Computer Graphics (CS 543) Lecture 1a: Introduction to Computer Graphics

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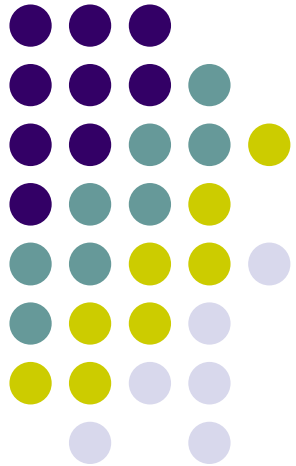


What is Computer Graphics (CG)?

- Computer graphics: algorithms, mathematics, data structures ..... that **computer uses to generate PRETTY PICTURES**
- Techniques (e.g. draw a cube, polygon) evolved over years
- Built into programmable libraries (OpenGL, DirectX, etc)

Computer-Generated!
Not a picture!

Photorealistic Vs Real-Time Graphics

Not this Class

- **Photo-realistic:** E.g ray tracing
  Highest quality image possible
  slow: may take **days** to render

This Class

- **Real Time graphics:** E.g. game engine
  Milliseconds to render (30 FPS)
  Lower image quality

Uses of Computer Graphics: Entertainment

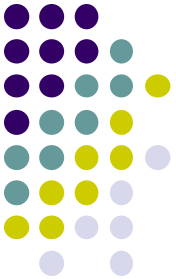
- **Entertainment:** games

