Computer Graphics (CS 4731) Lecture 1: 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 line, polygon) evolved over years
- Built into programmable libraries

Computer-Generated!
Not a picture!

Photorealistic Vs Real-Time Graphics

Not this Class

Maker's
Mark
WHISKY

This Class

M. BLV
exp sunday
ALL VEHICLES
EXP
WAY
NO TRUCKS
NVIDIA

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

- **Real Time graphics:** **Milliseconds** to render (30 FPS) But lower image quality

Uses of Computer Graphics: Entertainment

- **Entertainment:** games

Courtesy: Super Mario Galaxy 2

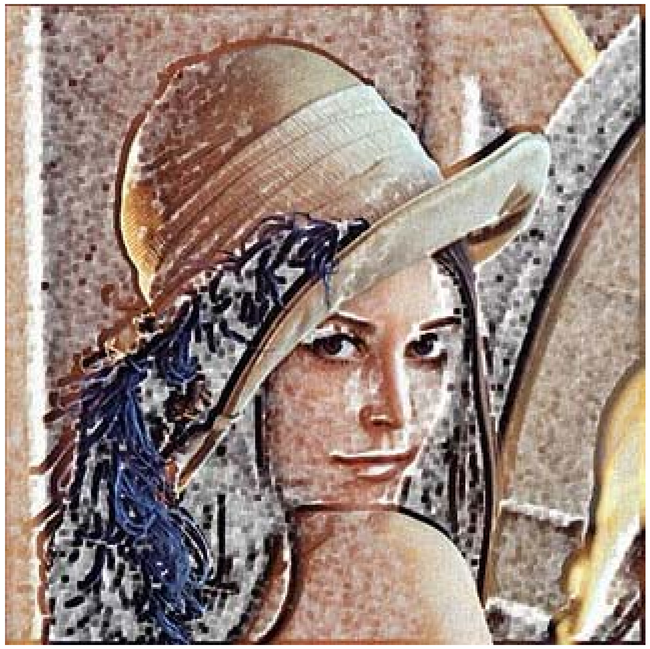
Movies

Courtesy: Spiderman

Uses of Computer Graphics

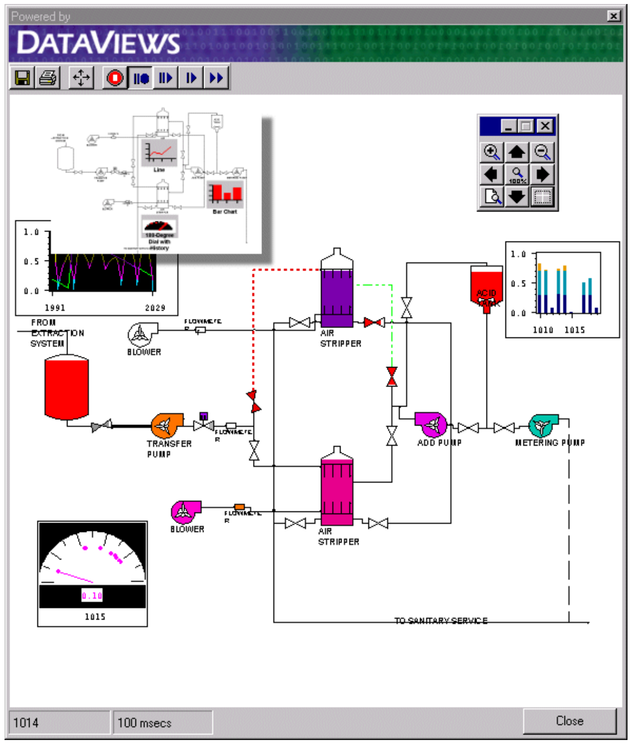
- **Image processing:**
  - alter images, remove noise, super-impose images

Original Image


Sobel Filter

Uses of Computer Graphics

- Monitor large systems or plants



Simulators

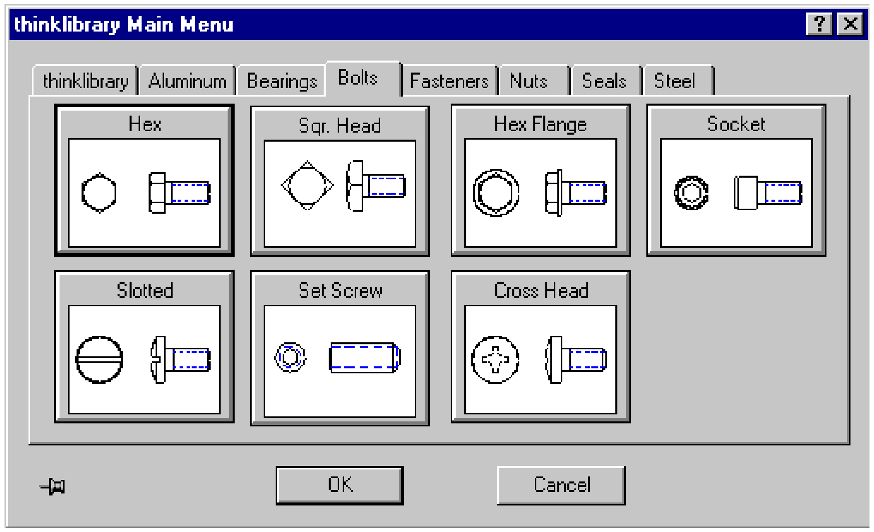
Courtesy:

