University of British Columbia
CPSC 314 Computer Graphics
Jan-Apr 2008

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Viewing/Projections IV

Week 4, Fri Feb 1

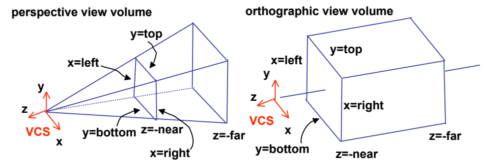
http://www.ugrad.cs.ubc.ca/~cs314/Vjan2008

News

- extra TA office hours in lab next week to answer questions
  - Mon 1-3
  - Tue 2-4
  - Wed 1-3
- reminder
  - Wed 2/6: Homework 1 due 1pm sharp
  - Wed 2/6: Project 1 due 6pm.

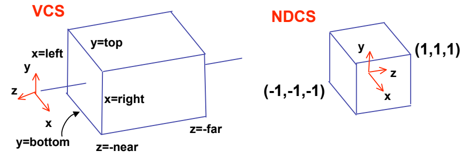
Review: View Volumes

- specifies field-of-view, used for clipping
- restricts domain of *z* stored for visibility test



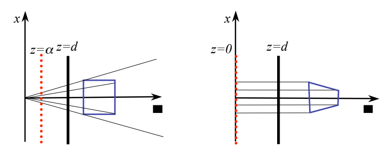
Review: Understanding Z

- z axis flip changes coord system handedness
  - RHS before projection (eye/view coords)
  - LHS after projection (clip, norm device coords)

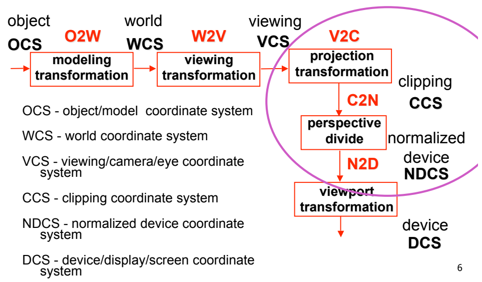


Review: Projection Normalization

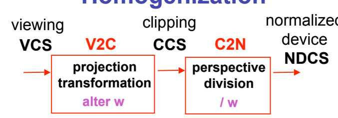
- warp perspective view volume to orthogonal view volume
  - render all scenes with orthographic projection!
  - aka perspective warp



Review: Projective Rendering Pipeline



Review: Separate Warp From Homogenization



- warp requires only standard matrix multiply
  - distort such that orthographic projection of distorted objects is desired persp projection
    - w is changed
  - clip after warp, before divide
  - division by w: homogenization

Reading for Viewing

- FCG Chapter 7 Viewing
- FCG Section 6.3.1 Windowing Transforms

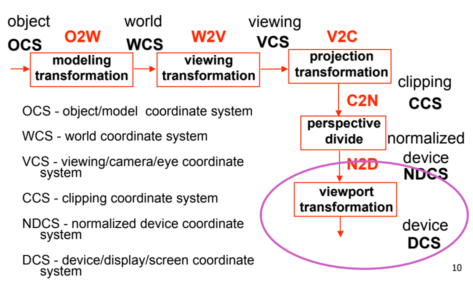
- RB rest of Chap Viewing
- RB rest of App Homogeneous Coords

Reading for Next Time

- RB Chap Color

- FCG Sections 3.2-3.3
- FCG Chap 20 Color
- FCG Chap 21.2.2 Visual Perception (Color)

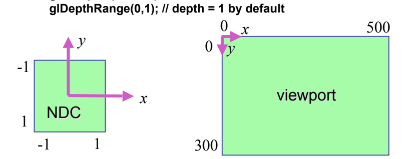
Projective Rendering Pipeline



NDC to Device Transformation

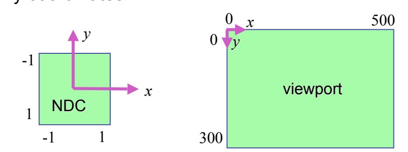
- map from NDC to pixel coordinates on display
  - NDC range is x = -1...1, y = -1...1, z = -1...1
  - typical display range: x = 0...500, y = 0...300
    - maximum is size of actual screen
    - z range max and default is (0, 1), use later for visibility

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



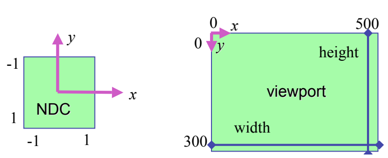
Origin Location

- 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



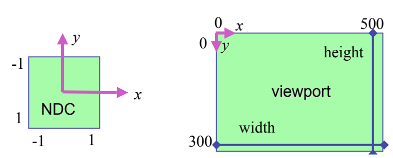
N2D Transformation

- 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)



