flip your y coordinates



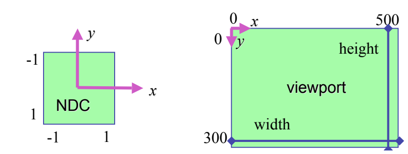
N2D Transformation

- general formulation
  - reflect in y for upper vs. lower left origin
  - scale by width, height, depth
  - translate by width/2, height/2, depth/2
    - FCG includes additional translation for pixel centers at (.5, .5) instead of (0,0)



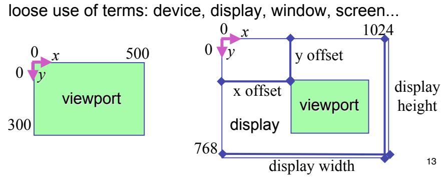
N2D Transformation

$$\begin{bmatrix}x_D\\y_D\\z_D\\1\end{bmatrix}=\begin{bmatrix}1 & 0 & 0 & \frac{width}{2}-\frac{1}{2}\\0 & 1 & 0 & \frac{height}{2}-\frac{1}{2}\\0 & 0 & 1 & \frac{depth}{2}\\0 & 0 & 0 & 1\end{bmatrix}\begin{bmatrix}\frac{width}{2} & 0 & 0 & 0\\0 & \frac{height}{2} & 0 & 0\\0 & 0 & \frac{depth}{2} & 0\\0 & 0 & 0 & 1\end{bmatrix}\begin{bmatrix}1 & 0 & 0 & 0\\0 & -1 & 0 & 0\\0 & 0 & 1 & 0\\0 & 0 & 0 & 1\end{bmatrix}\begin{bmatrix}x_N\\y_N\\z_N\\1\end{bmatrix}=\begin{bmatrix}\frac{width(x_N+1)-1}{2}\\\frac{height(-y_N+1)-1}{2}\\\frac{depth(z_N+1)}{2}\\1\end{bmatrix}$$

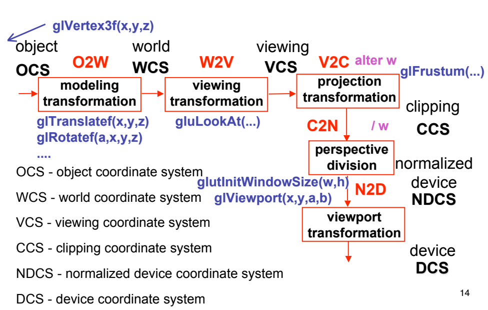


Device vs. Screen Coordinates

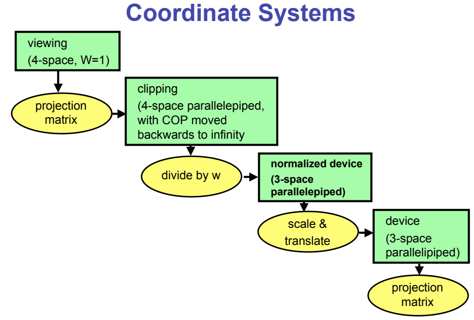
- viewport/window location wrt actual display not available within OpenGL
  - usually don't care
    - use relative information when handling mouse events, not absolute coordinates
  - could get actual display height/width, window offsets from OS
- loose use of terms: device, display, window, screen...



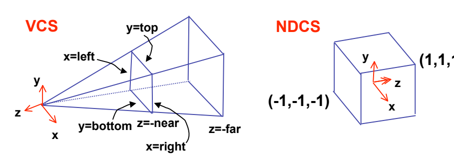
Projective Rendering Pipeline



Coordinate Systems



Perspective To NDCS Derivation



Perspective Derivation

simple example earlier:
$$\begin{bmatrix}x'\\y'\\z'\\w'\end{bmatrix}=\begin{bmatrix}1&0&0&0\\0&1&0&0\\0&0&1&0\\0&0&1/d&0\end{bmatrix}\begin{bmatrix}x\\y\\z\\1\end{bmatrix}$$

complete: shear, scale, projection-normalization

$$\begin{bmatrix}x'\\y'\\z'\\w'\end{bmatrix}=\begin{bmatrix}E&0&A&0\\0&F&B&0\\0&0&C&D\\0&0&-1&0\end{bmatrix}\begin{bmatrix}x\\y\\z\\1\end{bmatrix}$$