Dataviews.de

Courtesy: Evans and Sutherland

Uses of Computer Graphics

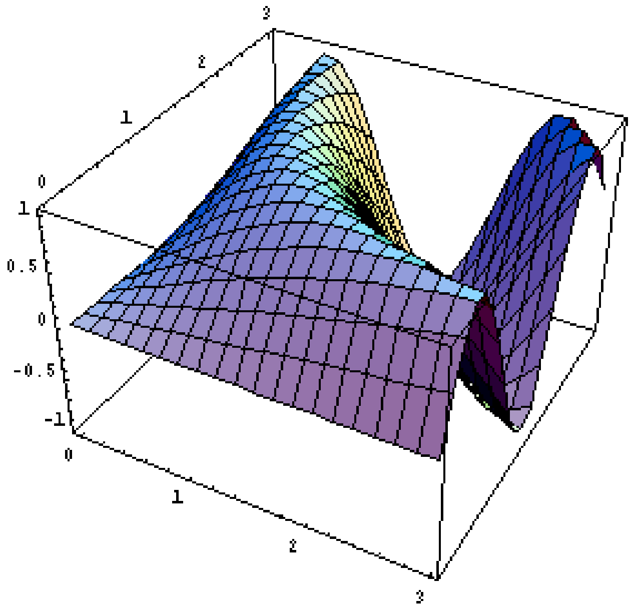
- **Computer-aided design:**



Courtesy:

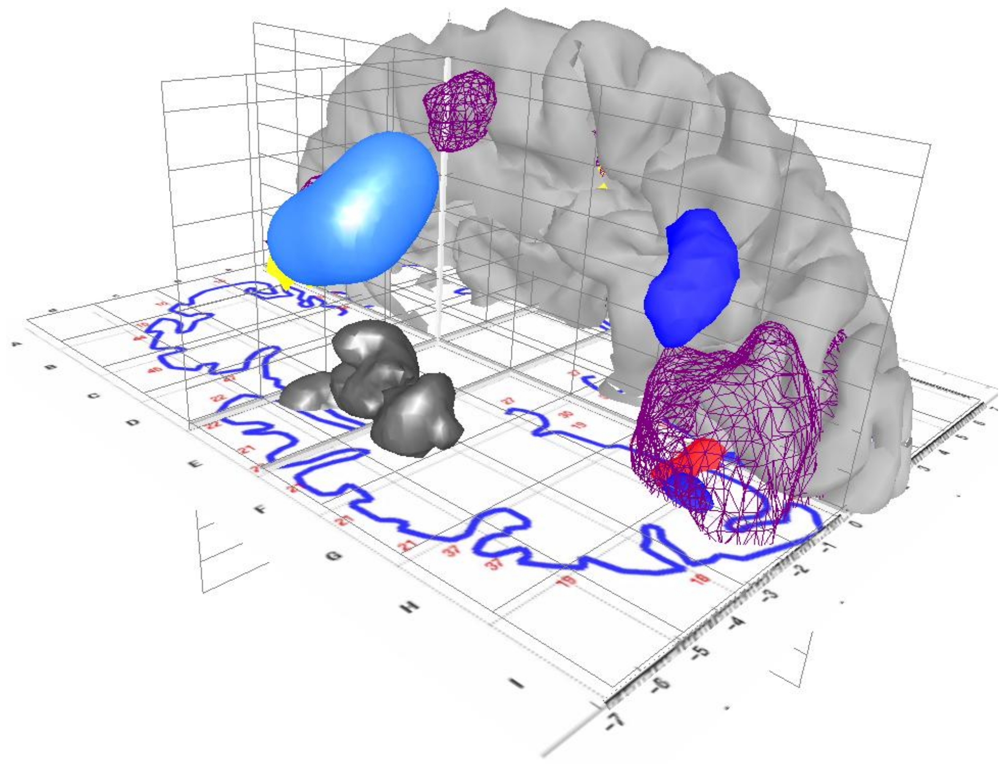
cadalog.com

Display math functions E.g matlab



Uses of Computer Graphics

- **Scientific analysis and visualization:**
  - molecular biology, weather, matlab, Mandelbrot set

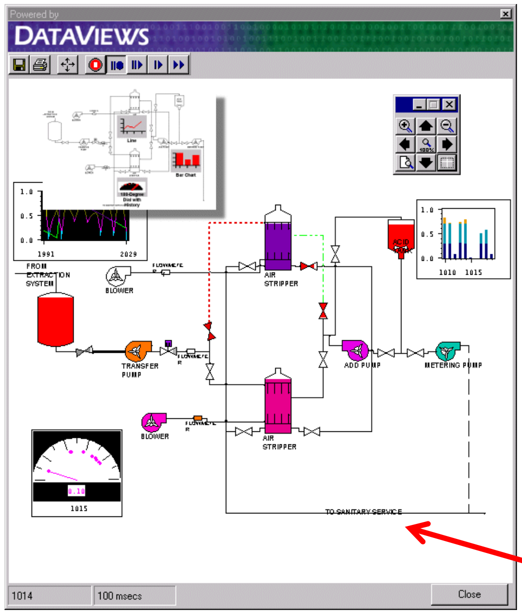


Courtesy:

