CS 430
Computer Graphics

Introduction
Week 1, Lecture 1

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Overview

• Course Policies/Issues
• Brief History of Computer Graphics
• The Field of Computer Graphics: A view from 66,000ft
• Structure of this course
• Homework overview
• Introduction and discussion of homework #1
Computer Graphics: Course Goals

• Provide introduction to *fundamentals* of 2D and 3D computer graphics
  – Representation (lines/curves/surfaces)
  – Drawing, clipping, transformations and viewing
  – Implementation of a basic graphics system
    • draw lines using Postscript
    • simple frame buffer with PBM & PPM format
    • ties together 3D projection and 2D drawing
Interactive Computer Graphics
CS 432

• Learn and program WebGL
• Computer Graphics was a pre-requisite
  – Not anymore
• Looks at graphics “one level up” from CS 430
• Useful for Games classes
• Core course in the Graphics, Vision and Interaction concentration
Advanced Rendering Techniques
CS 431

• Available as CS 636 Advanced Computer Graphics
• Offered infrequently
• 3D Computer Graphics
• CS 430 or CS 432 is a pre-requisite
• Implement Ray Tracing algorithm
• Lighting, rendering, photorealism
• Study Radiosity and Photon Mapping
ART Student Images
Computer Graphics: Technical Material

• Course coverage
  – Mathematical preliminaries
  – 2D lines and curves
  – Geometric transformations
  – Line and polygon drawing
  – 3D viewing, 3D curves and surfaces
  – Splines, B-Splines and NURBS
  – Solid Modeling
  – Color, hidden surface removal, Z-buffering
Computer Graphics: Course Highlights

- Bresenham’s scan conversion algorithm
- Cohen-Sutherland clipping algorithm
- Sutherland-Hodgman polygon clipping
- The De Casteljau Algorithm
- Polygon filling
- B-Splines, NURBS, De Boor’s Algorithm
- Z-buffer algorithm; backface culling
Computer Graphics: Course Management Issues

• All course policies are in the syllabus
• Extensive use of PDF handouts
• Must read email every day
• There will be 5 programming assignments (plan on 8-to-15 hrs)
• Suggestion: print out handouts before class, use them to take notes
• Weekly online quizzes starting Week 3
• Final exam on material not covered by the programming assignments
• Will take attendance for the first 3 weeks
• READ THE SYLLABUS!!
Computer Graphics: Collaboration Policies

• Thou Shall/May
  – write your own code
  – do your own math
  – attribute any work that is not your own
  – talk amongst yourselves, share ideas
  – use data structure libraries

• Thou Shall Not
  – share/copy code
  – use ideas without attribution
  – utilize geometry/graphics libraries
  – Use generative tools

• All code will be auto checked for plagiarism
• Violations will result in an automatic $F$
Go to class web page
CG Technical Areas

• Geometric Modeling
  – Mathematics and algorithms that define 2D and 3D geometric objects
CG Technical Areas

• Human/Computer Interaction
  – Methods for creating graphics data via user input

Surface Drawing, Steven Schkolne
CG Technical Areas

- **Lighting and Shading**
  - Math, physics and algorithms that specify how light interacts with matter
CG Technical Areas

• Rendering
  – Algorithms that take geometry, lighting, shading and viewing information and generate an image
CG Technical Areas

• Visualization and Visual Analytics
  – Techniques for visually communicating and exploring scientific, medical or abstract data
CG Technical Areas

- Perception
  - Study of how humans perceive light and information
CG Technical Areas

• Animation
  – Algorithms for making models change over time
CG Technical Areas

• Simulation
  – Using physics to make models move
CG Technical Areas

- Software and Hardware
  - Designing software and hardware systems to implement graphics algorithms
Computer Graphics: In The Beginning

- MIT - 1963
  Ivan Sutherland’s *Sketchpad*
- Modified oscilloscope for drawing
- The original CAD system

Courtesy Marc Levoy @ Stanford U
Computer Graphics from 66,000ft

• Display types
• Display/Rendering algorithms
• Application areas
  – Entertainment
  – CAD/CAM
  – Scientific & medical visualization
  – Training & education
  – Synthetic realities
  – Art and design
  – Games
2D Graphics

• Raster:

Pixels
  – X11 bitmap, XBM
  – X11 pixmap, XPM
  – GIF
  – TIFF
  – PNG
  – JPG

Lossy, jaggies when transforming, good for photos.

