Computer Graphics (CS 4731)
Lecture 1: Introduction to Computer Graphics

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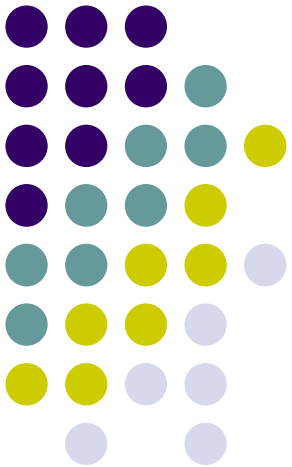
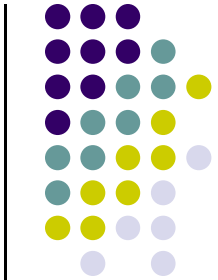


What is Computer Graphics (CG)?



- 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

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

This Class

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

Uses of Computer Graphics

- **Entertainment:** games

Courtesy: Final Fantasy XIV

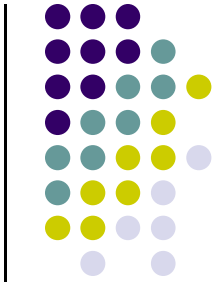
Courtesy: Super Mario Galaxy 2

Uses of Computer Graphics

- movies, TV, books, magazines

Courtesy: Shrek

Courtesy: Spiderman



Uses of Computer Graphics

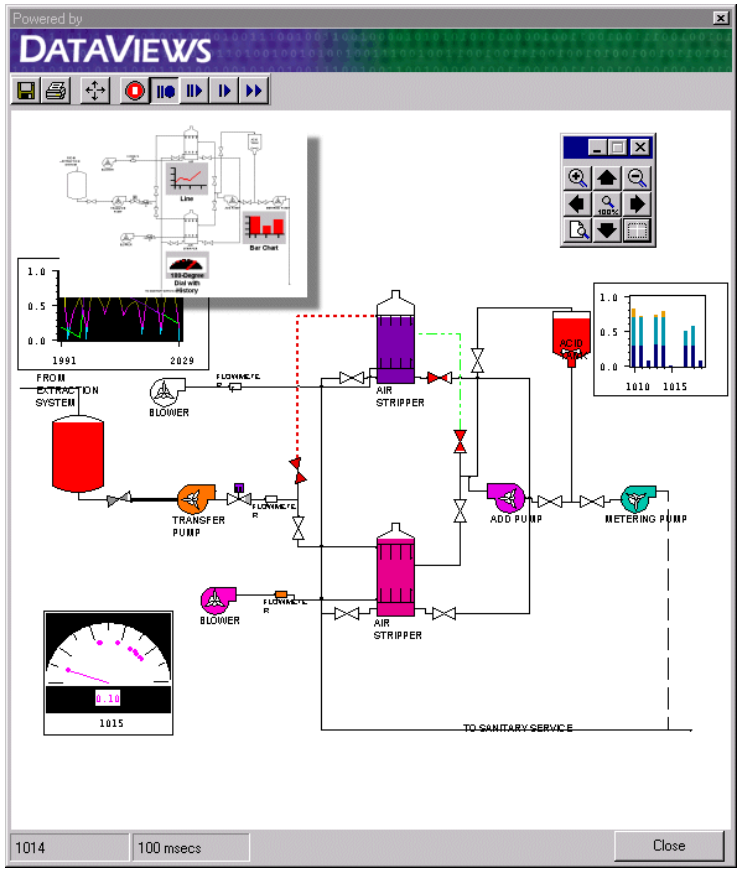
- **Image processing:**
  - alter images, remove noise, super-impose images

Original Image

Sobel Filter

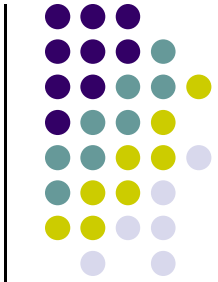
Uses of Computer Graphics

- **Process monitoring:**
  - Layout of large systems or plants



Courtesy:

Dataviews.de



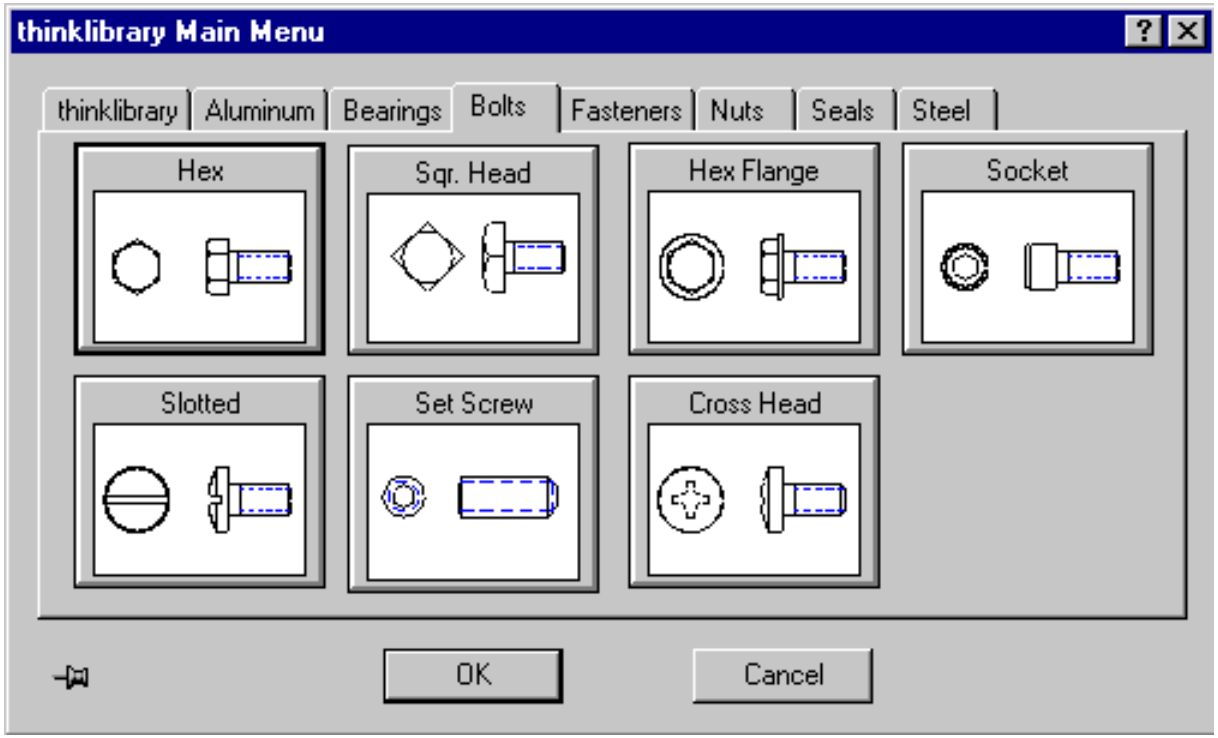
Uses of Computer Graphics

- **Display simulations:**
  - flight simulators, virtual worlds

Courtesy: Evans and Sutherland

Uses of Computer Graphics

- **Computer-aided design:**
  - architecture, electric circuit design

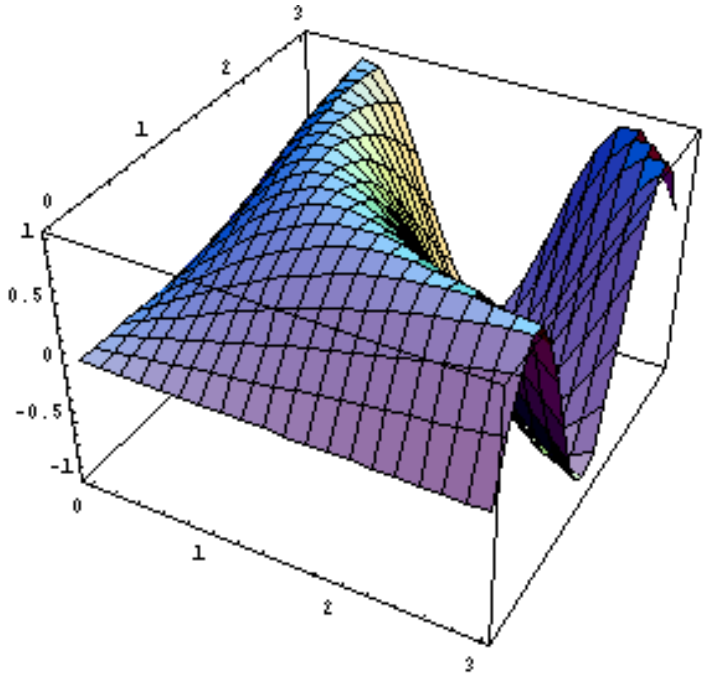


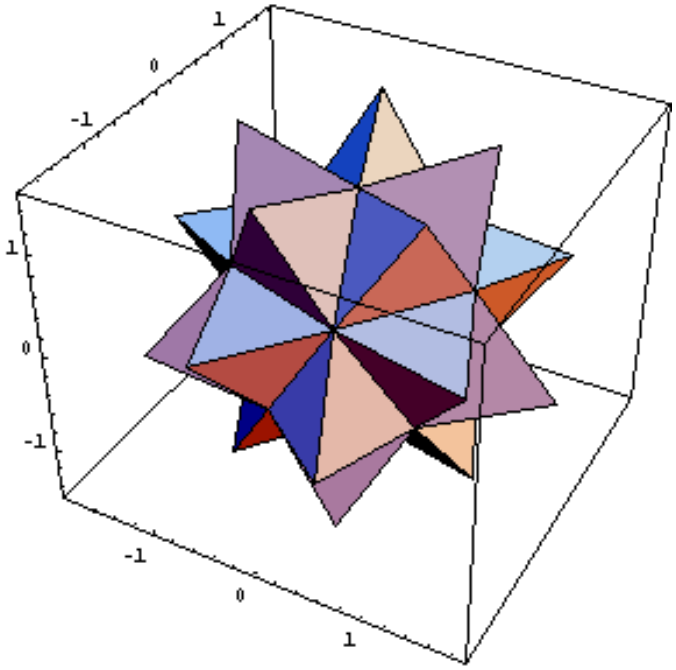
Courtesy:

