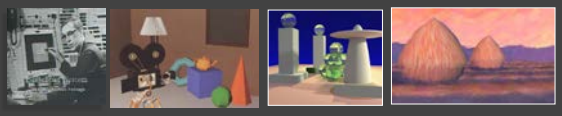
Computer Graphics

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
- Awards for research: White House PECASE (2008), SIGGRAPH Significant New Researcher (2007), ACM Fellow
- https://www.youtube.com/watch?v=qpyCXqXGe7I
- 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

MOOC Introductory Video

Course Staff

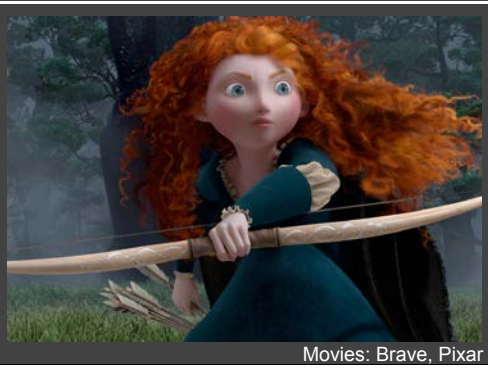
- Ravi Ramamoorthi
- Teaching Assistants:
  - Lifan Wu (will also maintain feedback servers)
  - Tiancheng Sun
  - Alex Kuznetsov

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

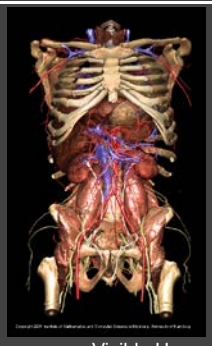
Computer Aided Design

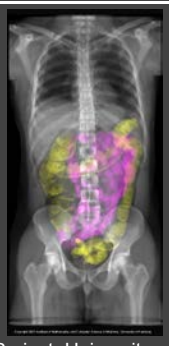
Interiors Professional

Mechanical CAD
Architectural CAD
Electronics CAD
Casual Users

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

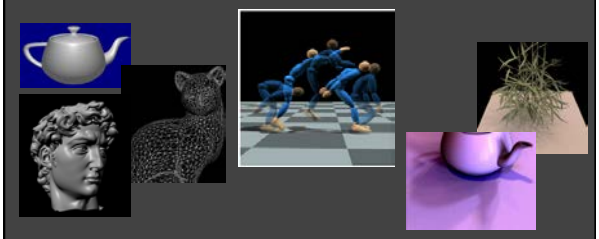
- From text to images to video (to 3D?)
- Image and video processing and photography
- Multimedia computers, tablets, phones
- Flickr, YouTube, WebGL
- Real, Virtual Worlds (Google Earth, Second Life)
- Electronic publishing
- Online gaming
- 3D printers and fabrication

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

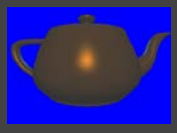
Modeling → Animation → Rendering



3D Graphics Pipeline

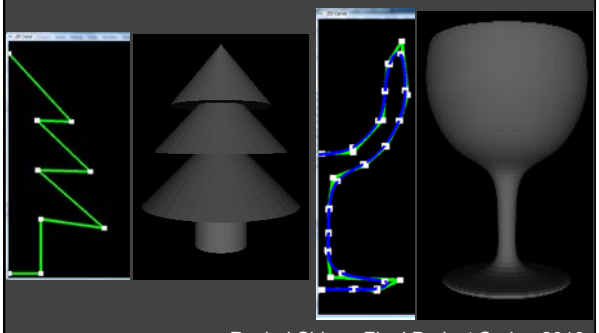
Modeling → Animation → Rendering

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

Curves for Modeling



Rachel Shiner, Final Project Spring 2010

3D Graphics Pipeline

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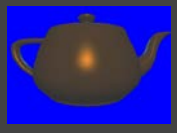
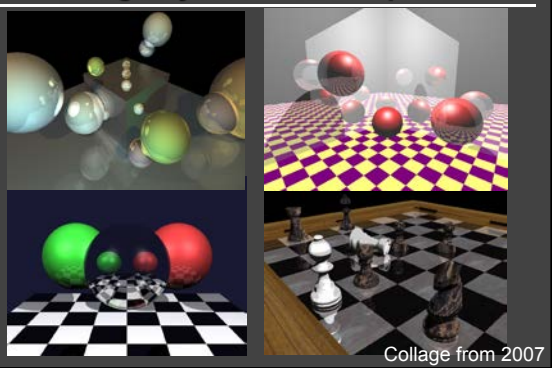


HW 3: Curves (Feb 27)
Bezier and B-Spline curves
To model and draw objects

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

HW 4: RayTracer (Mar 18)
Realistic images with ray tracing
(two basic approaches: rasterize
And raytrace images [HW 2,4])

Image Synthesis Examples



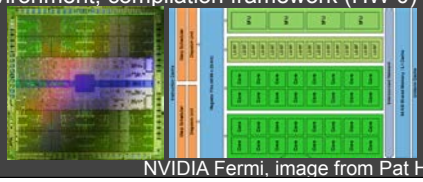
Collage from 2007

Logistics

- Website http://viscomp.ucsd.edu/classes/cse167/wi19 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?

