Computer Graphics

CSE 167 [Win 19], Lecture 1: Overview and History
Ravi Ramamoorthi
http://viscomp.ucsd.edu/classes/cse167/wi19

Goals

- **Systems**: Write complex 3D graphics programs (real-time scene in OpenGL, offline raytracer)
- **Theory**: Mathematical aspects and algorithms underlying modern 3D graphics systems
- This course is *not* about the specifics of 3D graphics programs and APIs like Maya, Alias, DirectX but about the concepts underlying them.

Instructor

Ravi Ramamoorthi http://www.cs.ucsd.edu/~ravir

- PhD Stanford, 2002. PhD thesis developed “Spherical Harmonic Lighting” widely used in games (e.g. Halo series), movies (e.g. Avatar), etc. (Adobe, ...)
- At Columbia 2002-2008, UC Berkeley 2009-2014
- “Monte Carlo denoising” inspired raytracing offline, real-time
- At UCSD since Jul 2014: Director, Center for Visual Computing
- https://www.youtube.com/watch?v=qpyCgXqXOe7
- Have taught Computer Graphics 10+ times
- Computer Graphics online MOOC (CSE 167x) has had 100,000+ registrations, 500,000 video views. Finalist for two inaugural edX Prizes. Will use edX edge, auto-feedback

Course Staff

- Ravi Ramamoorthi
- Teaching Assistants:
  - Lifan Wu (will also maintain feedback servers)
  - Tiancheng Sun
  - Alex Kuznetsov

Why Study 3D Computer Graphics?

- Applications (discussed next)
- Fundamental Intellectual Challenges

Some content inspired by Pat Hanrahan from Stanford’s CS148
Entertainment

Movies: Brave, Pixar 2012

Entertainment

Games: Halo 3, Bungie 2007

Lighting Simulation

Interior Design

Automobile Visualization

Computer Aided Design

Mechanical CAD
Architectural CAD
Electronics CAD
Casual Users

Interiors Professional

Google Sketchup

Visualization: Science and Medicine

Visible Human Project: University of Hamburg

Virtual Reality

- VR for design and entertainment
- Simulators: Surgical, Flight, Driving, Spacecraft
Digital Visual Media
- From text to images to video (to 3D?)
- Image and video processing and photography
- Multimedia computers, tablets, phones
- Flickr, YouTube, WebGL
- Real, Virtual Worlds (Google Earth, Second Life)
- Electronic publishing
- Online gaming
- 3D printers and fabrication

Why Study 3D Computer Graphics?
- Applications
- Fundamental Intellectual Challenges
  - Create and interact with realistic virtual world
  - Requires understanding of all aspects of physical world
  - New computing methods, displays, technologies
- Technical Challenges
  - Math of (perspective) projections, curves, surfaces
  - Physics of lighting and shading
  - 3D graphics software programming and hardware

3D Graphics Pipeline
- Modeling
- Animation
- Rendering

Curves for Modeling
- Rachel Shiner, Final Project Spring 2010

3D Graphics Pipeline
- HW 1: Transformations (Jan 23)
  Place objects in world, view them
  Simple viewer for a teapot

- HW 3: Curves (Feb 27)
  Bezier and B-Spline curves
  To model and draw objects

- HW 2: Scene Viewer (Feb 15)
  View scene, Lighting and Shading
  (with GLSL programmable shaders)

- HW 3: Curves (Feb 27)
  Bezier and B-Spline curves
  To model and draw objects

- HW 4: RayTracer (Mar 18)
  Realistic images with ray tracing
  two basic approaches: rasterize
  And raytrace images [HW 2,4]
### Logistics
- **Website**: [http://viscomp.ucsd.edu/classes/pge167wi19](http://viscomp.ucsd.edu/classes/pge167wi19) has most of the information (look at it carefully)
- **We will be leveraging MOOC infrastructure in a SPOC**
  - Please sign up for account at edX edge, join course, DEMO
  - edX edge is compulsory for most assignments, feedback systems
  - Optional for video lectures (class may differ a bit, more), problems
  - Must still submit “official” CSE 167 assignment (see website)
  - Please do ask us if you are confused; we are here to help
  - No required texts: OpenGL programming guide, GLSL optional
- **Office hours:** Tu/Thu 1-2pm
  - See website for sections, TA office hours. **Sign up for sections!**
- **Course newsgroup** on Piazza
- **Website** for late, collaboration policy, etc
- **Questions?**

### Innovation: Feedback Servers
- Feedback/Grading servers for all homeworks
- Submit images and/or code, compare to original
  - Program generates difference images, report url
  - Can get feedback multiple times, submit final url
  - All (except curves homework 3) run on edX edge
- "Feedback" not necessarily grading
  - Can run extra test cases, look at code, grade fairly
  - But use of feedback servers/edX edge is mandatory
- Will test out immediately with HW 0 images
  - HW 1 - 2 will have both code and image feedbacks
  - Can use any (laptop/desktop) computer. We also try to have the basement labs fully set up.