cadalog.com

Uses of Computer Graphics

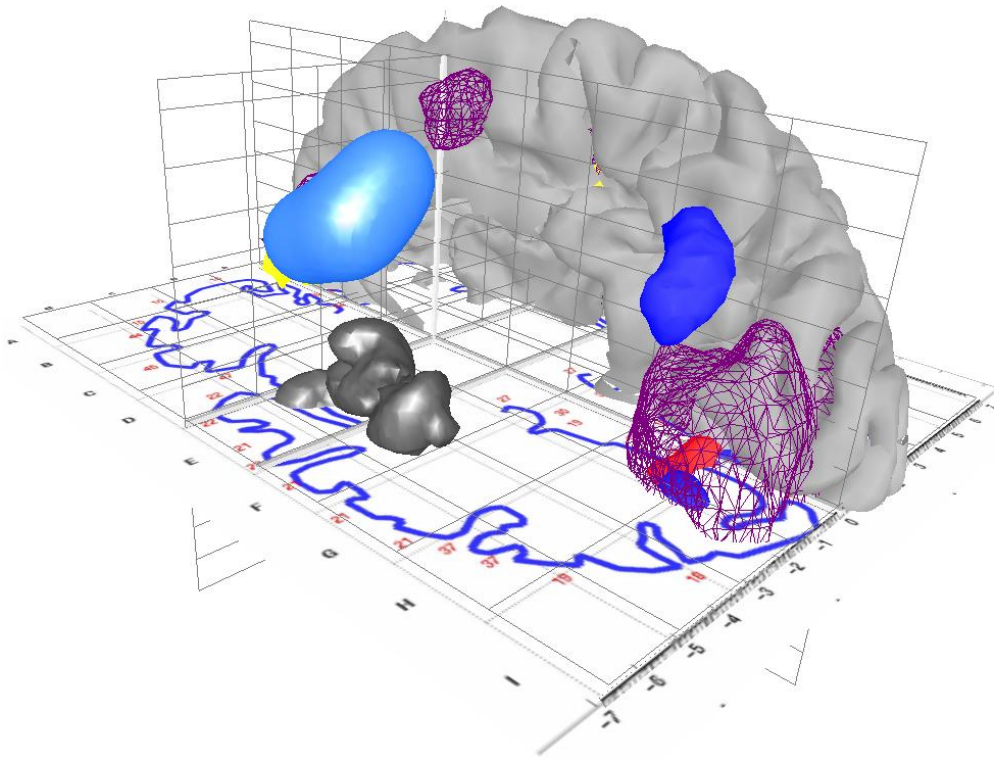
- Displaying Mathematical Functions
  - E.g., Mathematica®





Uses of Computer Graphics

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

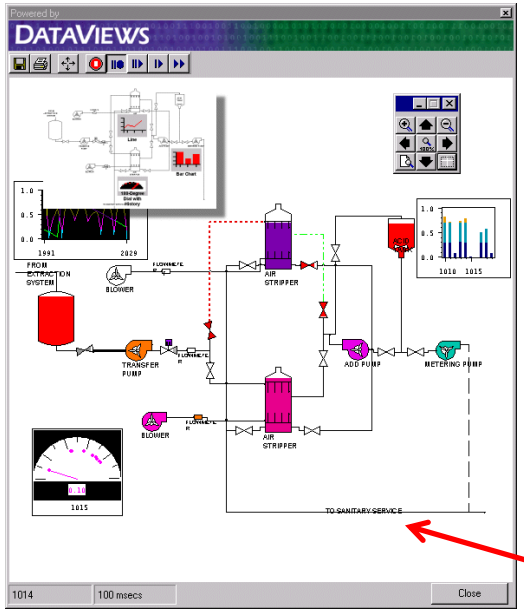


Courtesy:

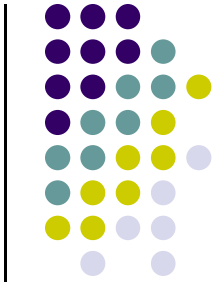
Human Brain Project, Denmark

2D Vs. 3D

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

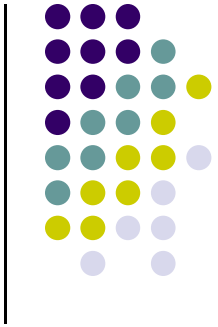


- This class covers both 2D & 3D!
- Also interaction: Clicking, dragging



About This Course

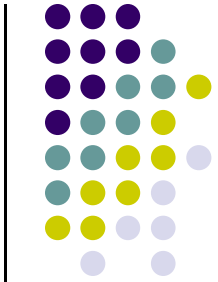
- Computer Graphics has many aspects
  - **Computer Scientists** create graphics tools (e.g. Maya, photoshop)
  - **Artists** use CG tools/packages to create pretty pictures
  - Most hobbyists follow artist path. Not much math!
- This Course: Computer Graphics for computer scientists!!!
- Teaches concepts, 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



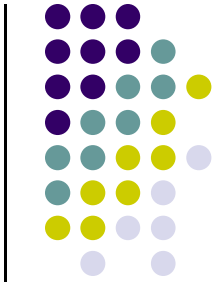
About This Course

- Class is concerned with:
  - How to build graphics tools
  - Underlying mathematics
  - Underlying data structures
  - Underlying algorithms
- This course is a lot of work. Requires:
  - Lots of coding in C/C++
  - Much more emphasis on shader programming than in past offerings
  - Lots of math, linear algebra, matrices
- We shall combine:
  - **Programmer's view:** Program OpenGL
  - **Under the hood:** Learn OpenGL internals (graphics algorithms, math, implementation)

Syllabus Summary



- 2 Exams (50%), 4 Projects (50%)
- Projects:
  - Develop OpenGL/GLSL code on any platform, must port to Zoolab machine
  - May discuss projects, turn in individual projects
- Class website: http://web.cs.wpi.edu/~emmanuel/courses/cs4731/C13/
- Text:
  - Interactive Computer Graphics: A Top-Down Approach with Shader-based OpenGL by Angel and Shreiner (6th edition), 2012
- Cheating: Immediate 'F' in the course
- Advice:
  - Come to class
  - Read the text
  - Understand concepts before coding

