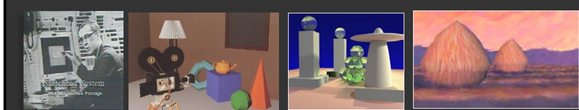
Computer Graphics

CSE 167 [Win 24], Lecture 1: Overview and History

Ravi Ramamoorthi

http://viscomp.ucsd.edu/classes/cse167/wi24



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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.

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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, 700,000 video views. Finalist for two inaugural edX Prizes. Will use UCSD Online, auto-feedback

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MOOC Introductory Video

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Course Staff

- Ravi Ramamoorthi
- Teaching Assistants:
  - Mustafa Yaldiz (myaldiz@ucsd.edu)
  - Nithin Raghavan (n2raghavan@ucsd.edu)
  - Liwen Wu (liw026@ucsd.edu)
  - Zhongyi Wang (zhw039@ucsd.edu)

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Why Study 3D Computer Graphics?

- Applications (discussed next)
- Fundamental Intellectual Challenges

Some content inspired by Pat Hanrahan from Stanford's CS148

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Entertainment

Movies: Brave, Pixar 2012

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Entertainment

Movies: Turning Red, Pixar 2022

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Entertainment

Games: Halo 3, Bungie 2007

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Entertainment

Games: Halo Infinite, Bungie 2021

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Lighting Simulation

Interior Design

Automobile Visualization

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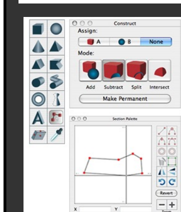
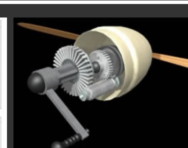
Computer Aided Design





Mechanical CAD
Architectural CAD
Electronics CAD
Casual Users

Interiors Professional

Google Sketchup

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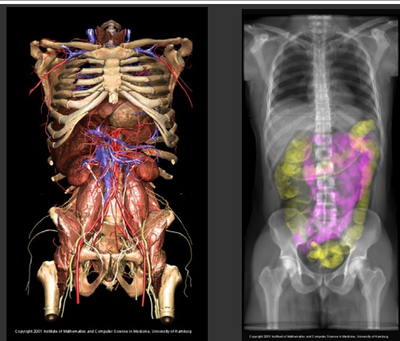
Visualization: Science and Medicine



Visible Human Project: University of Hamburg

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Virtual Reality

- VR for design and entertainment
- Simulators: Surgical, Flight, Driving, Spacecraft

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Virtual Reality: Metaverse

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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, Metaverse)
- Electronic publishing
- Online gaming
- 3D printers and fabrication

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NEURAL RADIANCE FIELDS

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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

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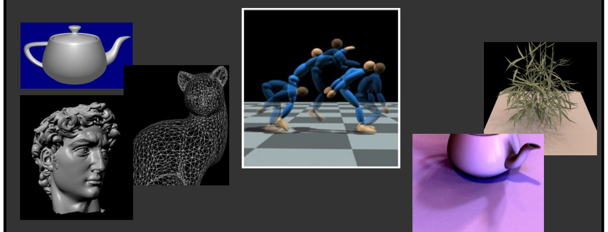
3D Graphics Pipeline

Modeling → Animation → Rendering



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3D Graphics Pipeline

Modeling → Animation → Rendering

HW 1: Transformations (Jan 26)
Place objects in world, view them
Simple viewer for a teapot

HW 3: Curves (Feb 28)
Bezier and B-Spline curves
To model and draw objects

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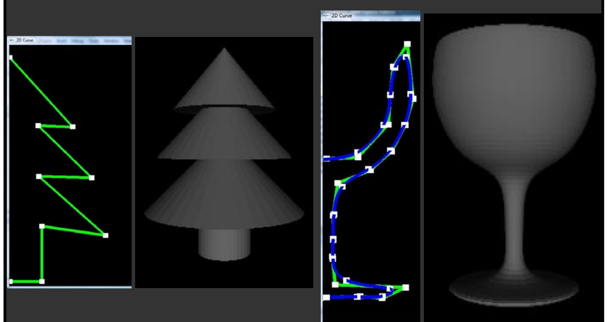
Curves for Modeling