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



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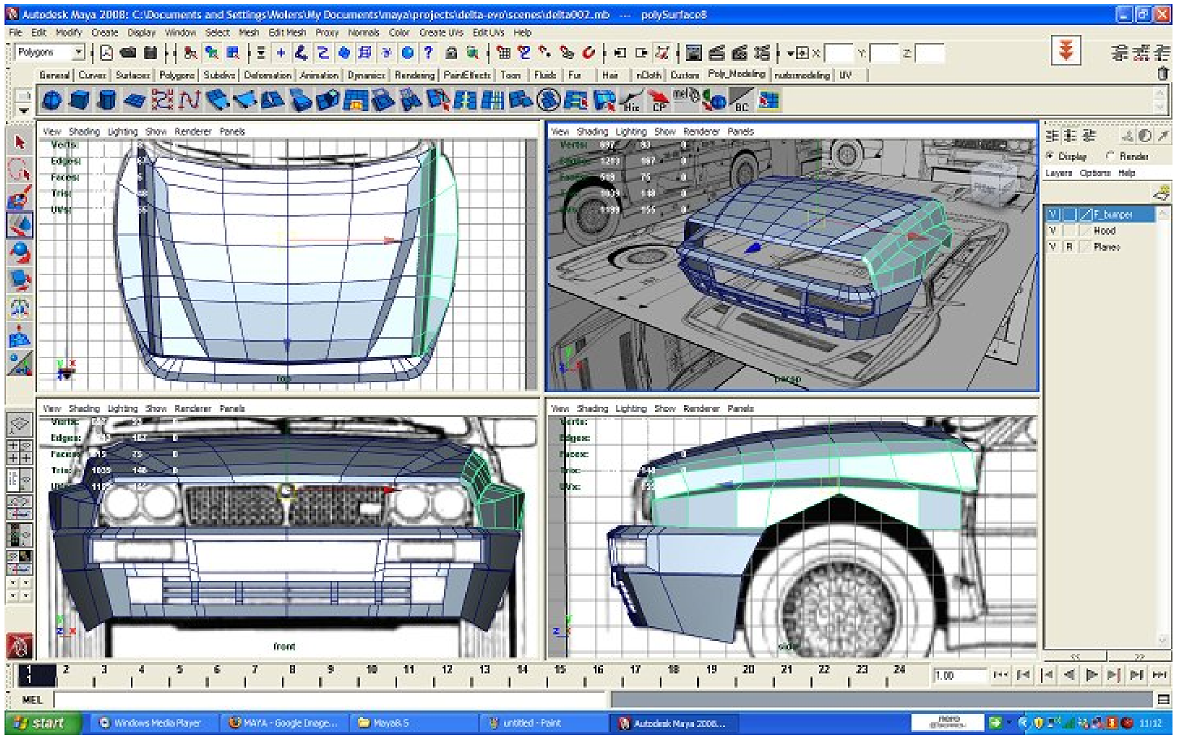
EXP WAY
NO TRUCKS
NVIDIA

- 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



About This Course

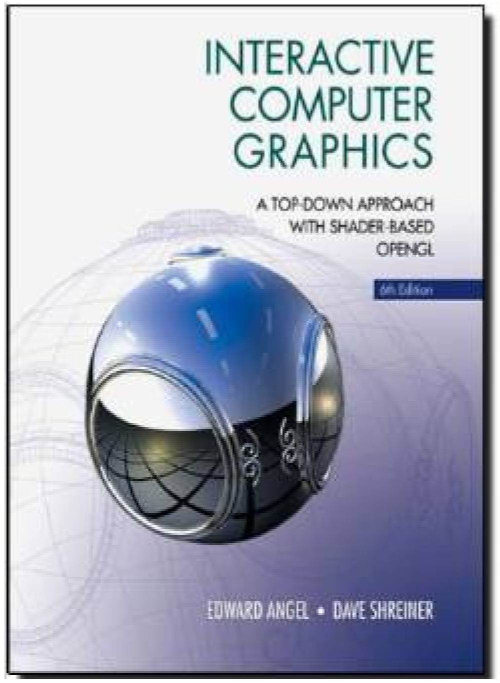
- Most hobbyists follow artist path. Not much math!
- This Course: Computer Graphics for computer scientists!!!
- Teaches concepts, uses OpenGL as concrete example
- Course is **NOT**
  - just about programming OpenGL
  - a comprehensive course in OpenGL. (Only parts of OpenGL covered)
  - about using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

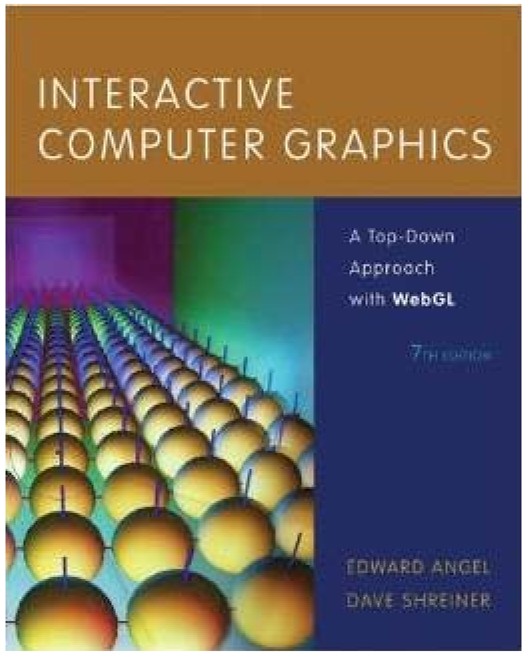
About This Course

- Class is concerned with:
  - How to build/program graphics tools
  - Underlying mathematics
  - Underlying data structures
  - Underlying algorithms
- This course is a lot of work. Requires:
  - Lots of coding in C/C++
  - Shader programming
  - Lots of math, linear algebra, matrices
- We shall 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** **…….. NOT 7th edition!!!**