Courtesy: Super Mario Galaxy 2

Movies

Courtesy: Spiderman

Uses of Computer Graphics

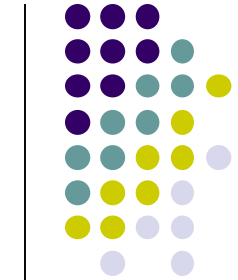


- **Image processing:**
  - alter images, remove noise, super-impose images

Original Image

Sobel Filter

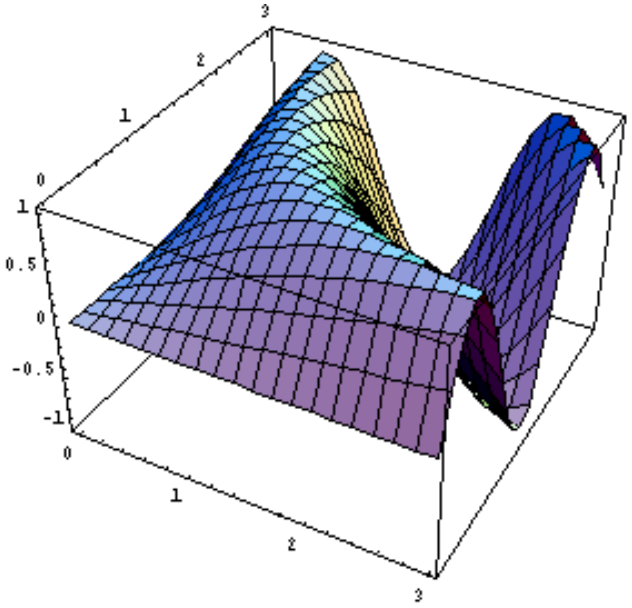
Uses of Computer Graphics



Simulators

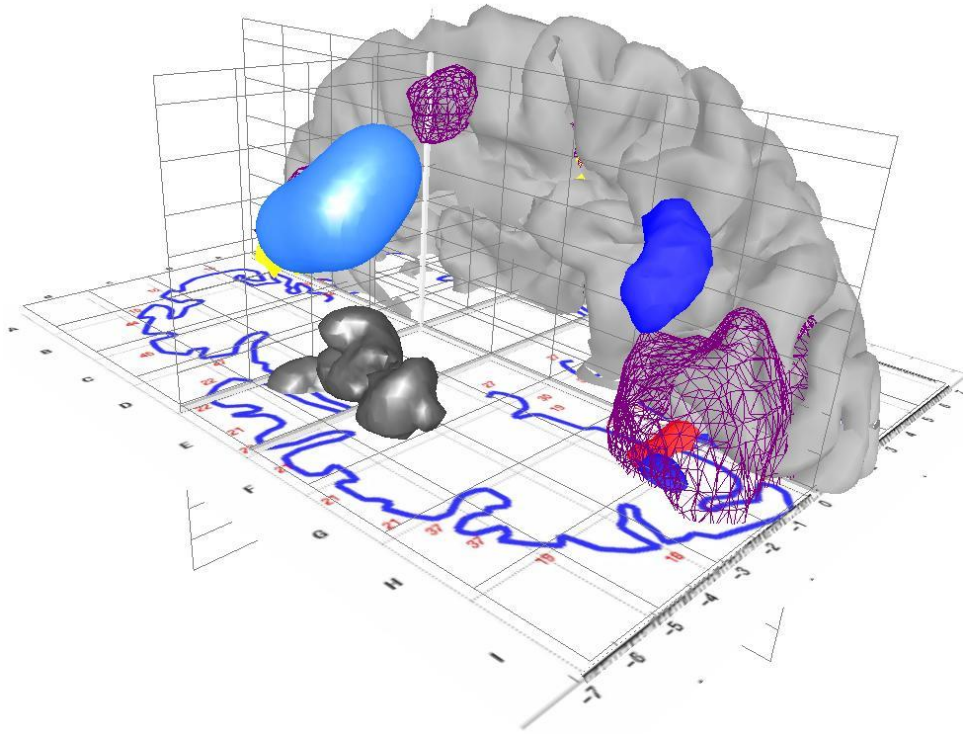
Courtesy: Evans and Sutherland

Display math functions
E.g matlab



Uses of Computer Graphics

- **Scientific analysis and visualization:**

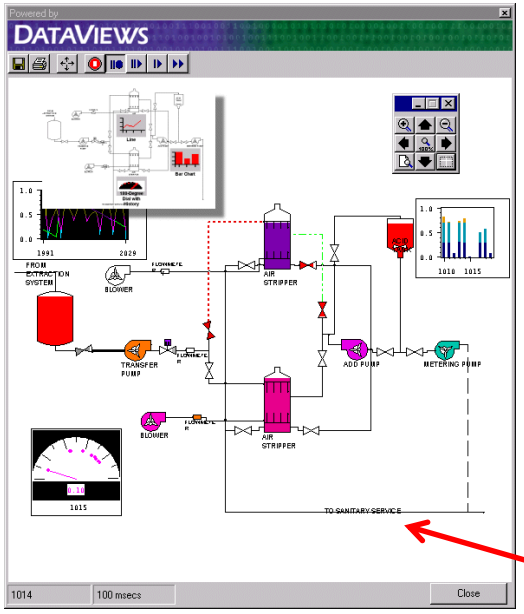


Courtesy:

Human Brain Project, Denmark

2D Vs. 3D

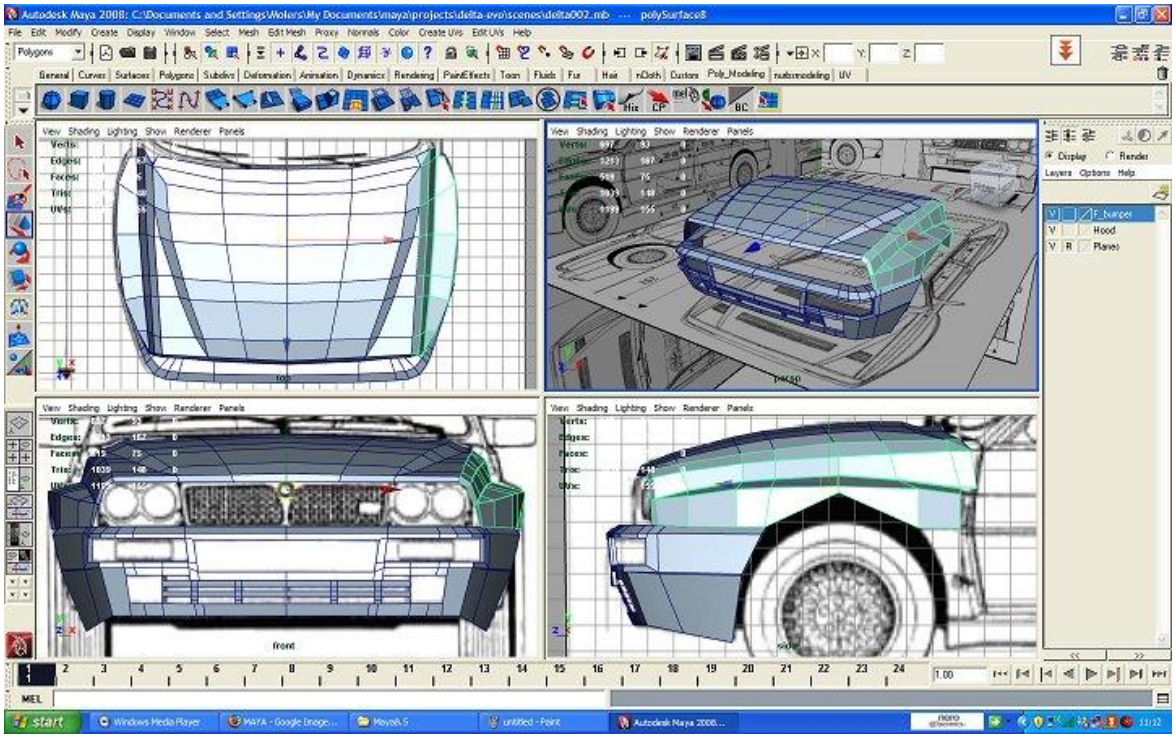
- 2-Dimensional (2D)
  - Flat
  - Objects no notion of distance from viewer
  - Only (x,y) color values on screen
- 3-Dimensional (3D)
  - Objects have distances from viewer
  - (x,y,z) values on screen

