Introduction to Computer Graphics

Prof. George Wolberg
Dept. of Computer Science
City College of New York
Course Description

• Intense introduction to computer graphics.
• Intended for advanced undergraduate and graduate students.
• Topics include:
  - OpenGL API, GLSL shading language
  - Geometric transformations
  - 3D viewing
  - Geometric modeling, curves and surfaces
  - Shading, texture mapping, compositing
# Syllabus

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
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<tbody>
<tr>
<td>1</td>
<td>Introduction, history, vector/raster graphics</td>
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<tr>
<td>2-4</td>
<td>OpenGL, GLSL, Qt</td>
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<td>5-6</td>
<td>Geometry, 2D/3D transformations</td>
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<td>7</td>
<td>Texture mapping</td>
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<td>Projections, perspective</td>
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<td>9</td>
<td>3D viewing</td>
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<td>10</td>
<td>Midterm</td>
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<td>11-12</td>
<td>Shading</td>
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<td>13-14</td>
<td>Curves and surfaces</td>
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Required Text

Supplementary Texts

• Supplementary Texts:
    • The definitive OpenGL programming reference
Grading

• The final grade is computed as follows:
  - Midterm exam: 25%
  - Final exam: 25%
  - Homework programming assignments: 50%
• Substantial programming assignments are due every three weeks.
• Proficiency in C/C++ is expected.
• Prereqs: CSc 221
Contact Information

• Prof. Wolberg
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• Teaching Assistant (TA): Siavash Zokai
  - Email: ccny.cs472@gmail.com

• See class web page for all class info such as office hours, homework and source code:
  www-CS.cs.ccny.cuny.edu/~wolberg/cs472
Objectives

• Broad introduction to Computer Graphics
  - Software
  - Hardware
  - Applications
• Top-down approach
• Shader-Based
• Programs in C/C++ will be assigned to reinforce understanding of the material
Prerequisites

• Good programming skills in C (or C++)
• Basic data structures
• Geometry
• Simple linear algebra
OpenGL Resources

- Can run OpenGL on any system
  - Desktop OpenGL on Windows, Mac, Linux
  - OpenGL ES on mobile platforms: iOS, Android
- Get Qt from www.qt.io/download-open-source
  - Graphical user interface toolkit for all platforms
  - Adds sliders, pushbuttons, advanced widgets to GUI
- www.opengl.org
  - Standards documents and sample code
- www.opengl-tutorial.org
  - Informative tutorials on basic and intermediate topics
- www.khronos.org
Outline: Part 1

• Part 1: Introduction
  - What is Computer Graphics?
  - Applications Areas
  - History
  - Image formation
  - Basic Architecture
Outline: Part 2

• Part 2: Modern OpenGL (shader-based)
  - Architecture
  - Qt for advanced GUIs
  - Simple programs in two and three dimensions
  - Basic shaders and GLSL
  - Interaction
Outline: Part 3

- Part 3: Texture Mapping
  - Buffers
  - Shader Applications
  - Compositing and Transparency
Outline: Part 4

• Part 4: Three-Dimensional Graphics
  - Geometry
  - Transformations
  - Homogeneous Coordinates
  - Viewing
  - Lighting and Shading
Outline: Part 5

• Part 5: Curves and Surfaces
  - Bezier Curves
  - Hermite Curves
  - B-Splines
  - Cubic Splines
  - Coons Patches
What is Computer Graphics?

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Objectives

• In this lecture, we explore what computer graphics is about and survey some application areas
• But we start with a historical introduction
Computer Graphics

• *Computer graphics* deals with all aspects of creating images with a computer
  - Hardware
  - Software
  - Applications
Related Fields

Image Processing

Image

Computer Graphics

Scene Description

Computer Vision
Example

• Where did this image come from?

• What hardware/software did we need to produce it?
Preliminary Answer

- **Application**: The object is an artist’s rendition of the sun for an animation to be shown in a domed environment (planetarium)
- **Software**: Maya for modeling and rendering but Maya is built on top of OpenGL
- **Hardware**: PC with discrete graphics (GPU) for modeling and rendering
Basic Graphics System

Input devices

Processor (CPU)

Graphics processor

Frame buffer

Output device

Image formed in frame buffer
CRT

Can be used as a line-drawing device (vector graphics) or to display contents of frame buffer (raster graphics)

• Computer graphics goes back to the earliest days of computing
  - Strip charts
  - Pen plotters
  - Simple displays using A/D converters to go from computer to calligraphic CRT

• Cost of refresh for CRT too high
  - Computers slow, expensive, unreliable

- **Wireframe** graphics
  - Draw only lines
  - Sketchpad
  - Display Processors
  - Storage tube

wireframe representation of sun object
Project Sketchpad

• Ivan Sutherland’s PhD thesis at MIT
  - Recognized the potential of man-machine interaction
  - Loop
    • Display something
    • User moves light pen
    • Computer generates new display
  - Sutherland also created many of the now common algorithms for computer graphics
Display Processor

- Rather than have host computer try to refresh display use a special purpose computer called a display processor (DPU)

  - Graphics stored in display list (display file) on display processor
  - Host *compiles* display list and sends to DPU
Direct View Storage Tube

• Created by Tektronix
  - Did not require constant refresh
  - Standard interface to computers
    • Allowed for standard software
    • Plot3D in Fortran
  - Relatively inexpensive
    • Opened door to use of computer graphics for CAD community

• Raster Graphics

• Beginning of graphics standards
  - IFIPS
    • GKS: European effort
      – Becomes ISO 2D standard
    • Core: North American effort
      – 3D but fails to become ISO standard

• Workstations and PCs
Raster Graphics

• Image produced as an array (the raster) of picture elements (pixels) in the frame buffer
Raster Graphics

• Allow us to go from lines and wireframes to filled polygons
PCs and Workstations

• Although we no longer make the distinction between workstations and PCs, historically they evolved from different roots
  - Early workstations characterized by
    • Networked connection: client-server model
    • High-level of interactivity
  - Early PCs included frame buffer as part of user memory
    • Easy to change contents and create images

Realism comes to computer graphics

- smooth shading
- environment mapping
- bump mapping

• Special purpose hardware
  - Silicon Graphics geometry engine
    • VLSI implementation of graphics pipeline

• Industry-based standards
  - PHIGS
  - RenderMan

• Networked graphics: X Window System

• Human-Computer Interface (HCI)

• OpenGL API
• Completely computer-generated feature-length movies (Toy Story) are successful
• New hardware capabilities
  - Texture mapping
  - Blending
  - Accumulation, stencil buffers

- Photorealism
- Graphics cards for PCs dominate market
  - Nvidia, ATI
- Game boxes and game players determine direction of market
- Computer graphics routine in movie industry: Maya, Lightwave
- Programmable pipelines
Computer Graphics: 2010-

- Xbox, Playstation
  - Realistic rendering, animation
- Kinect sensor
  - Gesture recognition
- Touchscreen interfaces
  - Phones, tablets, Windows 10
- 3D scanning and printing
  - Editing tools for rapid prototyping 3D models
- Virtual reality
  - Oculus Rift, Samsung Gear VR, Google Cardboard