INTERACTIVE COMPUTER GRAPHICS
A TOP-DOWN APPROACH WITH SHADER-BASED OPENGL
6th Edition
EDWARD ANGEL • DAVE SHREINER



Syllabus Summary

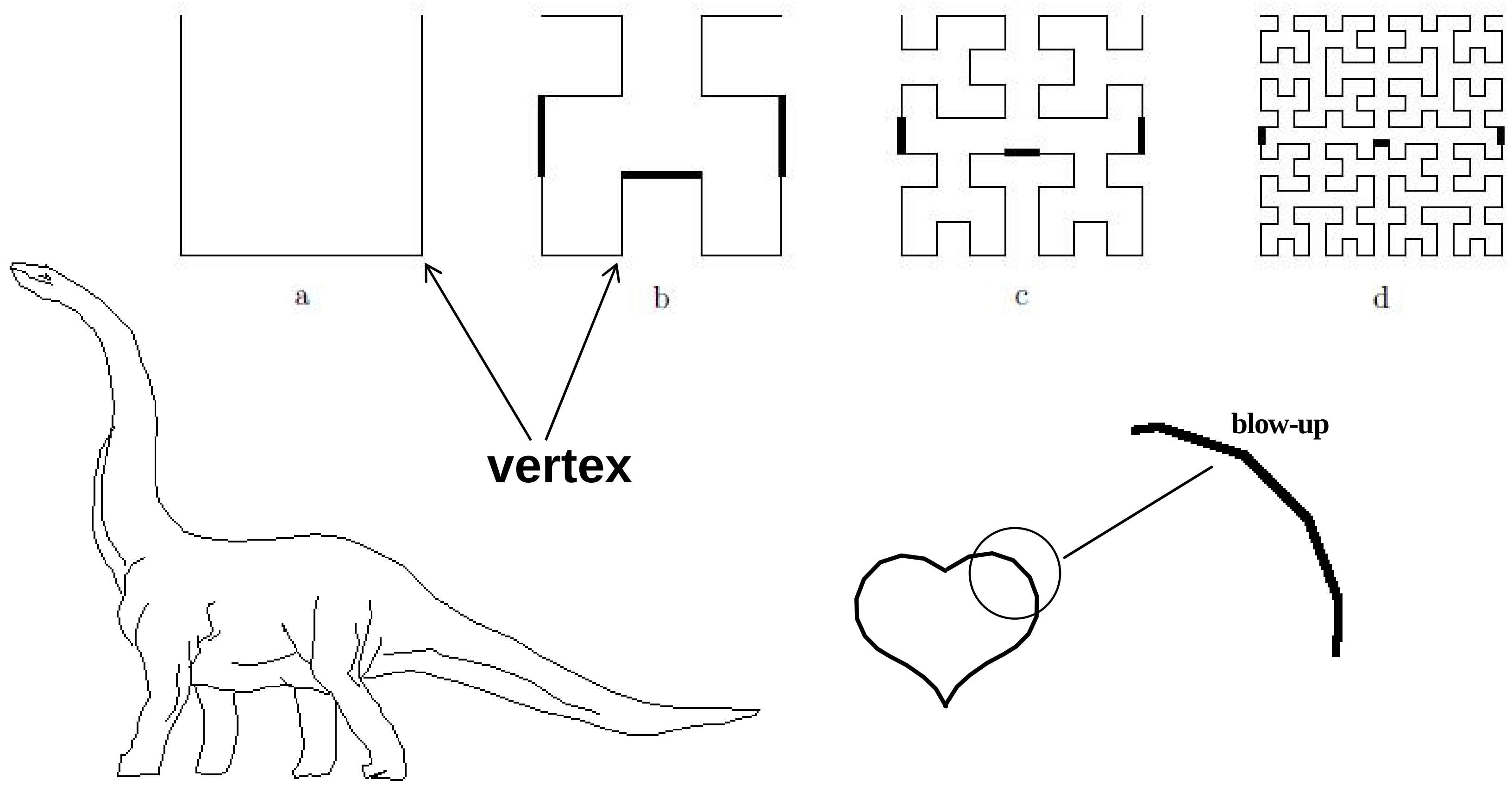
- 2 Exams (50%), 4 Projects (50%)
- Projects:
  - Develop OpenGL/GLSL code on any platform, must port to Zoolab machine
  - May discuss projects but turn in individual projects
- Class website: http://web.cs.wpi.edu/~emmanuel/courses/cs4731/A14/
- Cheating: Immediate 'F' in the course
- Advice:
  - Come to class
  - Read the text
  - Understand concepts before coding

Elements of 2D Graphics

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

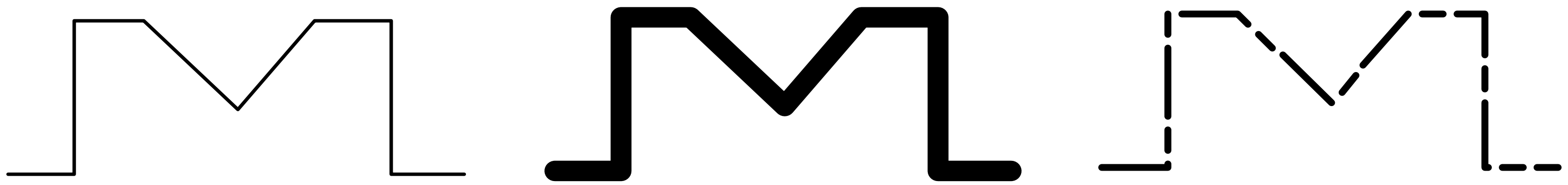
Elements of 2D Graphics

- **Polyline:** connected sequence of straight lines
- Straight lines connect **vertices** (corners)



Polyline Attributes

- Color
- Thickness
- Stippling of edges (dash pattern)