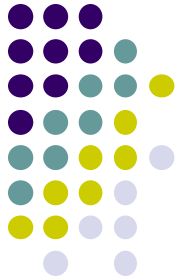


- This class covers both 2D & 3D!
- Also interaction: Clicking, dragging

About This Course

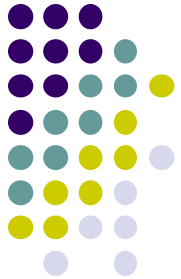
- Computer Graphics has many aspects
  - **Computer Scientists create/program** graphics tools (e.g. Maya, photoshop)
  - **Artists use** CG tools/packages to create pretty pictures
- Most hobbyists follow artist path. Not much math! E.g. use blender





About This Course

- This Course: Computer Graphics for computer scientists!!!
- Teaches concepts, uses OpenGL as concrete example
- Course is **NOT**
  - just about programming OpenGL
  - a comprehensive course in OpenGL. (Only parts of OpenGL covered)
  - about using packages like Maya, Photoshop

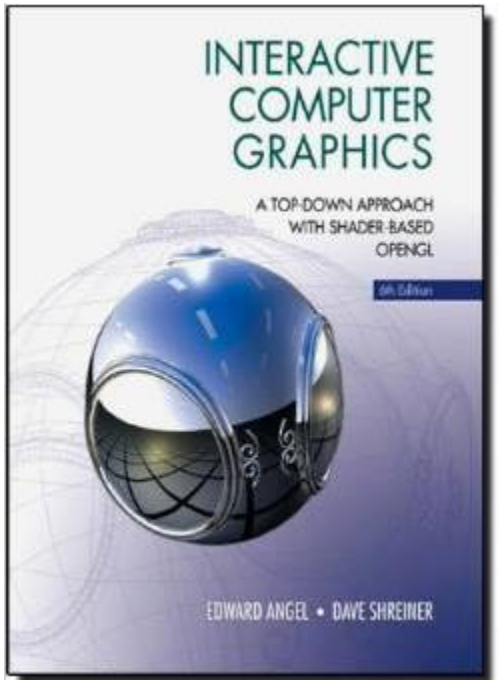


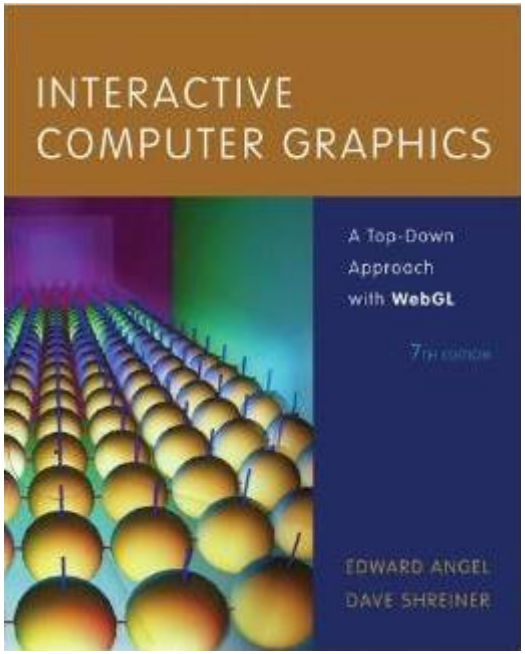
About This Course

- Class is concerned with:
  - How to program computer graphics
  - Underlying mathematics, data structures, algorithms
- This course is a lot of work. Requires:
  - C/C++, shader programming
  - Lots of math, linear algebra, matrices
- We will combine:
  - **Programmer's view:** Program OpenGL APIs
  - **Under the hood:** Learn OpenGL internals (graphics algorithms, math, implementation)

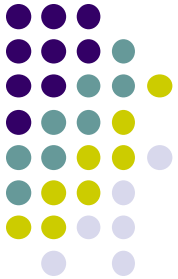
Course Text

- Interactive Computer Graphics: A Top-Down Approach with Shader-based OpenGL by Angel and Shreiner **(6th edition),** 2012
- **Buy 6th edition (pure OpenGL)** **……. NOT 7th edition (WebGL)!!!**



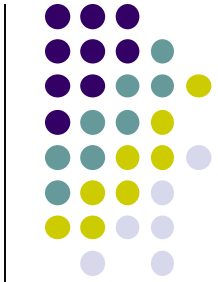


- Supplementary books available through the WPI library. How?



Syllabus Summary

- 3 Exams (50%), 5 Projects (50%)
- Projects:
  - Develop OpenGL/GLSL code on any platform, must port to Zoolab machine
  - May discuss projects but turn in individual projects
- Class website: http://web.cs.wpi.edu/~emmanuel/courses/cs543/f18/
- Cheating: Immediate ‘F’ in the course
  - **Note:** Using past projects on Internet, gitHub, bitBucket is cheating!
- Advice:
  - Come to class
  - Read textbook
  - Understand concepts before coding

