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
- Final exam on material not covered by the programming assignments
- 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
- All code will be auto checked for plagiarism
- Violations will result in an automatic F

CG Technical Areas

- Geometric Modeling
  - Mathematics and algorithms that define 2D and 3D geometric objects

Go to class web page
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 material

CG Technical Areas

- Rendering
  - Algorithms that take geometry, lighting, shading and viewing information and generate an image

- 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

- Animation
  - Algorithms for making models change over time
Computer Graphics: In The Beginning

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

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.
Adobe Photoshop: 2D Raster Graphics

Adobe Illustrator: 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
  - Catmull (1976) - Z-buffer hidden-surface algorithm
  - Crow (1977) - anti-aliasing

2D Raster Graphics

2D Vector Graphics

- 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

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
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
  - Mesar (1996) - painterly rendering

Application Areas

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

Lord Of the Rings Troll

Application Areas

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And Back Again

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

Application Areas

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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

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, ...)

Lombeyda & Breen @ CalTech

Boeing

Hamburg U, Germany

FakeSpace Cave

Augmented Reality

UCLA

Kimmel Center
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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<thead>
<tr>
<th>HW 1</th>
<th>HW 2</th>
<th>HW 3</th>
<th>HW 4</th>
<th>HW 5</th>
<th>EC</th>
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</thead>
<tbody>
<tr>
<td>Read Postscript file</td>
<td>Write Postscript file</td>
<td>3D Transformations</td>
<td>Window to Viewport Transformation</td>
<td>Write SMF file</td>
<td>3D geometry</td>
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<td>Read/Write PBM file</td>
<td>Line Drawing</td>
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<td>3D Viewing</td>
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<td>2D Transformations</td>
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<td>3D Camera/Scene</td>
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<td>Clip 2D lines</td>
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<td>HW1, HW2</td>
<td>HW2, HW3, HW5</td>
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<td>3D View</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 2nd
- Get started now!