Text

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

Big Text

Little Text

Shadow Text

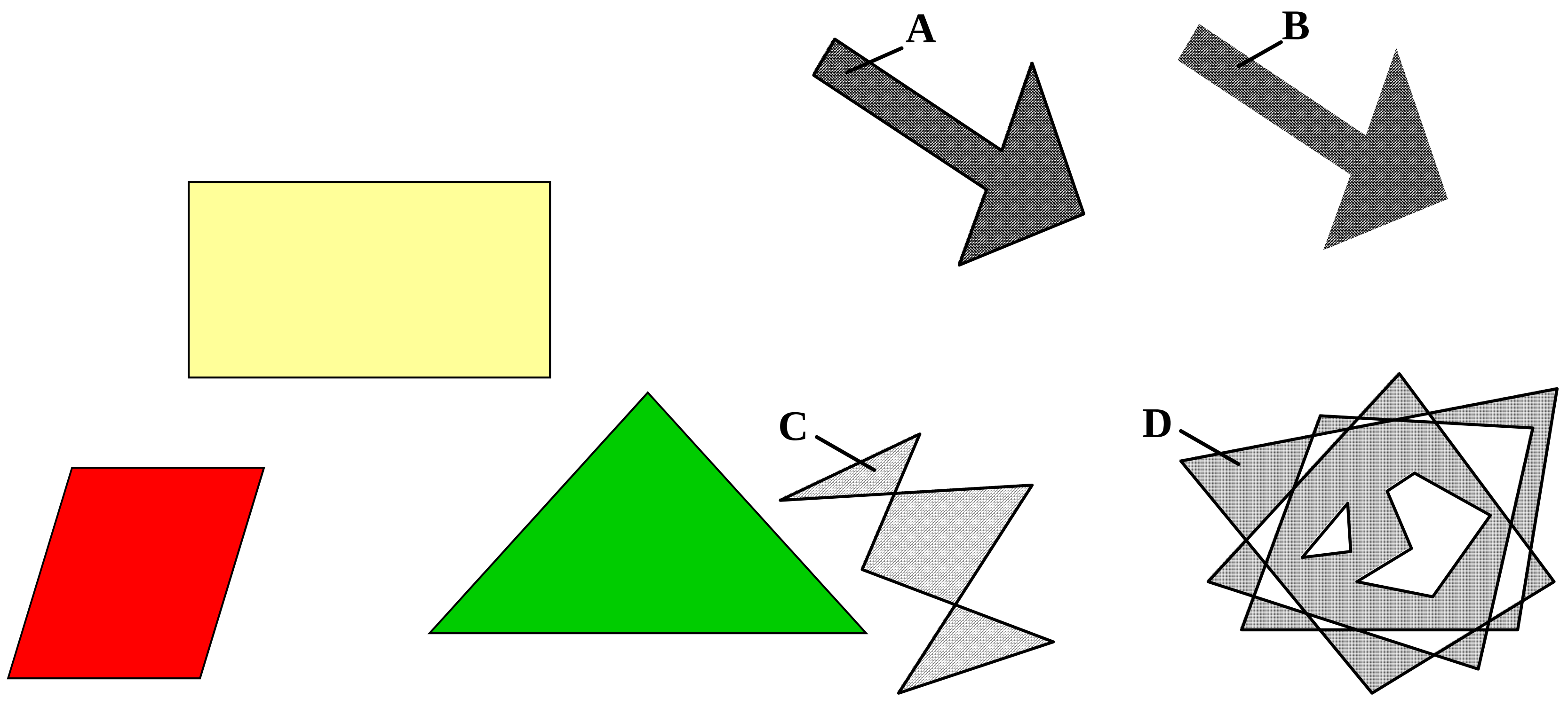
Distorted text

Rotated Text **Outlined text**

SMALLCAPS

Filled Regions

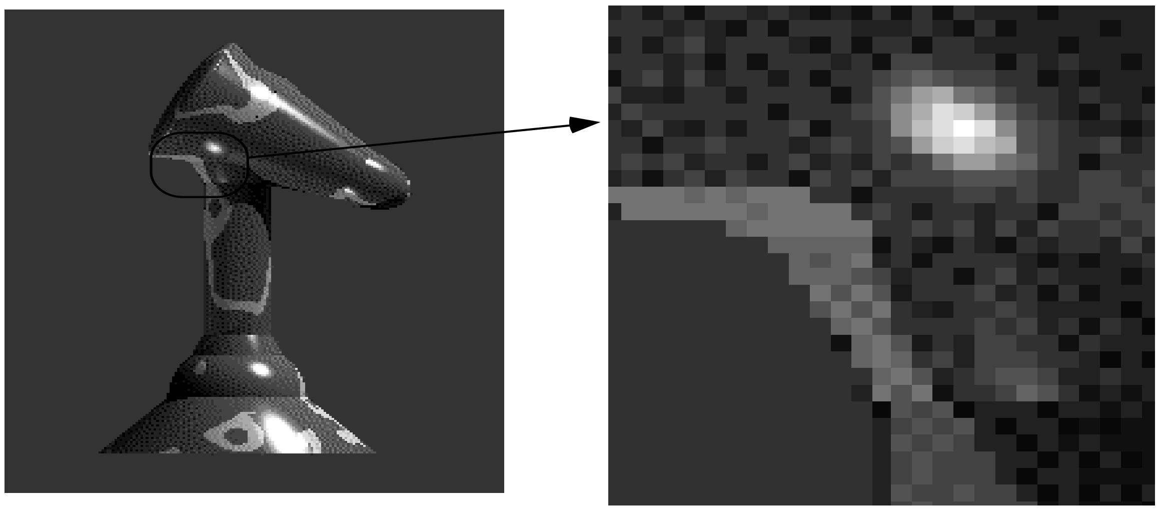
- **Filled region:** shape filled with some color or pattern
- Example: polygons



Raster Images

- Raster image (picture) consists of 2D matrix of small cells (pixels, for “picture elements”), in different colors or grayscale.