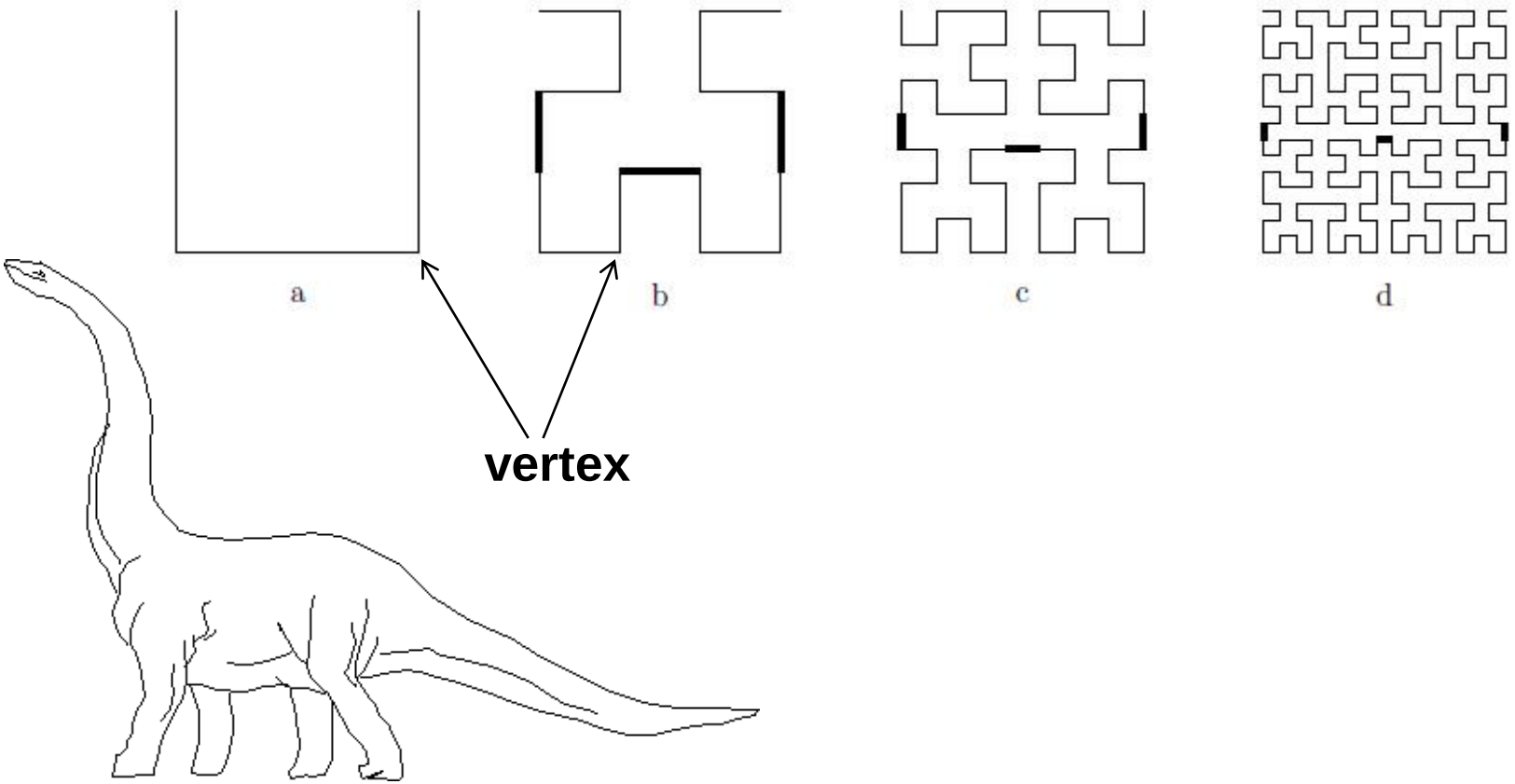


Elements of 2D Graphics

- Polylines
- Text
- Filled regions
- Raster images (pictures)

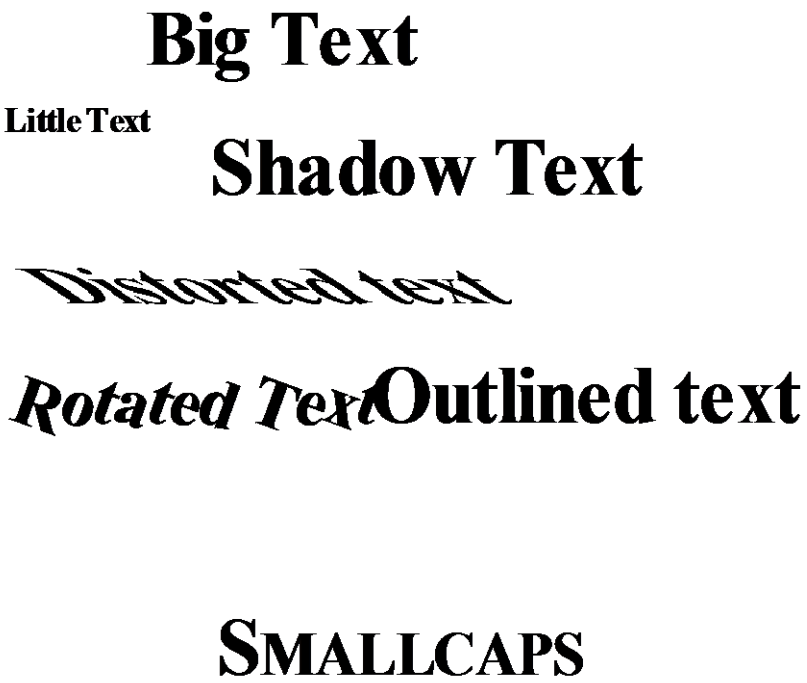
Elements of 2D Graphics

- **Polyline:** vertices (corners) connected by straight lines
- **Attributes:** line thickness, color, etc