Perspective Derivation

earlier:
$$\begin{bmatrix}x'\\y'\\z'\\w'\end{bmatrix}=\begin{bmatrix}1&0&0&0\\0&1&0&0\\0&0&1&0\\0&0&1/d&0\end{bmatrix}\begin{bmatrix}x\\y\\z\\1\end{bmatrix}$$

complete: shear, scale, projection-normalization

$$\begin{bmatrix}x'\\y'\\z'\\w'\end{bmatrix}=\begin{bmatrix}E&0&A&0\\0&F&B&0\\0&0&C&D\\0&0&-1&0\end{bmatrix}\begin{bmatrix}x\\y\\z\\1\end{bmatrix}$$

Perspective Derivation

earlier:
$$\begin{bmatrix}x'\\y'\\z'\\w'\end{bmatrix}=\begin{bmatrix}1&0&0&0\\0&1&0&0\\0&0&1&0\\0&0&1/d&0\end{bmatrix}\begin{bmatrix}x\\y\\z\\1\end{bmatrix}$$

complete: shear, scale, projection-normalization

$$\begin{bmatrix}x'\\y'\\z'\\w'\end{bmatrix}=\begin{bmatrix}E&0&A&0\\0&F&B&0\\0&0&C&D\\0&0&-1&0\end{bmatrix}\begin{bmatrix}x\\y\\z\\1\end{bmatrix}$$

Perspective Derivation

$$\begin{bmatrix}x'\\y'\\z'\\w'\end{bmatrix}=\begin{bmatrix}E&0&A&0\\0&F&B&0\\0&0&C&D\\0&0&-1&0\end{bmatrix}\begin{bmatrix}x\\y\\z\\1\end{bmatrix}$$

$$x'=Ex+Az \qquad y'=Fy+Bz \qquad z'=Cz+D \qquad w'=-z$$

$x=left \rightarrow x'/w'=1$

$x=right \rightarrow x'/w'=-1$

$y=top \rightarrow y'/w'=1$

$y=bottom \rightarrow y'/w'=-1$

$z=-near \rightarrow z'/w'=1$

$z=-far \rightarrow z'/w'=-1$

$$y'=Fy+Bz,\quad \frac{y'}{w'}=\frac{Fy+Bz}{w'},\quad 1=\frac{Fy+Bz}{w'},\quad 1=\frac{Fy+Bz}{-z},$$
$$1=F\frac{y}{-z}+B\frac{z}{-z},\quad 1=F\frac{y}{-z}-B,\quad 1=F\frac{top}{-(-near)}-B,$$
$$1=F\frac{top}{near}-B$$

Perspective Derivation

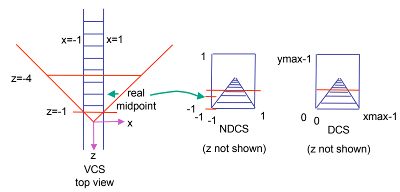
- similarly for other 5 planes
- 6 planes, 6 unknowns

$$\begin{bmatrix}\frac{2n}{r-l}&0&\frac{r+l}{r-l}&0\\0&\frac{2n}{t-b}&\frac{t+b}{t-b}&0\\0&0&\frac{-(f+n)}{f-n}&\frac{-2fn}{f-n}\\0&0&-1&0\end{bmatrix}$$

Perspective Example

tracks in VCS:
left x=-1, y=-1
right x=1, y=-1

view volume
left = -1, right = 1
bot = -1, top = 1
near = 1, far = 4



Perspective Example

view volume
- left = -1, right = 1
- bot = -1, top = 1
- near = 1, far = 4

$$\begin{bmatrix}\frac{2n}{r-l}&0&\frac{r+l}{r-l}&0\\0&\frac{2n}{t-b}&\frac{t+b}{t-b}&0\\0&0&\frac{-(f+n)}{f-n}&\frac{-2fn}{f-n}\\0&0&-1&0\end{bmatrix}\quad\begin{bmatrix}1&0&0&0\\0&1&0&0\\0&0&-5/3&-8/3\\0&0&-1&0\end{bmatrix}$$

