CS559 – Lecture 19 and 20
OpenGL Survival

These are course notes (not used as slides)
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The Basics of doing 3D Graphics

- Stuff you need to know to write programs
- Toolkit details best done by looking at code
  - And trying it yourself!
- See online tutorials (e.g. Survival Guide)
- See the red book
- Try to refresh the concepts behind using library
- Goal: get you to know enough to do Project

List of stuff you need to know

- Basics of Toolkits
- Dealing with a window
- Double buffering
- Drawing context
- Transformations / Coordinate Systems / Cameras
- 3D Viewing / Visibility (Z-Buffer)
- Polygon drawing
- Lighting
- Picking and UI

Basics of a toolkit

- OpenGL is for drawing graphics in a window
- Doesn't care where the window comes from
  - Need something to deal with Operating system
- Less good for text and widgets
- Use some toolkit to do windowing and UI support
  - FlTk – supports OpenGL well
  - Glut – simple, designed for doing OpenGL demos
  - Native windows – um, I can't comment

The Drawing Context

- OpenGL is *stateful*
  - Draw in the current window, current color, …
  - Contrast with stateless systems
    draw(x1,y1,x2,y2)
    draw(window, coordsys, x1, y1, x2, y2, color, pattern, …)
- Where is all that state kept?
  - Drawing Context
- Each window has its own state
  - Need mechanisms for keeping track of it
  - Making it the current state
  - FlTk does this for you (in draw, or with make_current)
- Beware! You can only draw with a current context

When does drawing happen

- Two different types of graphics toolkits
  - Immediate mode – stuff goes right to frame buffer
  - Retained mode – keep 3D objects on list, *system* draws all at once
- OpenGL supports both (usually immediate mode)
- What happens with a triangle

Double Buffering

- Double Buffering – independent of immediate/retained!
- Prevent from seeing partially drawn results
- (potentially) keep synced with screen refresh

- Draw into back buffer
- Swap-buffers

- FlTk will take care of this for you

When do I draw?

- When the window is “damaged”
- Periodically (animation / interaction)

- With FlTk:
- It calls the draw function when needed
  - NEVER call it yourself
- If you want to force a redraw, damage your window
  - It will be redrawn when appropriate

Where do I draw

- Screen coordinates – the main place everyone can agree
- OpenGL uses unit coordinates
  - Depth is -1 to 1 as well

- The Viewport
  - GL lets you limit things to a rectangular area of the screen
  - This is the only thing measured in pixels!

- Need to correct for aspect ration of screen

Getting my own coordinate system

- OpenGL only knows 1 coordinate system
  - The “Normalize Device Coordinates” - NDC
  - Viewport mapped to unit cube
  - There is actually 1 other coord system, but that’s a detail for lighting

- If you’re transformation is the identity, you get NDC

- All points transformed by the “current transformation”

OpenGL coordinate transforms

- OpenGL has 2 “current” transforms

  n = **P M x**

  n = point in NDC x = point in your coordinate system
  P = projection matrix M = Model View matrix
  P and M are both stacks (although P is a short stack
- Why 2 matrices?
  - Esoteric detail of lighting
- Only the perspective transform goes into **P**
  - Unless you’re doing something wierd
- **M** gives “camera coordinates”
  - Only lighting happens there in GL

Is OpenGL Post-Multiply?

- An internal detail – unless you look at the matrices

- Think of it as Post-Multiply
  - And if everything is being transposed, no big deal

- Only “load” is to load the transpose
  - OpenGL used to be pre-multiply, but since everyone else is post-multiply

How do I set the transform?

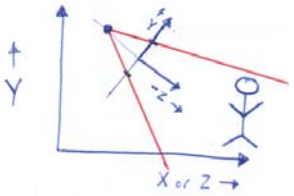
- Need to pick which matrix "stack"
  - Projection, ModelView
- Can either load, or post-multiply
  - Almost everything does a post-multiply
  - Except for the load operations
  - BEWARE: make sure to do a load identity first!
- Most matrix operations build a matrix and post-multiply it onto the "current" stack

Getting your coordinate systems

- Need things in camera coordinates
- Rotate and translate the world coordinates (and possibly scale)
- Think of placing and pointing the camera

Getting the camera scale?

- Projection does some scaling (by Z)
- Projection puts eye at z?
- Projection puts near clipping plane at -1, far plane at 1
- Use OpenGL's projection matrix
- Field of view/aspect ratio

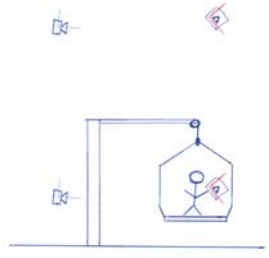


Moving coordinate systems

- Multiplying matrix means changing the coordinate system
- Or think about it as things closest to the object go first

Your own coordinate system

- Draw your triangle…
  - On a piece of paper
  - In your hand
  - When you're on a platform
  - On a crane
- Build transforms!
  - Camera->world
  - World->crane
  - Crane->top of crane
  - Crane->platform
  - Platform->person
  - Person->arm
  - Arm->paper . . .



Convenient ways to make transforms

- Projection
  - gluFrustum, glPerspective
- Matrix handling
  - Load, get, pushmatrix, popmatrix
  - Rarely load anything but the identity

Actually drawing

- Begin / end blocks of points
- Send each point by itself (or as an array)
- Uniformity in how you draw different things
  - Lines
  - Triangles
  - Strips of triangles
  - Quads
- Things are drawn in the “current” state
- Color, line style, …

Normal Vectors

- Assign per-vertex or per-triangle
- Unit vector towards the “outside”
- Not done automatically for you

- Will be very useful for lighting, so get in the habit

What color are things?

- Turn off lighting – and say colors directly

- Turn on lighting – and let the games begin!

- Idea: color of object is affected by lights
  - Need some light to see things
  - Direction of light affects how things look
  - Say where the lights are, how strong they are
  - What the reflectance of the surfaces are
- A whole topic for days in this class

What happens to stuff off the screen?

- Clipping
  - Things get chopped by a plane
  - Each side of the viewing volume
  - Other planes as well – if you want

- Important to do correctly and efficiently
- A lot of work into the methods – but really boring

Visibility

- Give polygons in any order (even back ones last)
- Use a Z-Buffer to store depth at each pixel

- Things that can go wrong:
  - Near and far planes DO matter
  - Backface culling and other tricks can be problematic
  - You may need to turn the Z-buffer on
  - Don’t forget to clear the Z-Buffer!

So, I got a black screen…

- Celebrate – you’ve gotten a window, and that’s step 1!

- Are you drawing at the right time?
- Do you have a drawing context?
- Are you drawing objects?
- Is the camera pointing at them?
- Are they getting mapped to the screen?
- Is something occluding them?
- Are they in the view volume?
- Are they lit correctly?
- And a zillion other things that can go wrong…