### Online Lectures
- Online lectures and screencasts for most course:
  - [http://viscomp.ucsd.edu/classes/pge167wi19/lecture.html](http://viscomp.ucsd.edu/classes/pge167wi19/lecture.html)
  (with English and Chinese subtitles (courtesy XuetangX))
  - Review for CSE 167 (but still have regular classes)
  - For general interest (share with non-CS 167 students)
- Originally recorded in 2012 for MOOC offering
  - CAVEAT: Does not include all material (curves)
  - Was updated in 2017 for more recent OpenGL
  - Same as video lectures on edX edge (some errata)
- Currently view lectures as complementary
  - Hence, viewing them optional (e.g. miss a class)
  - Please note caveats; "official" CSE 167 is in class
- May separately have UCSD screencasts

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### This is a Modernized Course
- Modern 3D Graphics Programming with GPUs
  - Modern OpenGL (3+), GLSL 330 core
  - Real-time feedback servers for all homeworks
- GLSL + Programmable Shaders from HW 1
- Should be very portable, but need to set up your environment, compilation framework (HW 0)

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### Demo of edX edge, Feedbacks

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### Image Synthesis Examples

Collage from 2007

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**Workload**

- Lots of fun, rewarding but may involve significant work
- 4 programming projects (+HW 0); almost all are time-consuming (individual except HW 4). START EARLY!!
- Course will involve understanding of mathematical, geometrical concepts taught (tested on midterm)
  - No final; will do a take-home small assignment instead
- Grade mostly programming, weights on website
  - Ignore weighting on edX site, we weight as on CSE 167 site
- Prerequisites: Solid C/C++/Java/Python programming background. Linear algebra (review on Thu) and general math skills. No knowledge of graphics/OpenGL needed.
  - Should be able to pick up C/C++, and look up some OpenGL
- Should be a difficult, but fun and rewarding course

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**CSE 167 is only a first step**

- *If you enjoy CSE 167 and do well:*
  - In Spring: CSE 190 (VR course; Schulze)
  - Next winter: CSE 165 (3DUI), 169 (Animation)
  - Graduate: CSE 274 (Topics), many 291s

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**To Do**

- Look at website
- Various policies for course. E-mail if confused.
- Sign up for edX edge, Piazza, etc.
- Skim assignments if you want. All are ready
- Assignment 0, Due Jan 16 next week (see website). [both parts needed, total 10 points]
- Set up compilation framework in HW 0, feedback
- Any questions?

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**History**

- Brief history of significant developments in field
- End with a video showcasing graphics

![Display](Manchester Mark I)

The term Computer Graphics was coined by William Fetter of Boeing in 1960
First graphic system in mid 1950s USAF SAGE radar data (developed MIT)

![Display](Xerox Star)

How far we’ve come: TEXT

**From Text to GUs**

- Invented at PARC circa 1975. Used in the Apple Macintosh, and now prevalent everywhere.

![Display](Windows 1.0)
Drawing: Sketchpad (1963)
- Sketchpad (Sutherland, MIT 1963)
- First interactive graphics system (VIDEO)
- Many concepts for drawing in current systems
  - Pop up menus
  - Constraint-based drawing
  - Hierarchical Modeling

Paint Systems
- Nowadays, image processing programs like Photoshop can draw, paint, edit, etc.

Image Processing
- Digitally alter images, crop, scale, composite
- Add or remove objects
- Sports broadcasts for TV (combine 2D and 3D processing)

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Modeling
- Spline curves, surfaces: 70s – 80s
- Utah teapot: Famous 3D model
- More recently: Triangle meshes often acquired from real objects

Rendering: 1960s (visibility)
- Roberts (1963), Appel (1967) - hidden-line algorithms
- Sutherland (1974) - visibility = sorting

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Rendering: 1970s (lighting)
- 1970s - raster graphics
  - Blinn (1974) - curved surfaces, texture
  - Catmull (1974) - 2-buffer hidden-surface algorithm

Images from F+DH, Pixar’s Shutterbug
Slide ideas for history of Rendering courtesy Marc Levoy.
### Rendering (1980s, 90s: Global Illumination)

<table>
<thead>
<tr>
<th>Early 1980s - Global Illumination</th>
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<tbody>
<tr>
<td>- Whitted (1980) - Ray tracing</td>
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<tr>
<td>- Goral, Torrance et al. (1984) - Radiosity</td>
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<tr>
<td>- Kajiya (1986) - The rendering equation</td>
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### History of Computer Animation

- 10 min clip from video on history of animation
  - [http://www.youtube.com/watch?v=LzZwiLUsx1g](http://www.youtube.com/watch?v=LzZwiLUsx1g)

- Covers sketchpad, animation, basic modeling, rendering
- A synopsis of what this course is about
- (watch offline if short on time)