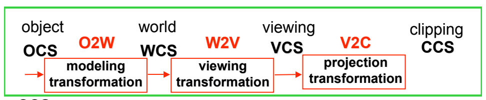
Perspective Example

$$\begin{bmatrix}1\\-1\\-5z_{VCS}/3-8/3\\-z_{VCS}\end{bmatrix}=\begin{bmatrix}1&&&\\&1&&\\&&-5/3&-8/3\\&&-1&\end{bmatrix}\begin{bmatrix}1\\-1\\z_{VCS}\\1\end{bmatrix}$$

/ w

$$x_{NDCS}=-1/z_{VCS}$$
$$y_{NDCS}=1/z_{VCS}$$
$$z_{NDCS}=\frac{5}{3}+\frac{8}{3z_{VCS}}$$

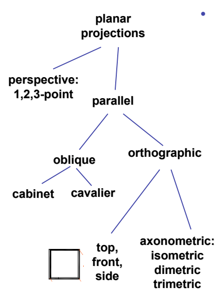
OpenGL Example



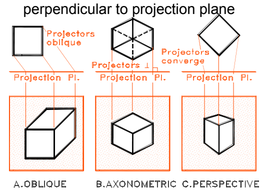

```
CCS   glMatrixMode( GL_PROJECTION );
      glLoadIdentity();
      gluPerspective( 45, 1.0, 0.1, 200.0 );
VCS   glMatrixMode( GL_MODELVIEW );
      glLoadIdentity();
      glTranslatef( 0.0, 0.0, -5.0 );
WCS   glPushMatrix()
      glTranslate( 4, 4, 0 );   W2O
OCS1  glutSolidTeapot(1);
      glPopMatrix();
      glTranslate( 2, 2, 0);    W2O
OCS2  glutSolidTeapot(1);
```

- transformations that are applied first are specified last

Projection Taxonomy



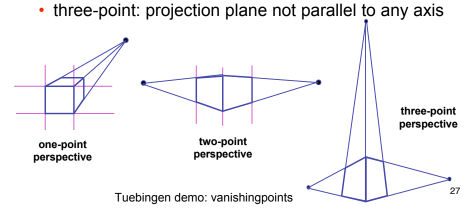
- perspective: projectors converge
  - orthographic, axonometric: projectors parallel and perpendicular to projection plane
  - oblique: projectors parallel, but not perpendicular to projection plane



http://ceprofs.tamu.edu/tkramer/ENGR%20111/5.1/20

Perspective Projections

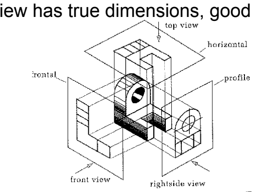
- projectors converge on image plane
- select how many vanishing points
  - one-point: projection plane parallel to two axes
  - two-point: projection plane parallel to one axis
  - three-point: projection plane not parallel to any axis



Tuebingen demo: vanishingpoints

Orthographic Projections

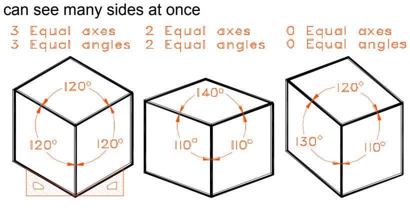
- projectors parallel, perpendicular to image plane
- image plane normal parallel to one of principal axes
- select view: top, front, side
- every view has true dimensions, good for measuring



http://www.cs.fit.edu/~wds/classes/cse5255/thesis/images/proj/orthoProj.gif

Axonometric Projections

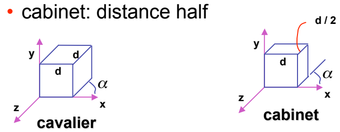
- projectors parallel, perpendicular to image plane
- image plane normal not parallel to axes
- select axis lengths
- can see many sides at once



http://ceprofs.tamu.edu/tkramer/ENGR%20111/5.1/20

Oblique Projections

- projectors parallel, oblique to image plane
- select angle between front and z axis
  - lengths remain constant
- both have true front view
  - cavalier: distance true
  - cabinet: distance half



Tuebingen demo: oblique projections