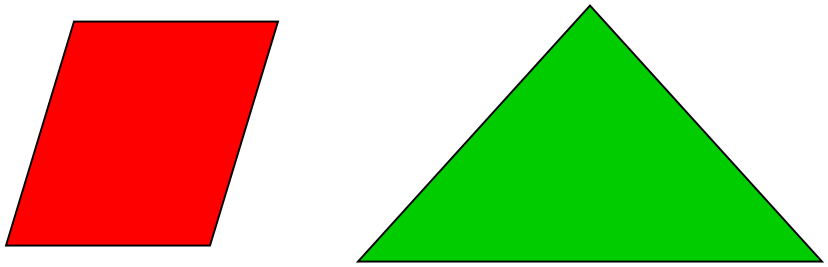
Text

- **Text attributes:** Font, color, size, spacing, and orientation
- Devices have:
  - **text mode**
  - **graphics mode**.
- **Graphics mode:** Text is drawn
- **Text mode:** Text produced by character generator, not drawn

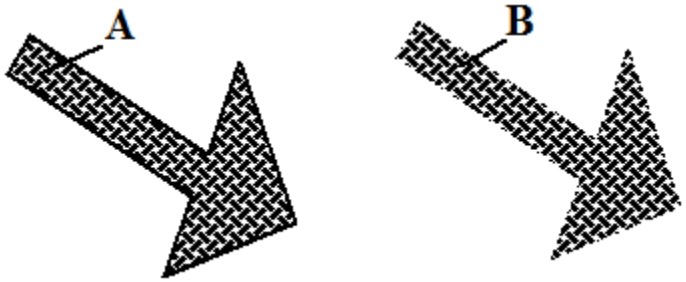


Filled Regions

- **Filled region:** shape filled with a color or pattern
- E.g: polygons



Polygons Filled with Color



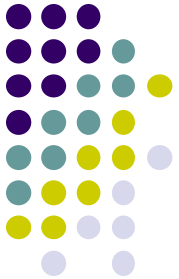
Polygons Filled with Pattern

Raster Images

- Raster image (picture): 2D matrix of pixels (picture elements), in different colors or grayscale.

Grayscale Image

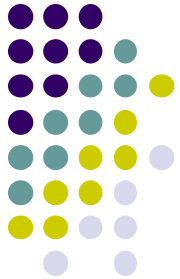
Color Image



Computer Graphics Libraries

- Functions to draw line, circle, image, etc
- Previously device-dependent
  - Different OS => different graphics library
  - Tedious! Difficult to port (e.g. move program Windows to Linux)
  - Error Prone
- Now cross-platform, device-independent libraries
  - **APIs:** OpenGL, DirectX
  - Working OpenGL program few changes to move from Windows to Linux, etc

Graphics Processing Unit (GPU)



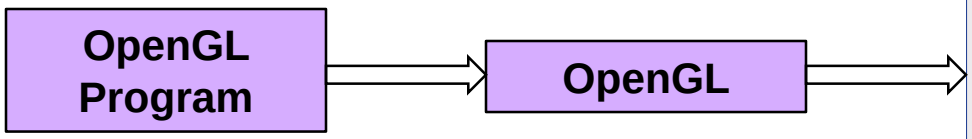
- OpenGL implemented on GPU chip/hardware => FAST!!
- **Programmable:** as shaders
- GPU located either on
  - PC motherboard (Intel) or
  - Separate graphics card (Nvidia or ATI)