Middle image: magnified showing pixels (squares)



Computer Graphics Tools

- Hardware tools
  - **Output devices:** Video monitors, printers
  - **Input devices:** Mouse/trackball, pen/drawing tablet, keyboard
  - Graphics cards/accelerators (GPUs)
- Software tools (low level)
  - Operating system
  - Editor
  - Compiler
  - Debugger
  - Graphics Library (OpenGL)

Graphics Processing Unit (GPU)

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

GPU on PC motherboard

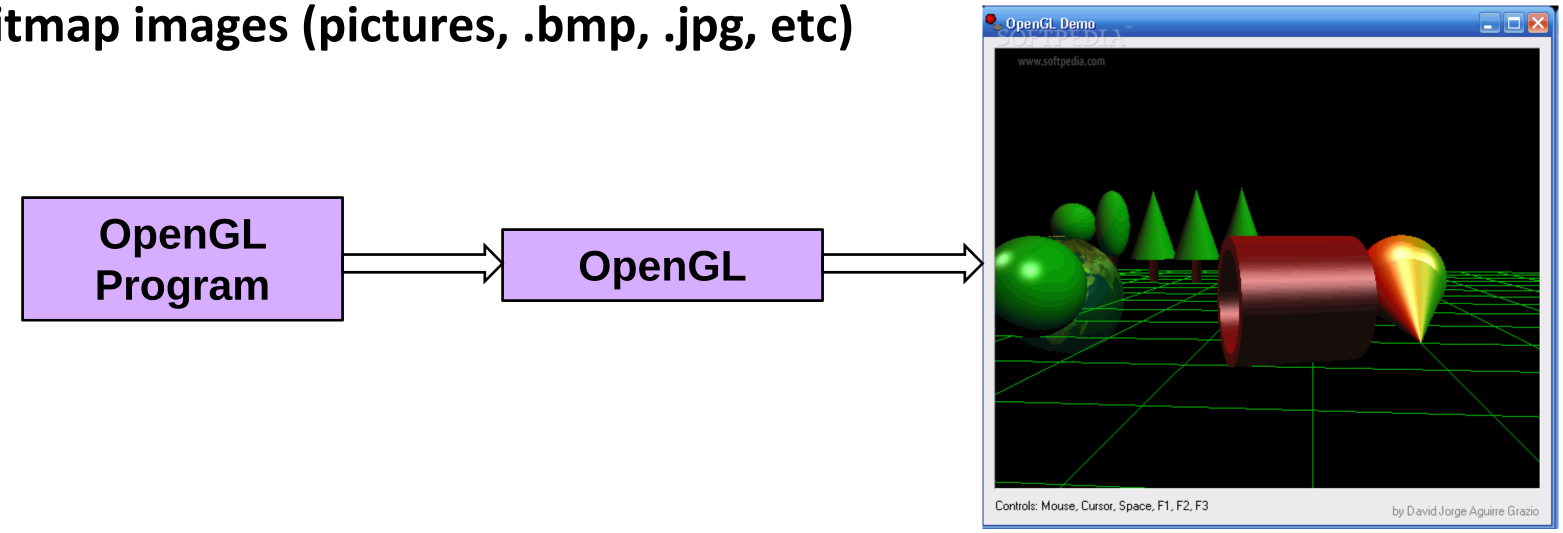
GPU on separate PCI express card

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 device-independent libraries
  - **APIs:** OpenGL, DirectX
  - Working OpenGL program minimal changes to move from Windows to Linux, etc

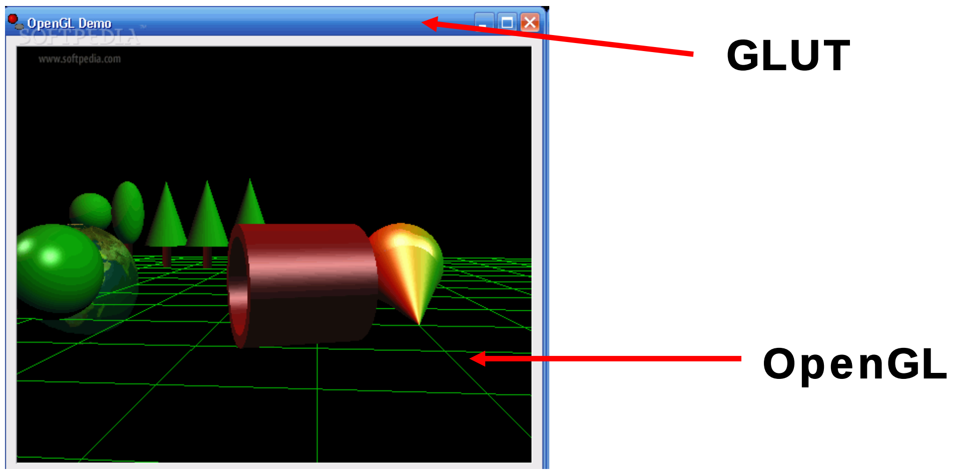
OpenGL Basics

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


OpenGL Program
OpenGL
OpenGL Demo
www.softpedia.com
Controls: Mouse, Cursor, Space, F1, F2, F3
by David Jorge Aguirre Grazio

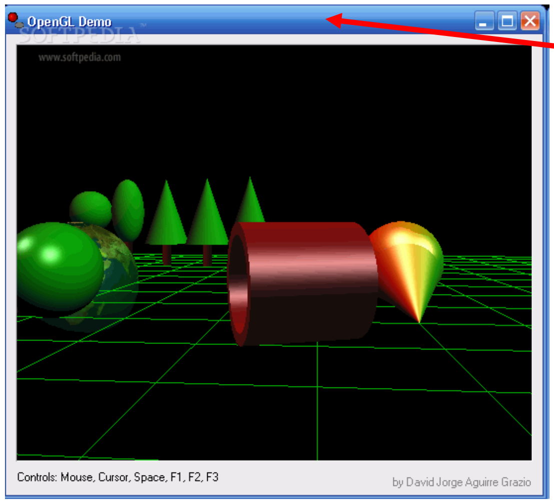
GL Utility Toolkit (GLUT)