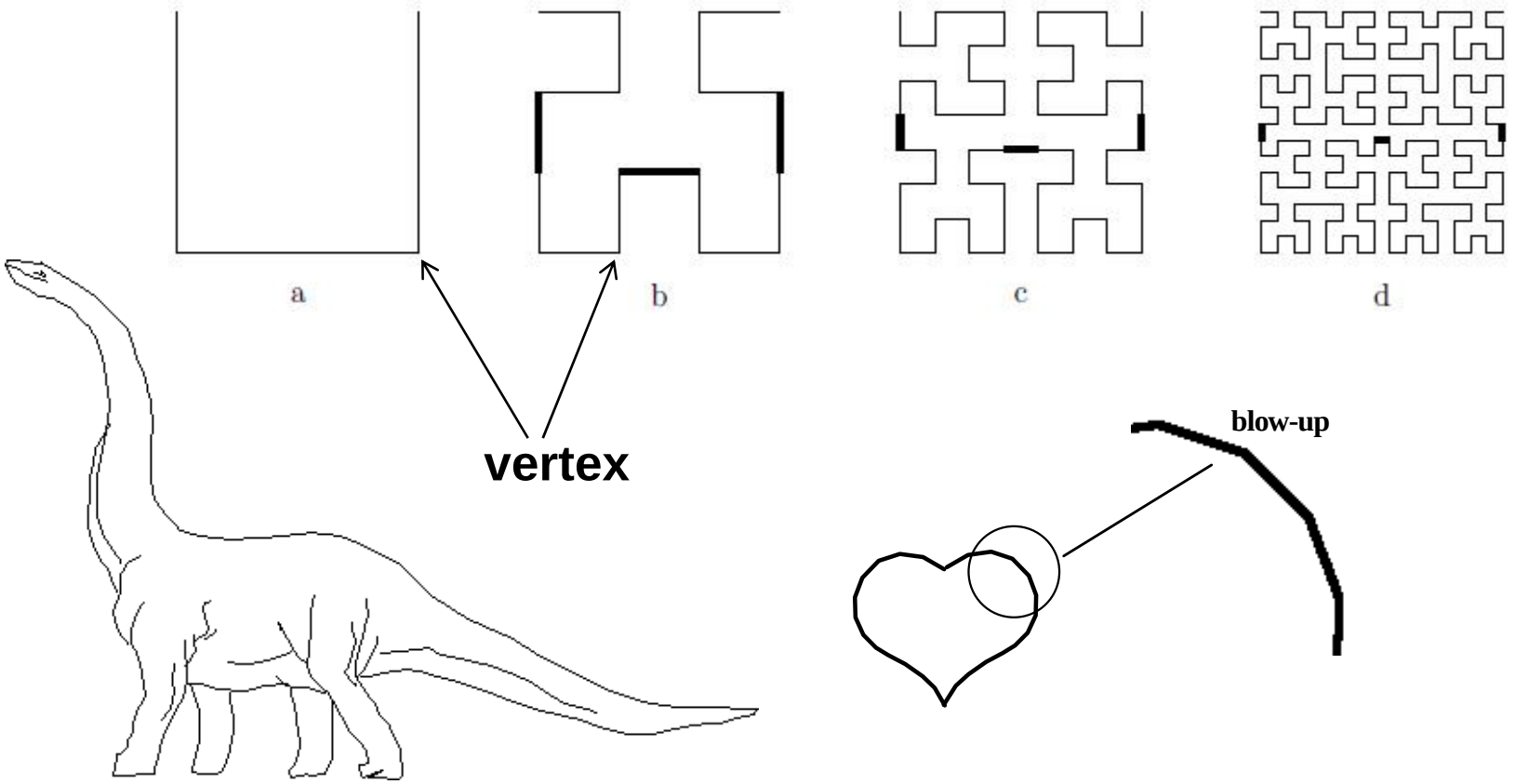


Elements of 2D Graphics

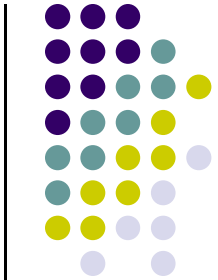
- Polylines
- Text
- Filled regions
- Raster images (pictures)