• Vector:

Drawing instructions
  – Postscript
  – CGM
  – Fig
  – DWG

Non-lossy, smooth when scaling, good for line art and diagrams.
2D Graphics

- Raster:

- Vector:
Adobe Photoshop: 2D Raster Graphics
2D Raster Graphics
Adobe Illustrator: 2D Vector Graphics
2D Vector Graphics
3D Rendering

• 1960s - the visibility problem
  – Roberts (1963), Appel (1967) - hidden-line algorithms
  – Sutherland (1974) - visibility = sorting

• 1970s - raster graphics
  – Gouraud (1971) - diffuse lighting
  – Phong (1974) - specular lighting
  – Blinn (1974) - curved surfaces, texture
  – Crow (1977) - anti-aliasing

Courtesy Marc Levoy @ Stanford U
3D Rendering

Toward Reality in the 1980s

- global illumination
  - Whitted (1980) - ray tracing
  - Goral, Torrance et al. (1984), Cohen (1985) - radiosity
  - Kajiya (1986) - the rendering equation

- photorealism
  - Cook & Torrance (1982) – rough surface reflectance
  - Cook (1984) - shade trees
  - Perlin (1985) - shading languages
  - Hanrahan and Lawson (1990) - RenderMan

Courtesy Marc Levoy @ Stanford U
Away from Reality

- early 1990s - non-photorealistic rendering
  - Drebin et al. (1988), Levoy (1988) - volume rendering
  - Haeberli (1990) - impressionistic paint programs
  - Salesin et al. (1994-) - automatic pen-and-ink illustration
  - Meier (1996) - painterly rendering

Courtesy Marc Levoy @ Stanford U
And Back Again

- late 1990s & 2000s - photon mapping, subsurface scattering and participating medium
  – H. Wann Jensen
Application Areas

- **Entertainment**
- CAD/CAM
- Scientific & Medical visualization
- Training & Education
- Synthetic Realities
  - VR, AR, etc.
- Art and design
- Games

Pixar
Lord Of the Rings Troll
Application Areas

- Entertainment
- **CAD/CAM**
- Scientific & Medical visualization
- Training & Education
- Synthetic Realities
  - VR, AR, etc.
- Art and design
- Games

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Regli et al @ Drexel
Application Areas

- Entertainment
- CAD/CAM
- **Scientific & Medical Visualization**
- Training & Education
- Synthetic Realities
  - VR, AR, etc.
- Art and design
- Games

Lombeyda & Breen @ CalTech
Application Areas

- Entertainment
- CAD/CAM
- Scientific visualization
- Training & Education
- Synthetic Realities – VR, AR, etc.
- Art and design
- Games
Application Areas

- Entertainment
- CAD/CAM
- Scientific visualization
- Training & Education
- **Synthetic Realities**
  - VR, AR, etc.
- Art and design
- Games
Application Areas

- Entertainment
- CAD/CAM
- Scientific visualization
- Training & Education
- Synthetic Realities
  - VR, AR, etc.
- *Art and design*
- Games
Application Areas

- Entertainment
- CAD/CAM
- Scientific visualization
- Training & Education
- Synthetic Realities
  - VR, AR, etc.
- Art and design
- Games
Programming Assignments

• **No APIs**: OpenGL, GLUT, Mesa, DirectX…
• Just line and filled polygon rendering
  – Color in last assignment
• Output in the form of
  – Lines (Postscript)
  – 2D ASCII bitmaps (PBM and PPM)
• Program source (and makefile) turned in via Bb Learn
• **Executable MUST RUN on Linux** *(tux)*
• **Whatever language you want**, so long as you can deliver a program that TA can run *(c, c++, java, python, …)*
For programming assignments

• Compute line segments. Export as Postscript.
• Use PBM as B/W “software” frame buffers
• We will be implementing parts of the **2D Engine, 3D Engine** and **Pixel Cache** of a graphics accelerator
• Issue: How to translate the mathematics of 2D/3D shapes to the 2D screen?
• Tip: Renew your friendship with your linear algebra textbook
• Read homeworks ahead. It will help you to structure your code for future requirements.
Assignment Dependencies

- Every HW - Read in geometry and write out lines or images
- HW1 - Clip 2D lines and export them
- HW2 - Clip 2D polygons and draw edges with HW1
- HW3 - Use HW2 to clip 2D polygons and fill in interiors
- HW4 - Project 3D polygon edges (3D lines) into 2D. Draw them with HW2
- HW5 - Project 3D triangles into 2D. Combine HW3 and HW4, and add depth buffer
- EC - Generate lines and draw with HW1
### Programming Assignments Dependencies

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<th>HW4</th>
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<td>Read &quot;Postscript&quot; File</td>
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<td>Polygon Filling</td>
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<td>3D Geometry</td>
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<td>3D Viewing</td>
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Data Structures

- 2D Lines
- Initially B/W, then RGB Frame Buffer
- 2D/3D polygons (vertices and edges)
- Triangle mesh
- 3D camera/scene
When it’s all over!
Don’t forget ICG & ART!
Programming assignment 1

• Input PostScript-like file
• Output Lines as Postscript
• Primary I/O formats for the course
• Create data structure to hold points and lines in memory (the world model)
• Implement 2D translation, rotation and scaling of the world model
• Implement line clipping
• Due October 13th
• Get started now!