- 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
  - Interfaces with different windowing systems
  - Easy porting between windowing systems. Fast prototyping

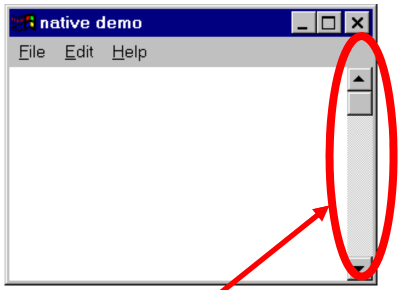


GL Utility Toolkit (GLUT)

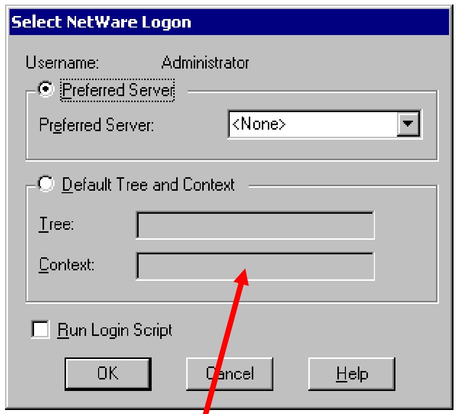
- No bells and whistles
  - No sliders
  - No dialog boxes
  - No elaborate menus, etc
- To add bells and whistles, use system's API or GLUI:
  - X window system
  - Apple: AGL
  - Microsoft :WGL, etc


OpenGL Demo
www.softpedia.com
Controls: Mouse, Cursor, Space, F1, F2, F3
by David Jorge Aguirre Grazio

GLUT (minimal)



Slider



Username: Administrator
(●) Preferred Server
Preferred Server: <None>
( ) Default Tree and Context
Tree:
Context:
[ ] Run Login Script

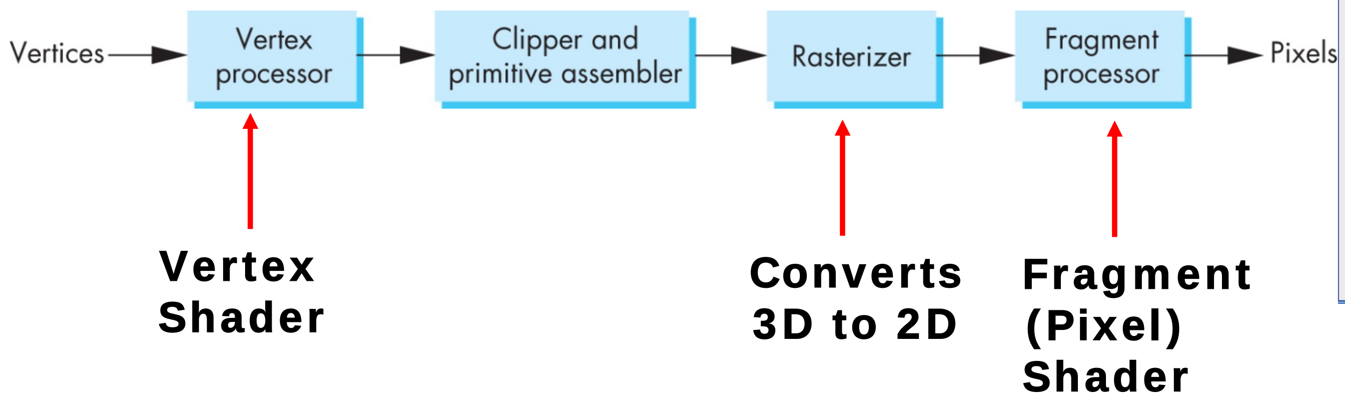
Dialog box

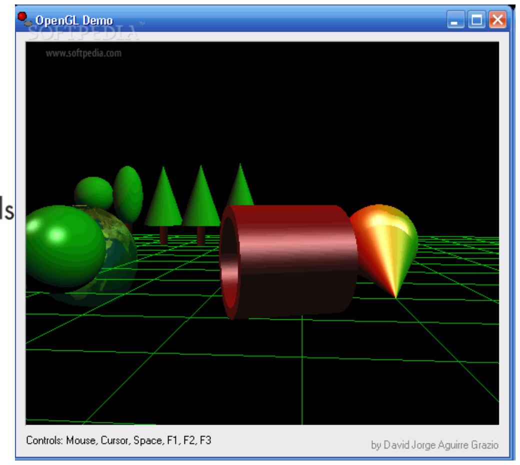
OpenGL Basics

- Low-level graphics rendering API
- Maximal portability
  - **Display device independent (Monitor type, etc)**
  - **Operating system independent (Unix, Windows, etc)**
  - **Window system independent based (Windows, X, etc)**
- OpenGL programs behave same on different devices, OS

Simplified OpenGL Pipeline

- Vertices go in, sequence of steps (vertex processor, clipper, rasterizer, fragment processor) image rendered
- **This class:** learn algorithms and order of these steps