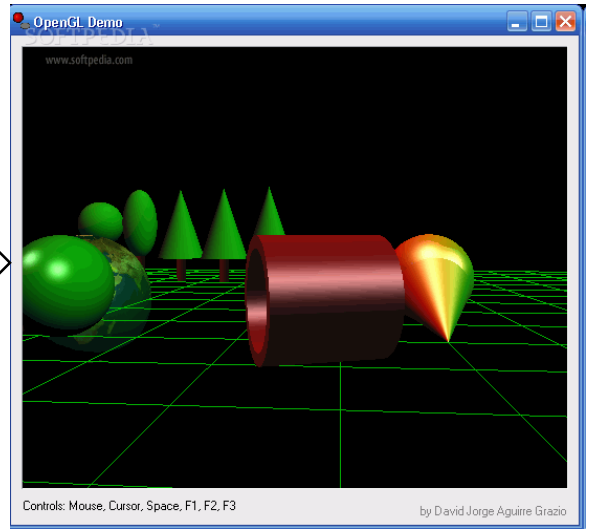
GPU on PC motherboard

GPU on separate PCI express card

OpenGL Basics

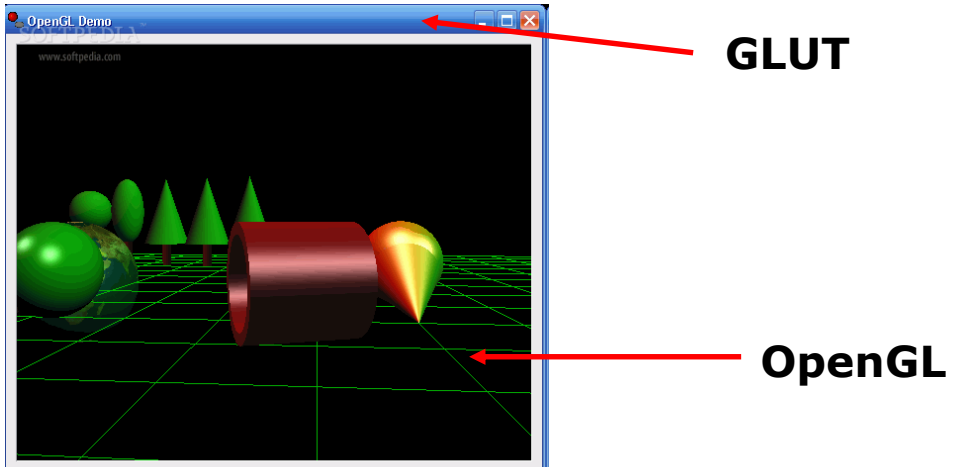
- OpenGL's function is Rendering (drawing)
- Rendering? – Convert geometric/mathematical object descriptions into images
- OpenGL can render (draw):
  - **2D and 3D**
  - **Geometric primitives (lines, dots, etc)**
  - **Bitmap images (pictures, .bmp, .jpg, etc)**





GL Utility Toolkit (GLUT)

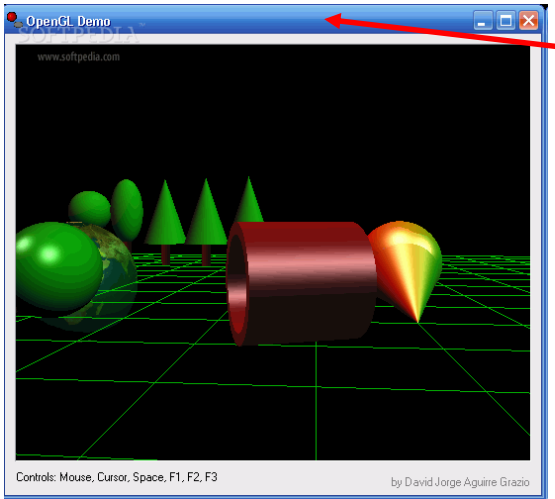
- OpenGL does **NOT** manage drawing window
- OpenGL
  - Window system independent
  - Concerned only with drawing (2D, 3D, images, etc)
  - No window management (create, resize, etc), very portable
- GLUT:
  - Minimal window management
  - Runs on different windowing systems (e.g. Windows, Linux)
  - Program that uses GLUT easily ported between windowing systems.



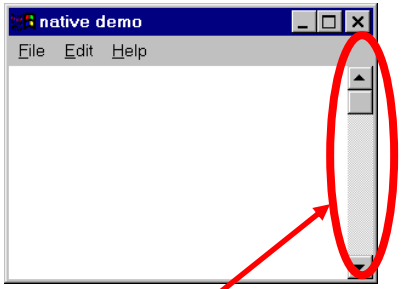
GL Utility Toolkit (GLUT)

- No bells and whistles
  - No sliders, dialog boxes, elaborate menus, etc

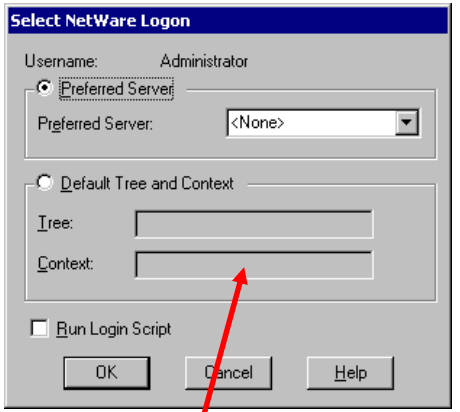
- To add bells and whistles, use system's API (or GLUI):
  - X window system
  - Apple: AGL
  - Microsoft :WGL, etc



GLUT (minimal)