Elements of 2D Graphics

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

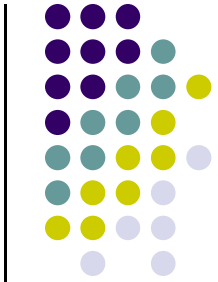


Polyline Attributes



- 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

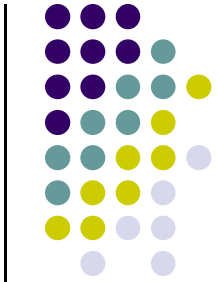
Shadow Text

Distorted text

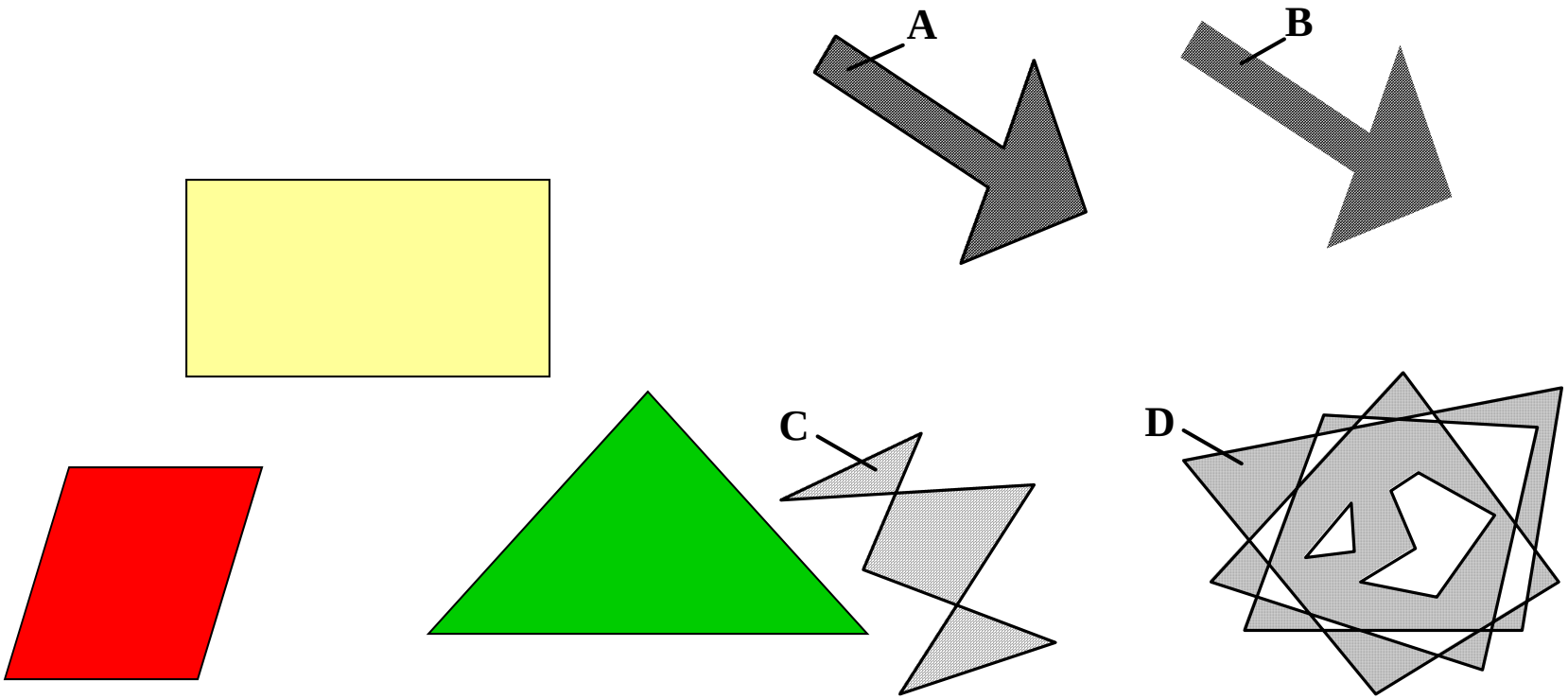
Rotated Text **Outlined text**

SMALLCAPS

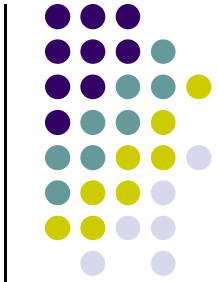
Filled Regions



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

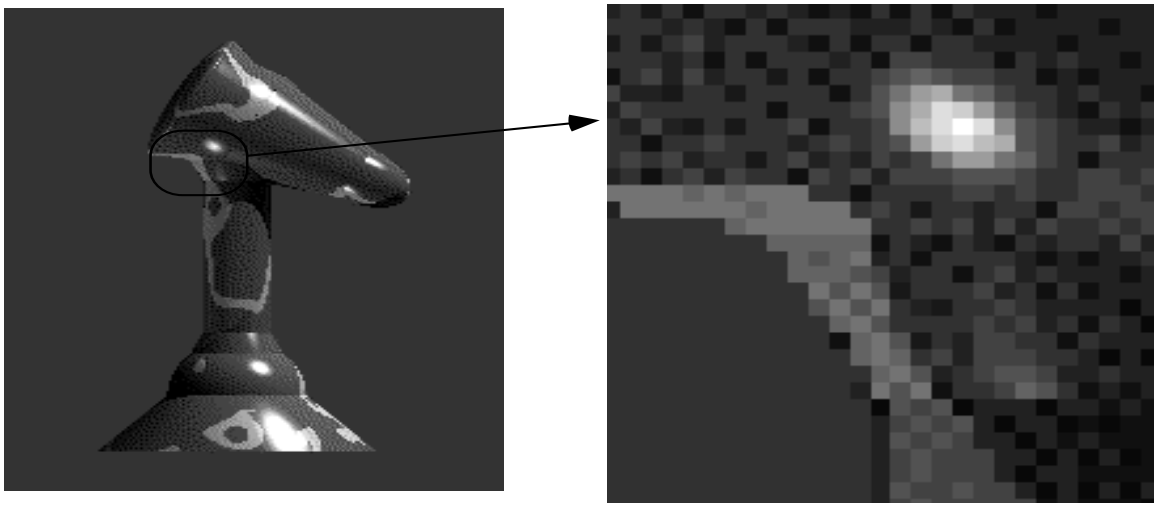


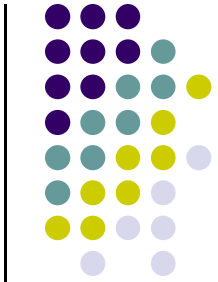
Raster Images



- Raster image (picture) is made up of many small cells (pixels, for “picture elements”), in different colors or grayscale.

(Right: magnified image showing pixels.)

