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

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Transformations V

Week 3, Wed Jan 24

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

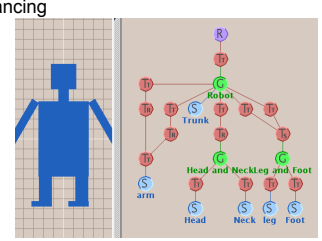
Reading for Next 3 Lectures

- FCG Chapter 7 Viewing
- FCG Section 6.3.1 Windowing Transforms

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

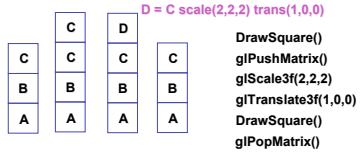
Review: Transformation Hierarchies

- transforms apply to graph nodes beneath them
- design structure so that object doesn't fall apart
- instancing



Review: Matrix Stacks

- OpenGL matrix calls postmultiply matrix M onto current matrix P, overwrite it to be PM
  - or can save intermediate states with stack
  - no need to compute inverse matrices all the time
  - modularize changes to pipeline state
  - avoids accumulation of numerical errors



Assignments

Assignments

- project 1
  - out today, due 5:59pm Fri Feb 2
    - you should start very soon!
  - build armadillo out of cubes and 4x4 matrices
    - think cartoon, not beauty
  - template code gives you program shell, Makefile
    - http://www.ugrad.cs.ubc.ca/~cs314/Vjan2007/p1.tar.gz
- written homework 1
  - out today, due 3pm Fri Feb 2
  - theoretical side of material

Project 1 Advice

- do not model everything first and only then worry about animating
- interleave modelling, animation
  - add body part, then animate it
  - discover if on wrong track sooner
  - depenencies: can't get anim credit if no model
  - use middle body as scene graph root
- check from all camera angles

Project 1 Advice

- finish all required parts before
  - going for extra credit
  - playing with lighting or viewing
- ok to use glRotate, glTranslate, glScale
- ok to use glutSolidCube, or build your own
  - where to put origin? your choice
    - center of object, range - .5 to +.5
    - corner of object, range 0 to 1

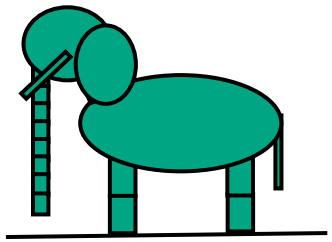
Project 1 Advice

- visual debugging
  - color cube faces differently
  - colored lines sticking out of glutSolidCube faces
- thinking about transformations
  - move physical objects around
  - play with demos
    - Brown scenegraph applets

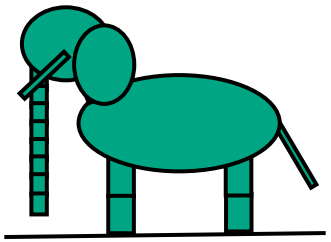
Project 1 Advice

- first: jump cut from old to new position
  - all change happens in single frame
- do last: add smooth transition
  - change happens gradually over 30 frames
  - key click triggers animation loop
    - explicitly redraw 30 times
    - linear interpolation:
      each time, param += (new-old)/30
  - example: 5-frame transition