OpenGL Demo
www.softpedia.com
Controls: Mouse, Cursor, Space, F1, F2, F3
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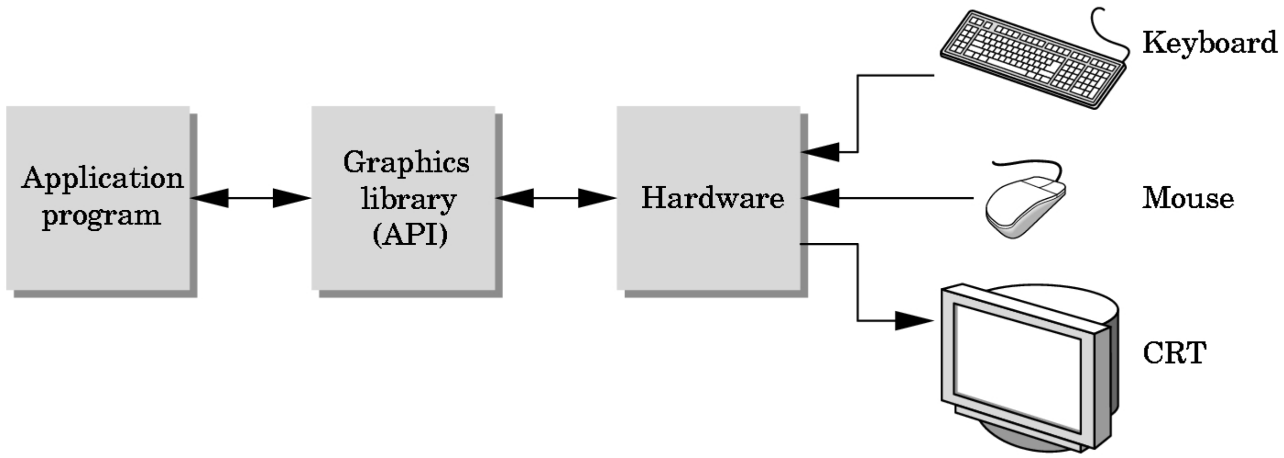
OpenGL Programming Interface

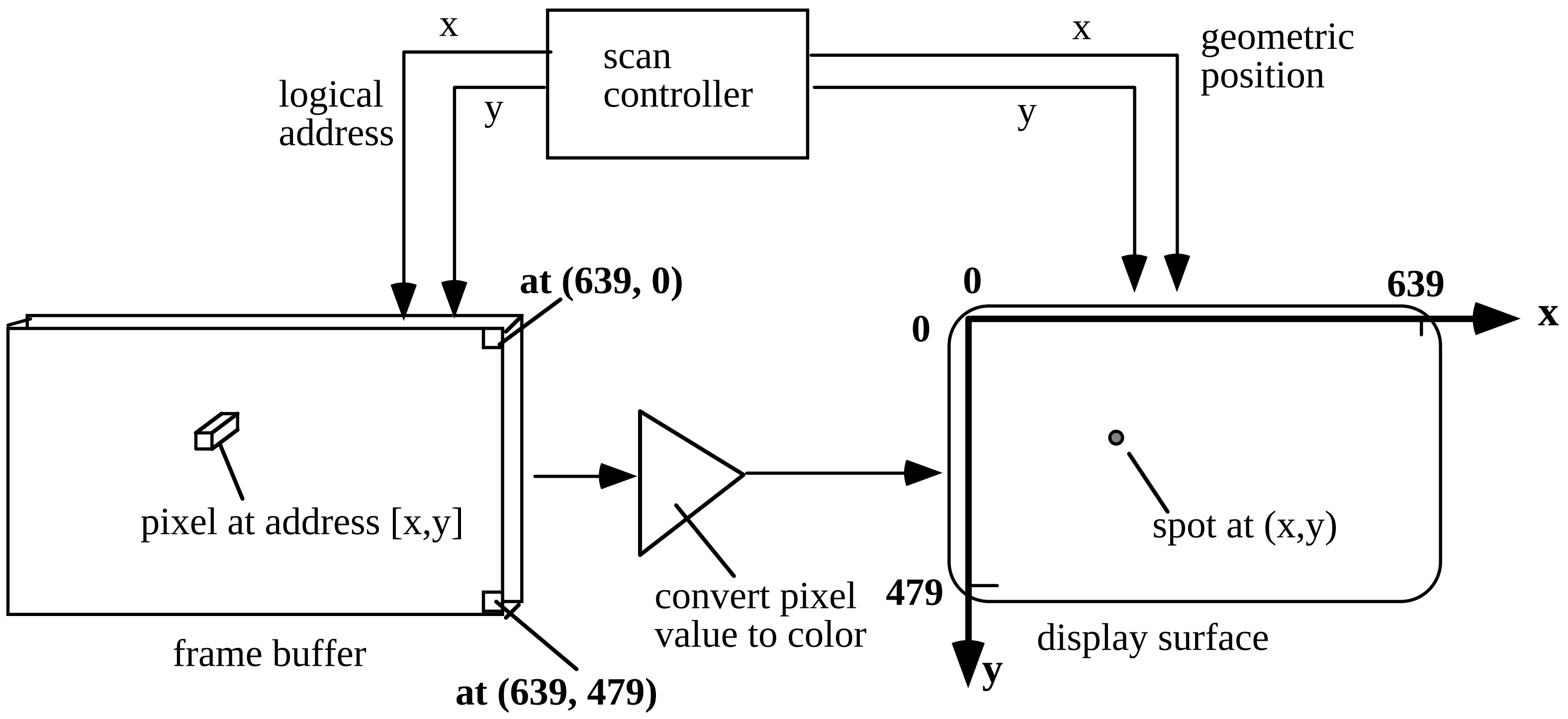
- Programmer view of OpenGL?
  - Application Programmer Interface (API)
  - Writes OpenGL Application programs. E.g

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



Framebuffer

- Dedicated memory location:
  - Draw in 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