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)

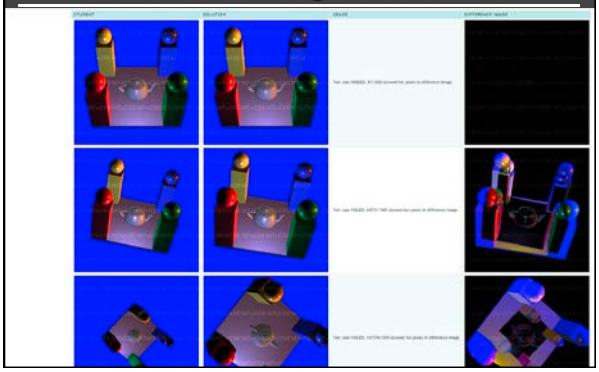


NVIDIA Fermi, image from Pat Hanrahan

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.

Demo of edX edge, Feedbacks



Online Lectures

- Online lectures and screencasts for most course:
  - http://viscomp.ucsd.edu/classes/cse167/wi19/index.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

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

CSE 167 is only a first step

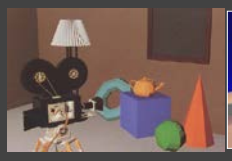
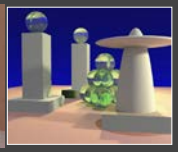
- *If you enjoy CSE 167 and do well*:
- In Spring: CSE 190 (VR course; Schulze)
- Next winter: CSE 165 (3DUI), 169 (Animation)
- Graduate: CSE 274 (Topics), many 291s

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?

History

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

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)

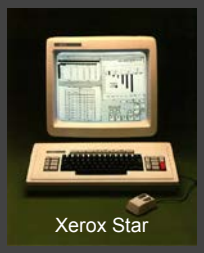
How far we've come: TEXT

Manchester Mark I

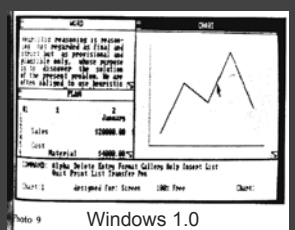
Display →

From Text to GUIs

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



Xerox Star



Windows 1.0

Drawing: Sketchpad (1963)

- Sketchpad (Sutherland, MIT 1963)
- First interactive graphics system (VIDEO)
- Many of concepts for drawing in current systems
  - Pop up menus
  - Constraint-based drawing
  - Hierarchical Modeling

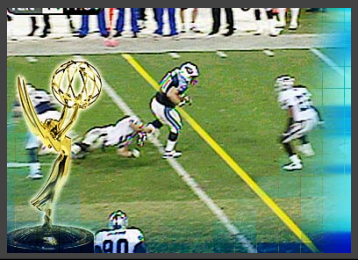
Paint Systems

- SuperPaint system: Richard Shoup, Alvy Ray Smith (PARC, 1973-79)

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

Image Processing

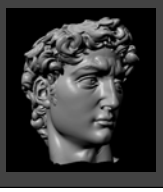
- Digitally alter images, crop, scale, composite
- Add or remove objects
- Sports broadcasts for TV (combine 2D and 3D processing)



Modeling

- Spline curves, surfaces: 70^{s} – 80^{s}
- Utah teapot: Famous 3D model

- More recently: Triangle meshes often acquired from real objects



Rendering: 1960s (visibility)

- Roberts (1963), Appel (1967) - hidden-line algorithms
- Warnock (1969), Watkins (1970) - hidden-surface
- Sutherland (1974) - visibility = sorting

Images from FvDFH, Pixar's Shutterbug
Slide ideas for history of Rendering courtesy Marc Levoy

Rendering: 1970s (lighting)

1970s - raster graphics

- Gouraud (1971) - diffuse lighting, Phong (1974) - specular lighting
- Blinn (1974) - curved surfaces, texture
- Catmull (1974) - Z-buffer hidden-surface algorithm

Rendering (1980s, 90s: Global Illumination)

early 1980s - global illumination

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

History of Computer Animation

- 10 min clip from video on history of animation
- http://www.youtube.com/watch?v=LzZwiLUVaKg
- Covers sketchpad, animation, basic modeling, rendering
- A synopsis of what this course is about
- (watch offline if short on time)