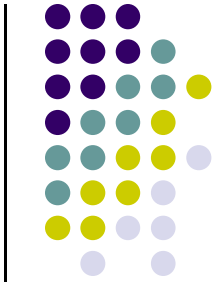




Computer Graphics Tools

- **Require** hardware and software 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)

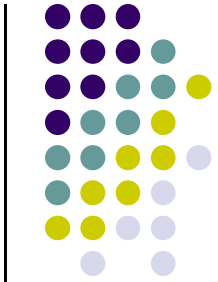
Graphics Processing Unit (GPU)



- OpenGL implemented in hardware => FAST!!
- **Programmable:** in last 10 years (now as shaders)
- Located either on PC motherboard (Intel) or Separate graphics card (Nvidia or ATI)

On PC motherboard

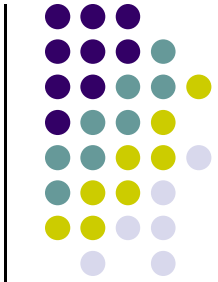
On separate PCI express card



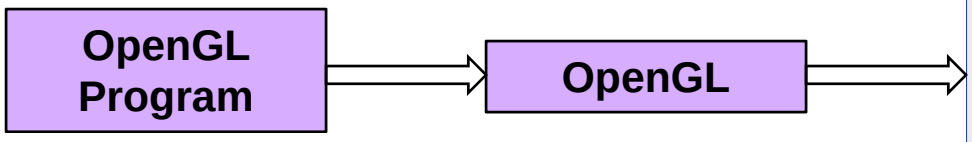
Computer Graphics Libraries

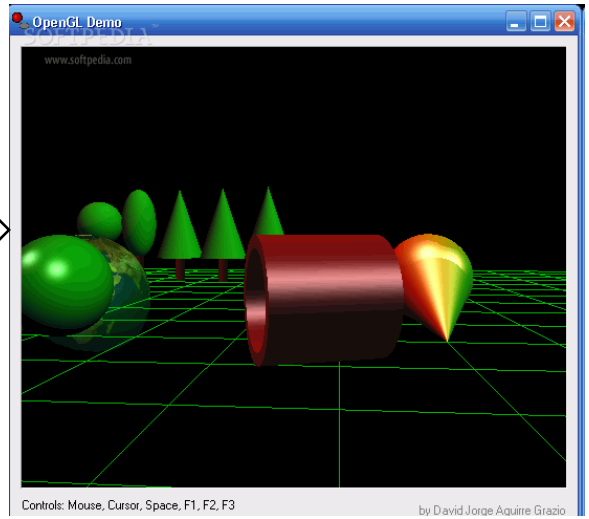
- Functions to draw line, circle, image, etc
- Previously device-dependent
  - Different OS => different graphics library
  - Tedious! Difficult to port (e.g. move program Windows to Linux)
  - Error Prone
- Now device-independent libraries
  - **APIs:** OpenGL, DirectX
  - Working OpenGL program easily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

OpenGL Basics

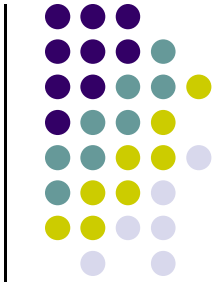


- OpenGL's function – Rendering (or drawing)
- Rendering? – Convert geometric/mathematical object descriptions into images
- OpenGL can render:
  - **2D and 3D**
  - **Geometric primitives (lines, dots, etc)**
  - **Bitmap images (pictures, .bmp, .jpg, etc)**
- OpenGL does **NOT** manage drawing window

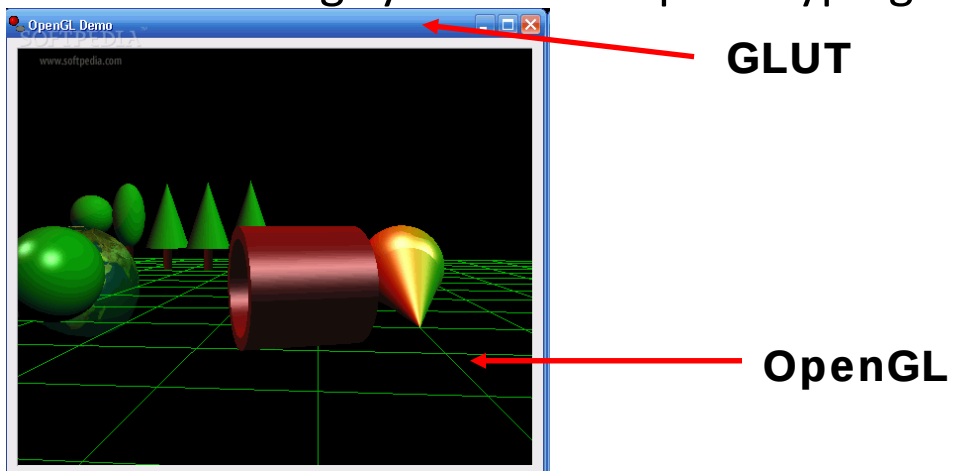




GL Utility Toolkit (GLUT)

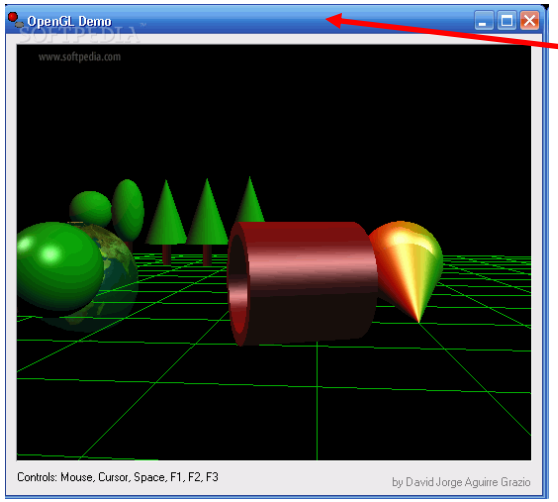


- OpenGL
  - Window system independent
  - Concerned only with drawing (2D, 3D, images, etc)
  - No window management (create, resize, etc), very portable
- GLUT:
  - Minimal window management
  - Interfaces with different windowing systems
  - Easy porting between windowing systems. Fast prototyping

