CS 543: Computer Graphics

Introduction

Robert W. Lindeman
Associate Professor
Interactive Media & Game Development
Department of Computer Science
Worcester Polytechnic Institute
gogo@wpi.edu

(with lots of help from Prof. Emmanuel Agu :-){}
What to Expect

- This course is mainly about how to create pretty pictures
  - Algorithms, mathematics, data structures
  - Over 40 years of research

- Today, a big chunk is available off the shelf
  - Just make OpenGL or DirectX library calls
  - Use WebGL to remove platform dependencies

- We want to learn what is inside these libraries
  - We use WebGL as one example of how things could be done
  - At work, you may only use OpenGL, or a Game Engine
  - The really interesting jobs will ask you to go further!
Summary of Syllabus

- 2 Exams (50%), 4 Projects (50%)
- Projects will use WebGL
- Write code on any platform (Zoo Lab - FL A21)
- Must run in a Web browser
- Program in JavaScript
- Can discuss with others, turn in unique project
- All material on class Website
  - [www.cs.wpi.edu/~gogo/courses/cs543/](http://www.cs.wpi.edu/~gogo/courses/cs543/)

- Text
Assignments

- Many phases to homework:
  - Understand/design/code/debug/test/eat/test some more
  - Encouraged to discuss approaches
  - Must hand in your own work only

- Cheating:
  - Many reasons not to do it!
  - Immediate 'F' in the course

- Advice for doing well:
  1. Do the assigned reading
  2. Come to class
  3. Ask questions (class, office hours, MyWPI discussions)
  4. Make sure you understand before coding
  5. Don't share your code with others!

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What to Expect (cont.)

☐ This course is about Computer Graphics, not WebGL
  ■ How would one *build* WebGL or OpenGL?
  ■ Focus on underlying methods
  ■ Other methods besides WebGL

☐ This course is heavy on
  ■ Coding (JavaScript, shaders)
  ■ Efficiency (speed & space)
  ■ Pretty pictures
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 photo!
Photorealistic vs. Real-Time Graphics

- **Photorealistic**
  - High quality
  - Slow to render (days)

- **Real-Time graphics**
  - Lower quality
  - Fast to render (60 FPS)

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Uses of Computer Graphics

- **Entertainment**
  - Games

Courtesy: *Final Fantasy XIV*

Courtesy: *Super Mario Galaxy 2*
Uses of Computer Graphics

Entertainment

- Movies, TV, books, magazines

Courtesy: Shrek

Courtesy: Spider-Man
Uses of Computer Graphics

- Image processing
  - Alter images, remove noise, super-impose images
Uses of Computer Graphics

- **Process monitoring**
  - Layout of large systems or plants
  - Monitor manufacturing process
  - User control automatic and manual control

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

![Diagram of computer-aided design tools](cadalog.com)

**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
2 Dimensional vs. 3 Dimensional

- **2D**
  - No notion of distance from viewer
  - Only (x, y) color values on screen

- **3D**
  - Objects have distance from viewer
  - (x, y, z) values on screen

- This class covers both 2D & 3D!
- Also interaction, e.g., clicking, dragging, etc.
Related Areas to CG

- Modeling: Shape of objects in a scene
- Shading & Lighting: Surface & Environmental effects
- Post Production: Tweaking the images
- Computer Vision: Extracting info from images
- Scientific Visualization: Making sense of data
- Animation: Making things move over time and space
- HCI: Incorporating user interaction
CG Tools

- **Hardware tools**
  - Output devices
    - Monitors, projection systems, VR helmets, printers
  - Input devices
    - Mouse/trackball, pen/tablet, keyboard, other
  - Graphics accelerators

- **Software tools**
  - IDEs (VS, Eclipse)
  - Editor (emacs, vi)
  - Compiler (g++)
  - Debugger
  - Graphics libraries

- **Your eyes**
What is a CG Library?

- Low-level routines
  - Points, lines, circles, text, etc.

- High-level routines
  - Pull-down menus, window management, etc.

- Some of this has traditionally been device dependent
  - Difficult to port, error prone

- Now we have device/platform independence (almost)
  - WebGL, OpenGL, DirectX, etc.
  - XBOX, PS1/2/3/4/Vita/..., Wii, DS, smartphones, etc.
Game Engines

- Game Engines are frameworks that handle many aspects of games at a high level
  - Sit on top of low-level libraries (OpenGL/DirectX)
What is a Game Engine?

- A resource manager that supports an entertainment (usually) application
- Graphical (audio, etc.) rendering
- A user interface
- Script handling
- Event processing
  - Time, collisions, etc.
- File I/O
- Asset-creation tools
  - Models, graphics, sound, etc.
- Optional
  - Networking
  - AI
About This Course

- **Computer Graphics has many aspects**
  - **Computer Scientists**
    - *Create/program* CG tools/packages
      (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 WebGL as a concrete example**

☐ **Course is NOT…**
   - just about programming WebGL
   - a comprehensive course in OpenGL/WebGL. (Only covers parts)
   - 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 JavaScript
  - Shader programming
  - Lots of math, linear algebra, matrices

- **We shall combine:**
  - **Programmer’s view:** Program WebGL APIs
  - **Under the hood:** Learn OpenGL internals (graphics algorithms, math, implementation)
Evolution of Rendered Images

- Multiple ways of representing things

- Wireframe
- Flat shading
- Smooth shading
- Environment mapping
- Bump mapping
Current State:
Things are pretty good right now...
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)
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)
Graphics Processing Unit (GPU)

- OpenGL implemented in hardware => FAST!!
- **Programmable:** As shaders
- Located either on PC motherboard (Intel) or Separate graphics card (nVidia or AMD/ATI)
Computer Graphics Libraries

- Functions to a 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.

- Now even more!
  - **Browser as app:** WebGL
Simplified WebGL/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

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OpenGL Programming Interface

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

Input devices → Processor (CPU) → Graphics processor → Frame buffer → Output device

Image formed in frame buffer

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Framebuffer

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

- Angel & Shreiner, Interactive Computer Graphics (7th edition), Chapter 1