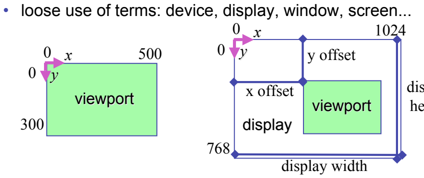
N2D Transformation

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

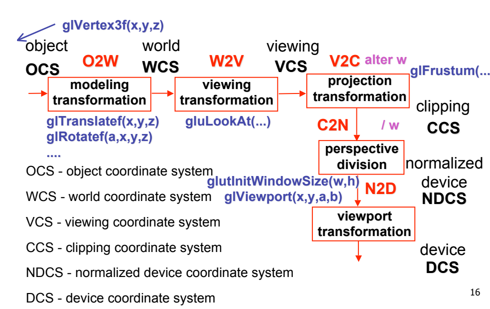


Device vs. Screen Coordinates

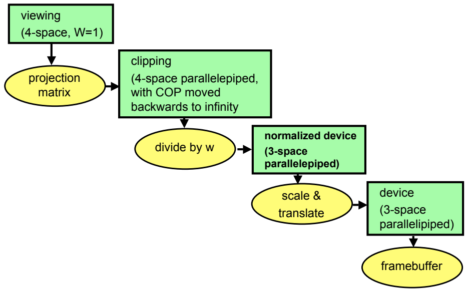
- viewport/window location wrt actual display not available within OpenGL
  - usually don't care
    - use relative information when handling mouse events, not absolute coordinates
  - could get actual display height/width, window offsets from OS
- loose use of terms: device, display, window, screen...



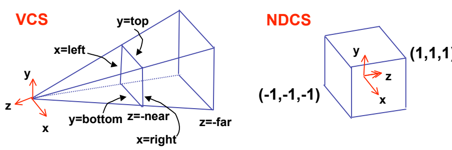
Projective Rendering Pipeline



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

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

Perspective Derivation

earlier:

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

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Perspective Derivation

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

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

$$x=left \rightarrow x'/w'=1$$
$$x=right \rightarrow x'/w'=-1$$
$$y=top \rightarrow y'/w'=1$$
$$y=bottom \rightarrow y'/w'=-1$$
$$z=-near \rightarrow z'/w'=1$$
$$z=-far \rightarrow z'/w'=-1$$

$$y'=Fy+Bz,\quad \frac{y'}{w'}=\frac{Fy+Bz}{w'},\quad 1=\frac{Fy+Bz}{w'},\quad 1=\frac{Fy+Bz}{-z},$$

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

$$1=F\frac{top}{near}-B$$

Perspective Derivation

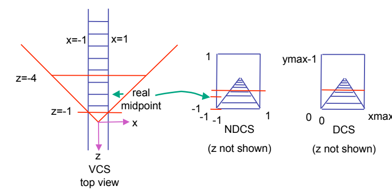
- similarly for other 5 planes
- 6 planes, 6 unknowns

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

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
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- near = 1, far = 4

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

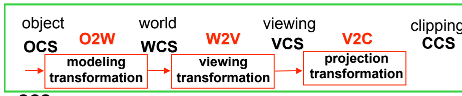
Perspective Example

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

/ w

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

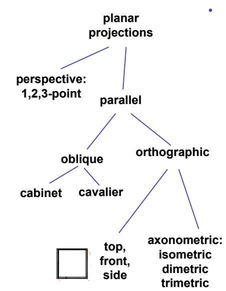
OpenGL Example



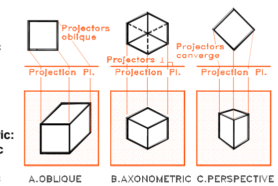

```
CCS   glMatrixMode( GL_PROJECTION );
      glLoadIdentity();
      gluPerspective( 45, 1.0, 0.1, 200.0 );
VCS   glMatrixMode( GL_MODELVIEW );
      glLoadIdentity();
      glTranslatef( 0.0, 0.0, -5.0 );
WCS   glPushMatrix()
      glTranslate( 4, 4, 0 );    W2O
OCS1  glutSolidTeapot(1);
      glPopMatrix();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

- transformations that are applied first are specified last

Projection Taxonomy



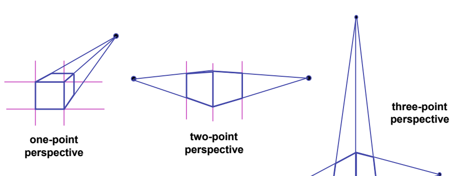
- perspective: projectors converge
- orthographic, axonometric: projectors parallel and perpendicular to projection plane
- oblique: projectors parallel, but not perpendicular to projection plane



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

Perspective Projections

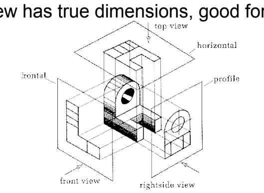
- projectors converge on image plane
- select how many vanishing points
  - one-point: projection plane parallel to two axes
  - two-point: projection plane parallel to one axis
  - three-point: projection plane not parallel to any axis



Tuebingen demo: vanishingpoints

Orthographic Projections

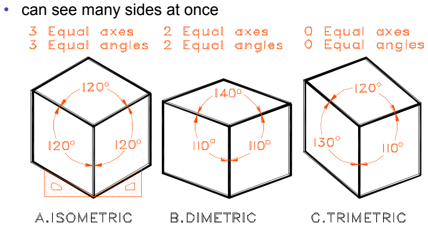
- projectors parallel, perpendicular to image plane
- image plane normal parallel to one of principal axes
- select view: top, front, side
- every view has true dimensions, good for measuring



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

Axonometric Projections

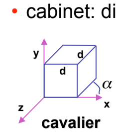
- projectors parallel, perpendicular to image plane
- image plane normal not parallel to axes
- select axis lengths
- can see many sides at once

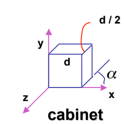


http://ceprofs.tamu.edu/tkramer/ENGR%20111/5.1/20

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