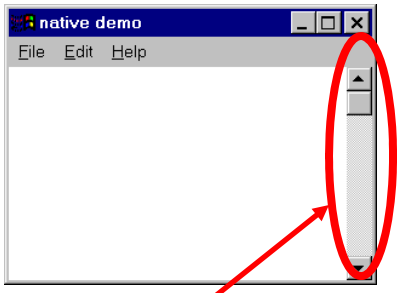


GL Utility Toolkit (GLUT)

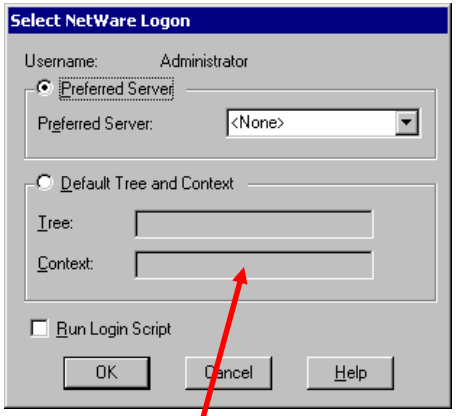
- No bells and whistles
  - No sliders
  - No dialog boxes
  - No elaborate menus, etc
- To add bells and whistles, use system's API or GLUI:
  - X window system
  - Apple: AGL
  - Microsoft :WGL, etc



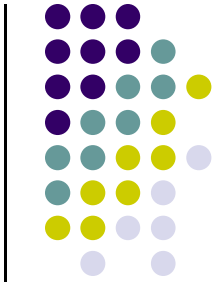
GLUT (minimal)



Slider



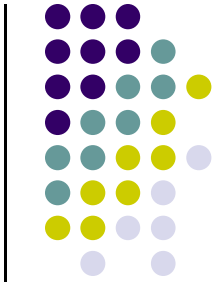
Dialog box



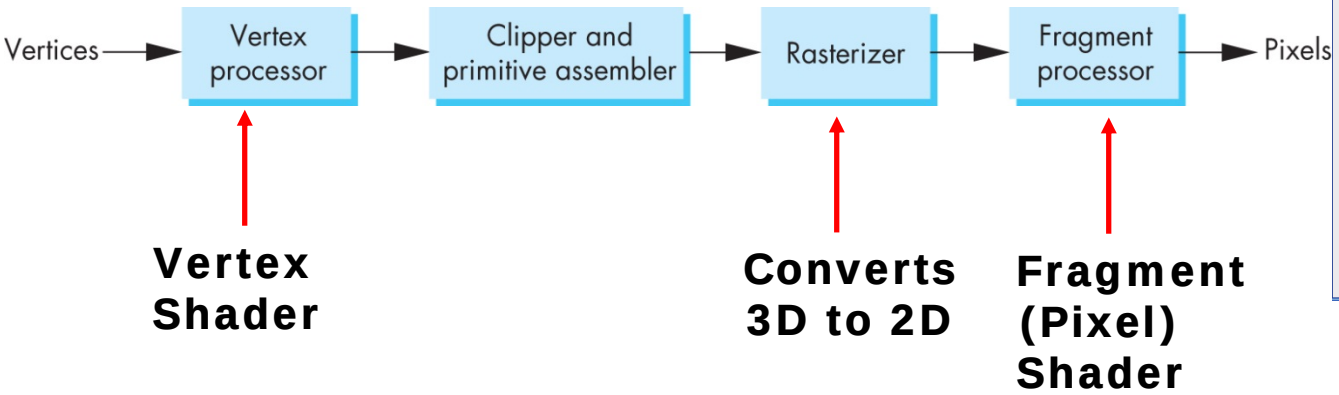
OpenGL Basics

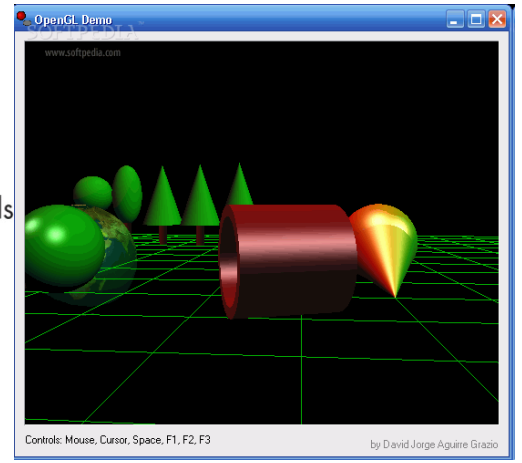
- Low-level graphics rendering API
- Maximal portability
  - **Display device independent (Monitor type, etc)**
  - **Window system independent based (Windows, X, etc)**
  - **Operating system independent (Unix, Windows, etc)**
- OpenGL programs behave same on different devices, OS

Simplified OpenGL Pipeline

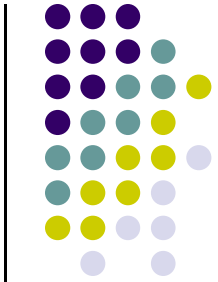


- Vertices go in, sequence of steps (vertex processor, clipper, rasterizer, fragment processor) image rendered