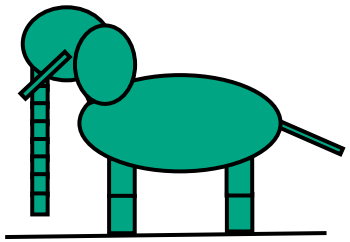
Tail Wag Frame 0



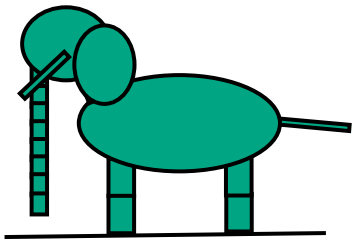
Tail Wag Frame 1



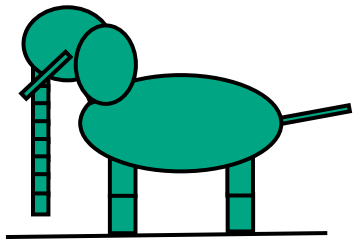
Tail Wag Frame 2



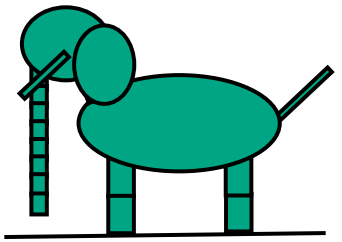
Tail Wag Frame 3



Tail Wag Frame 4



Tail Wag Frame 5



Project 1 Advice

- transitions
  - safe to linearly interpolate parameters for glRotate/glTranslate/glScale
  - do not interpolate individual elements of 4x4 matrix!

Style

- you can lose up to 15% for poor style
- most critical: reasonable structure
  - yes: parametrized functions
  - no: cut-and-paste with slight changes
- reasonable names (variables, functions)
- adequate commenting
  - rule of thumb: what if you had to fix a bug two years from now?
- global variables are indeed acceptable

Version Control

- bad idea: just keep changing same file
- save off versions often
  - after got one thing to work, before you try starting something else
  - just before you do something drastic
- how?
  - not good: commenting out big blocks of code
  - a little better: save off file under new name
    - p1.almostworks.cpp, p1.fixedbug.cpp
- much better:use version control software
  - strongly recommended

Version Control Software

- easy to browse previous work
- easy to revert if needed
- for maximum benefit, use meaningful comments to describe what you did
  - "started on tail", "fixed head breakoff bug", "leg code compiles but doesn't run"
- useful when you're working alone
- critical when you're working together
- many choices: RCS, CVS, subversion
  - RCS is a good place to start
    - easy to use, installed on lab machines

RCS Basics

- setup, just do once in a directory
  - mkdir RCS
- checkin
  - ci –u p1.cpp
- checkout
  - co –l p1.cpp
- see history
  - rcs log p1.cpp
- compare to previous version
  - rcsdiff p1.cpp
- checkout old version to stdout
  - co –p1.5 p1.cpp > p1.cpp.5

Graphical File Comparison

- installed on lab machines
  - xfdiff4 (side by side comparison)
  - xwdiff (in-place, with crossouts)
- Windows: windiff
  - http://keithdevens.com/files/windiff
- Macs: FileMerge
  - in /Developer/Applications/Utilities

Display Lists

Display Lists

- precompile/cache block of OpenGL code for reuse
  - usually more efficient than immediate mode
    - exact optimizations depend on driver
  - good for multiple instances of same object
    - but cannot change contents, not parametrizable
  - good for static objects redrawn often
    - display lists persist across multiple frames
    - interactive graphics: objects redrawn every frame from new viewpoint from moving camera
  - can be nested hierarchically
- snowman example

  http://www.lighthouse3d.com/opengl/displaylists

One Snowman

```
void drawSnowMan() {

glColor3f(1.0f, 1.0f, 1.0f);

// Draw Body
glTranslatef(0.0f ,0.75f, 0.0f);
glutSolidSphere(0.75f,20,20);

// Draw Head
glTranslatef(0.0f, 1.0f, 0.0f);
glutSolidSphere(0.25f,20,20);

// Draw Eyes
glPushMatrix();
glColor3f(0.0f,0.0f,0.0f);
glTranslatef(0.05f, 0.10f, 0.18f);
glutSolidSphere(0.05f,10,10);
glTranslatef(-0.1f, 0.0f, 0.0f);
glutSolidSphere(0.05f,10,10);
glPopMatrix();

// Draw Nose
glColor3f(1.0f, 0.5f , 0.5f);
glRotatef(0.0f,1.0f, 0.0f, 0.0f);
glutSolidCone(0.08f,0.5f,10,2);
}
```


Instantiate Many Snowmen

```
// Draw 36 Snowmen
for(int i = -3; i < 3; i++)
  for(int j=-3; j < 3; j++) {
  glPushMatrix();
  glTranslatef(i*10.0, 0, j * 10.0);
  // Call the function to draw a snowman
  drawSnowMan();
  glPopMatrix();
}
```