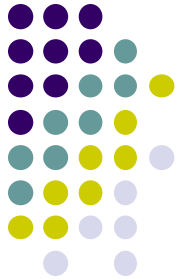


Slider



Dialog box

OpenGL Basics: Portability

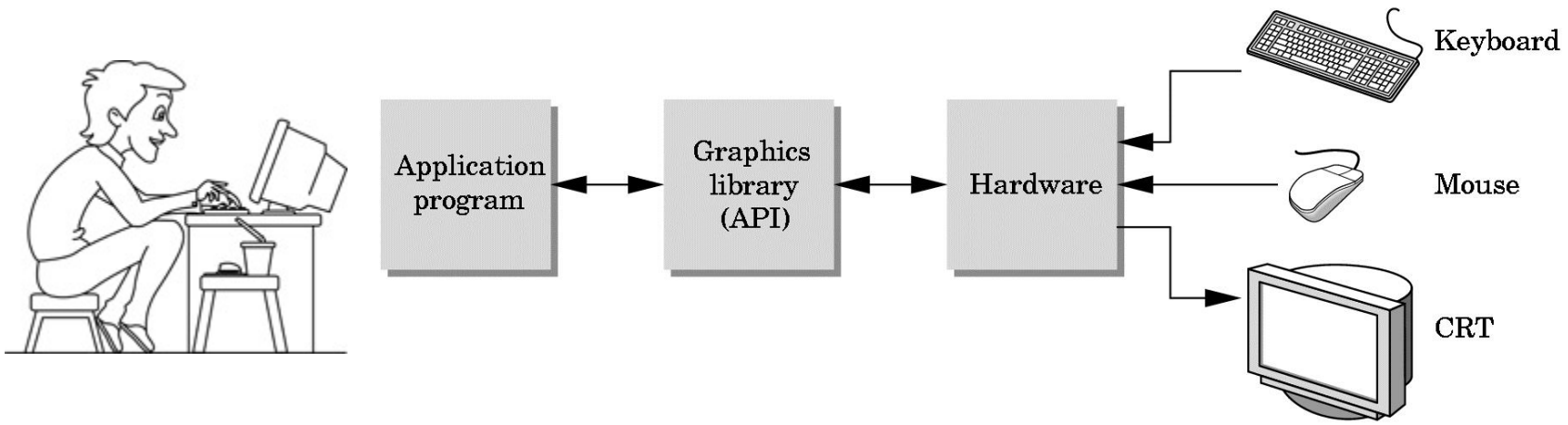


- OpenGL programs behave same on different devices, OS
- Maximal portability
  - **Display device independent (Monitor type, etc)**
  - **OS independent (Unix, Windows, etc)**
  - **Window system independent based (Windows, X, etc)**
- E.g. If student writes OpenGL code on Apple Mac at home, it runs well on Zoolab Windows machines

OpenGL Programming Interface

- Programmer view of OpenGL
  - Application Programmer Interface (API)
  - Writes OpenGL application programs. E.g

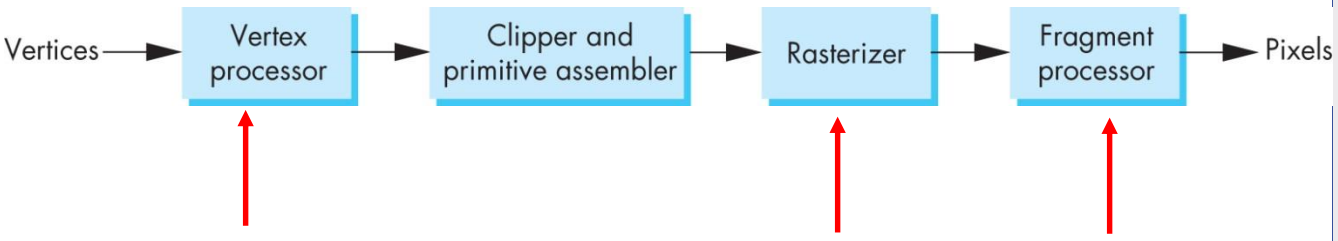
```
glDrawArrays(GL_LINE_LOOP, 0, N);
glFlush( );
```



Simplified OpenGL Pipeline

- Vertices input, sequence of rendering steps (vertex processor, clipper, rasterizer, fragment processor) image rendered

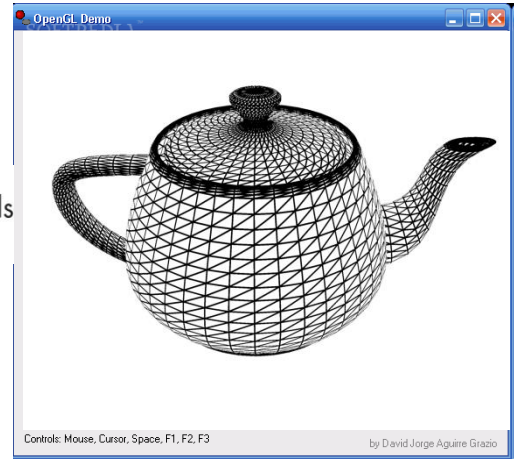
- **This class:** learn graphics rendering steps, algorithms, their order