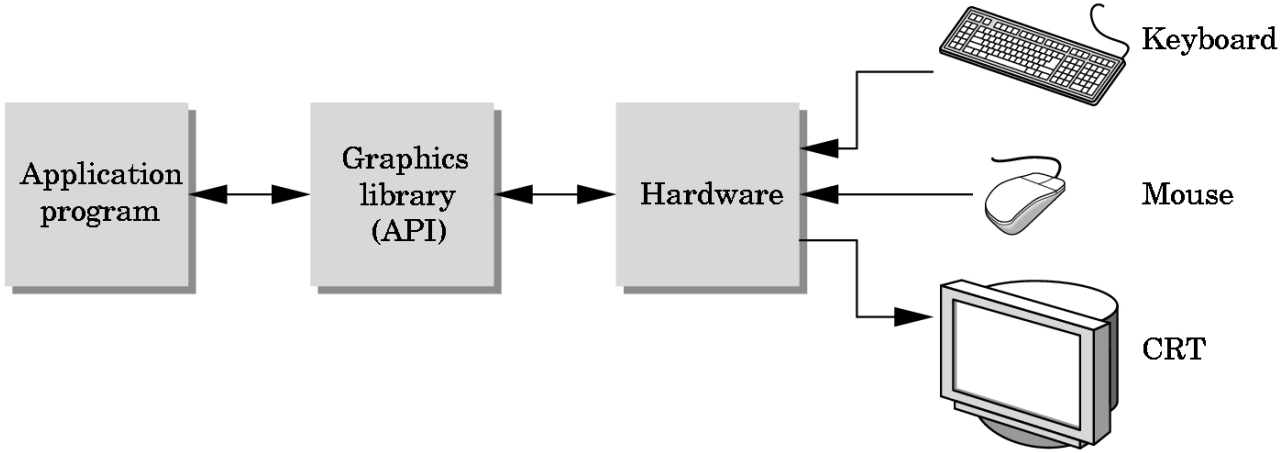




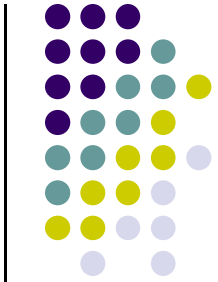
OpenGL Programming Interface



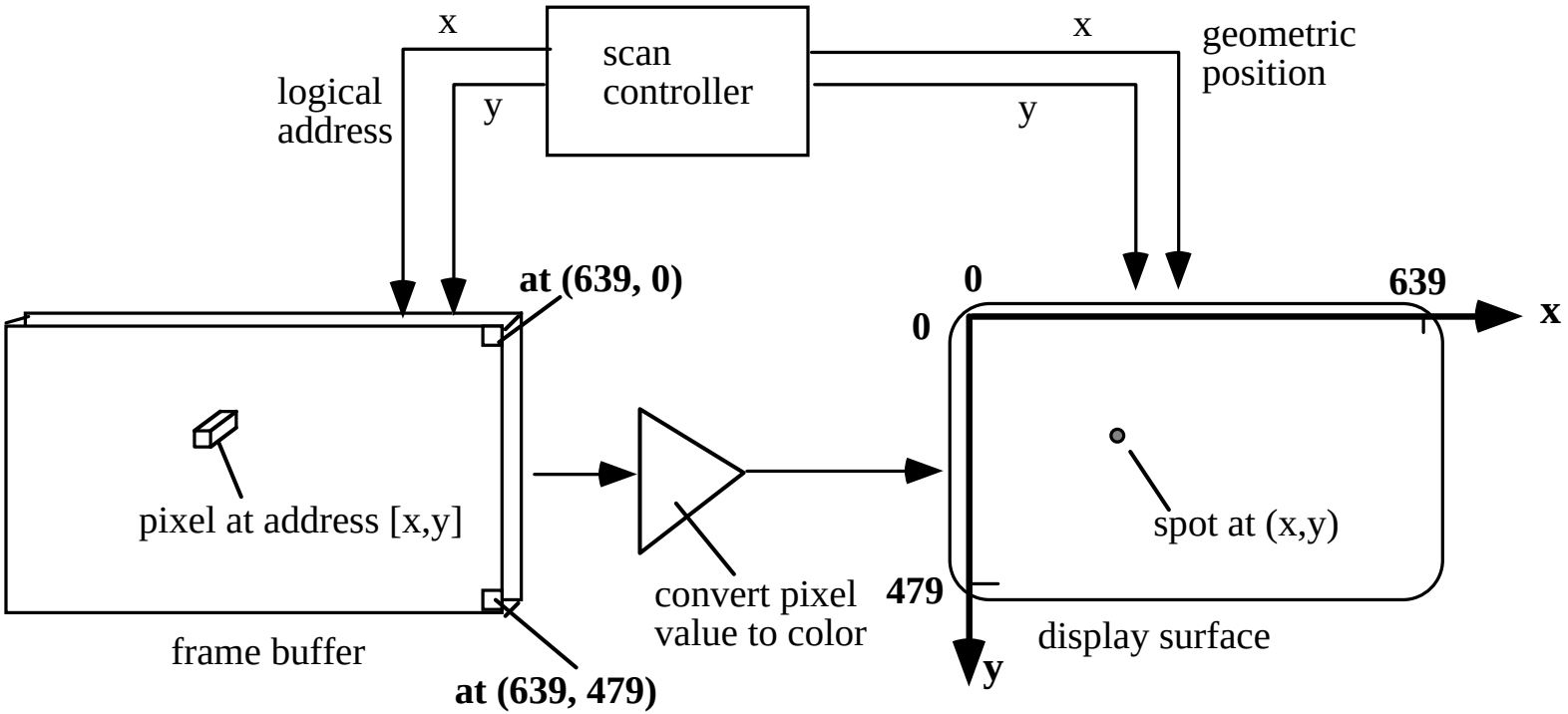
- Programmer view of OpenGL?
  - Application Programmer Interface (API)
  - Writes OpenGL Application programs

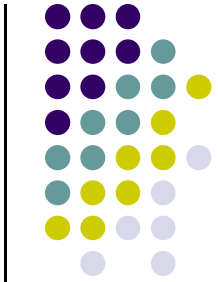


Framebuffer



- 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