36K polygons, 55 FPS

Making Display Lists

```
GLuint createDL() {
GLuint snowManDL;
// Create the id for the list
snowManDL = glGenLists(1);
glNewList(snowManDL,GL_COMPILE);
drawSnowMan();
glEndList();
return(snowManDL); }

snowmanDL = createDL();
for(int i = -3; i < 3; i++)
  for(int j=-3; j < 3; j++) {
    glPushMatrix();
    glTranslatef(i*10.0, 0, j * 10.0);
    glCallList(snowmanDL);
    glPopMatrix(); }
```

36K polygons, 153 FPS

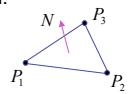
Transforming Normals

Transforming Geometric Objects

- lines, polygons made up of vertices
- just transform the vertices, interpolate between
- does this work for everything? no!

Computing Normals

- polygon:



$$N = (P_2 - P_1) \times (P_3 - P_1)$$

- assume vertices ordered CCW when viewed from visible side of polygon
- normal for a vertex
  - specify polygon orientation
  - used for lighting
  - supplied by model (i.e., sphere), or computed from neighboring polygons

Transforming Normals

- what is a normal?
  - a **direction**
    - homogeneous coordinates: w=0 means direction
  - often normalized to unit length
  - vs. points/vectors that are object vertex locations
- what are normals for?
  - specify orientation of polygonal face
  - used when computing lighting

- so if points transformed by matrix **M**, can we just transform normal vector by **M** too?

Transforming Normals

$$\begin{bmatrix} x' \\ y' \\ z' \\ 0 \end{bmatrix} = \begin{bmatrix} m_{11} & m_{12} & m_{13} & T_x \\ m_{21} & m_{22} & m_{23} & T_y \\ m_{31} & m_{32} & m_{33} & T_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 0 \end{bmatrix}$$

- translations OK: w=0 means unaffected
- rotations OK
- uniform scaling OK

- these all maintain direction

Transforming Normals

- nonuniform scaling does not work
- x-y=0 plane
  - line x=y
  - normal: [1,-1,0]
    - direction of line x=-y
    - (ignore normalization for now)

Transforming Normals

- apply nonuniform scale: stretch along x by 2
  - new plane x = 2y
- transformed normal: [2,-1,0]

$$\begin{bmatrix}2\\-1\\0\\0\end{bmatrix} = \begin{bmatrix}2&0&0&0\\0&1&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}\begin{bmatrix}1\\-1\\0\\0\end{bmatrix}$$

  - normal is direction of line x = -2y or x+2y=0
  - not perpendicular to plane!
  - should be direction of 2x = -y

Planes and Normals

- plane is all points perpendicular to normal
  - $N \cdot P = 0$ (with dot product)
  - $N^{\mathrm{T}} P = 0$ (matrix multiply requires transpose)

$$N = \begin{bmatrix}a\\b\\c\\d\end{bmatrix}, P = \begin{bmatrix}x\\y\\z\\w\end{bmatrix}$$

- explicit form: plane = $ax + by + cz + d$

Finding Correct Normal Transform

- transform a plane

$$\begin{matrix}P\\N\end{matrix} \longrightarrow \begin{matrix}P' = MP\\N' = QN\end{matrix}$$

given M, what should Q be?

$N'^{T} P' = 0$ — stay perpendicular

$(QN)^{T}(MP) = 0$ — substitute from above

$N^{T} Q^{T} MP = 0$ — $(\mathbf{AB})^{\mathrm{T}} = \mathbf{B}^{\mathrm{T}}\mathbf{A}^{\mathrm{T}}$

$Q^{T} M = I$ — $\mathbf{N}^{\mathrm{T}}\mathbf{P} = 0$ if $\mathbf{Q}^{\mathrm{T}}\mathbf{M} = \mathbf{I}$

$$\mathbf{Q} = \left(\mathbf{M}^{-1}\right)^{\mathrm{T}}$$

thus the normal to any surface can be transformed by the inverse transpose of the modelling transformation