Vertex Shader

Converts 3D to 2D

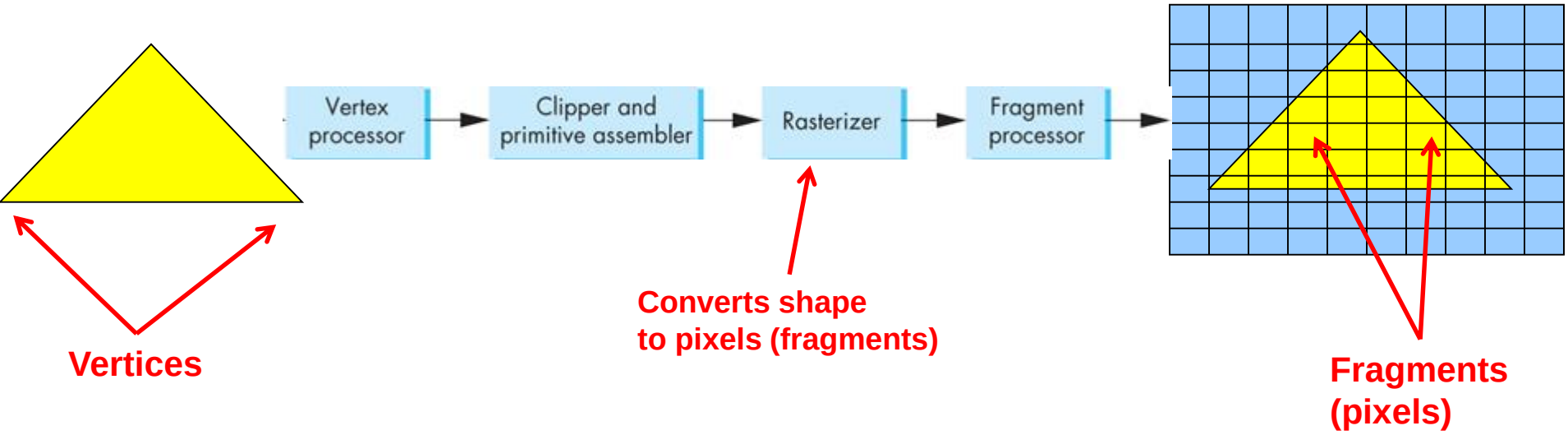
Fragment (Pixel) Shader



Vertex Vs Fragment

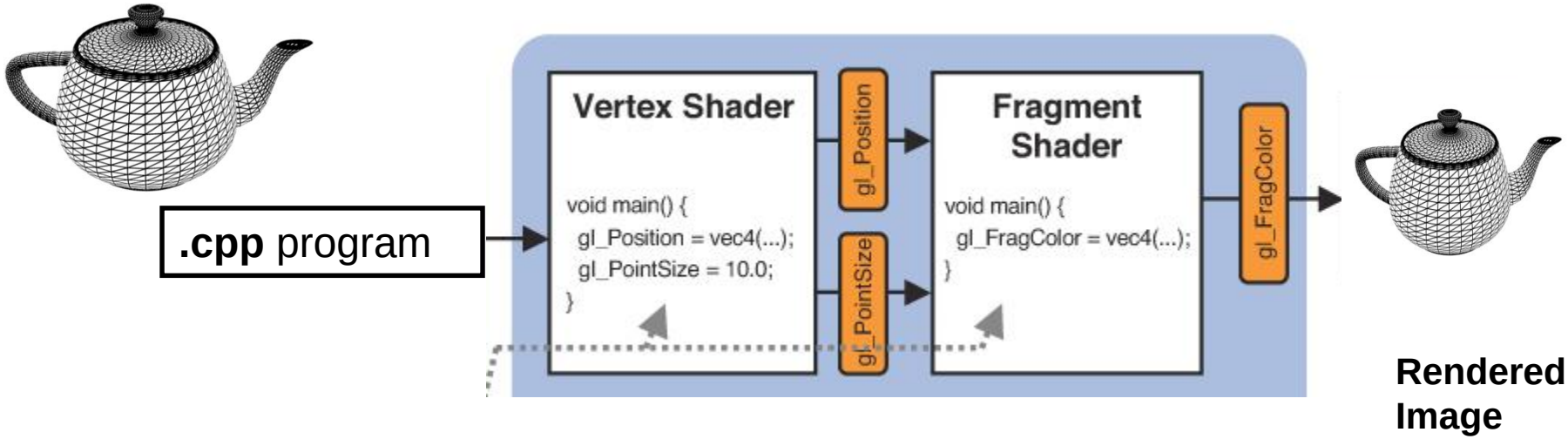
- To draw a shape, OpenGL colors a corresponding group of pixels (fragments) called **rasterization**
  - **E.g** yellow triangle converted to group of pixels to be colored yellow

- **Vertex shader** code manipulates vertices of shapes
- **Fragment shader** code manipulates pixels

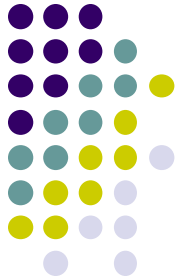


OpenGL Program?

- Usually has 3 files:
  - **.cpp file:** containing OpenGL code, main( ) function
    - Does initialization, generates/loads geometry to be drawn
  - **Vertex shader:** manipulates vertices (e.g. move vertices)
  - **Fragment shader:** manipulates pixels/fragments (e.g change pixel/fragment color)

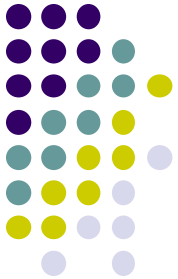


Framebuffer



- Dedicated memory location:
  - Draw into framebuffer => shows up on screen
  - Located either on CPU (software) or GPU (hardware)

References



- Angel and Shreiner, Interactive Computer Graphics (6th edition), Chapter 1
- Hill and Kelley, Computer Graphics using OpenGL (3rd edition), Chapter 1