Rachel Shiner, Final Project Spring 2010

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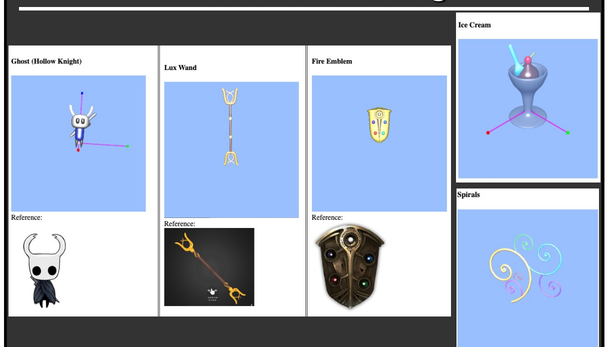
Curves for Modeling



James Zhao. HW 3 Extra Credit Winter 2023

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3D Graphics Pipeline

Modeling → Animation → Rendering

HW 1: Transformations (Jan 26)
Place objects in world, view them
Simple viewer for a teapot

HW 3: Curves (Feb 28)
Bezier and B-Spline curves
To model and draw objects

HW 2: Scene Viewer (Feb 14)
View scene, Lighting and Shading
(with GLSL programmable shaders)

HW 4: RayTracer (Mar 19)
Realistic images with ray tracing
(two basic approaches: rasterize
And raytrace images [HW 2,4])

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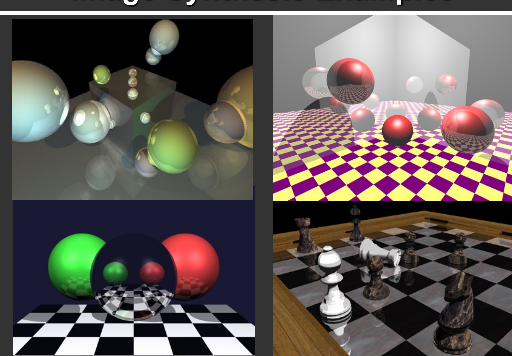
Image Synthesis Examples



Collage from 2007

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Logistics

- Website http://viscomp.ucsd.edu/classes/cse167/wi24 has most of the information (look at it carefully)
- *We will be leveraging MOOC infrastructure in a SPOC*
  - Please sign up for account at UCSD online, join course: **DEMO**
  - UCSD online 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
  - See website for sections, TA office hours.
- Course newsgroup on Piazza
- Website for late, collaboration policy, etc
- Questions?

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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)

NVIDIA Fermi, image from Pat Hanrahan

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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 UCSD Online
- "Feedback" not necessarily grading
  - Can run extra test cases, look at code, grade fairly
  - But use of feedback servers/UCSD Online 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.

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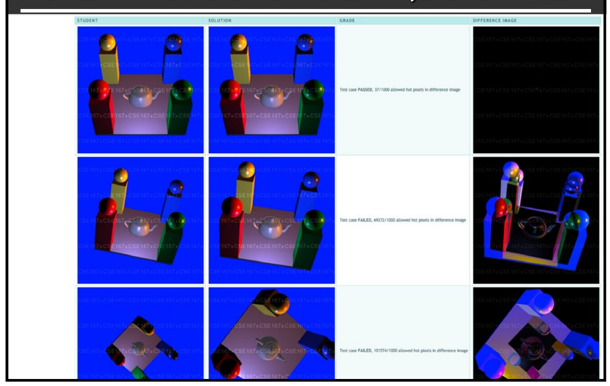
Demo of edX/UCSD Online, Feedbacks



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Online Lectures

- Online lectures and screencasts for most course:
  - http://viscomp.ucsd.edu/classes/cse167/wi24/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 UCSD online (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
- UCSD Canvas lectures from last year

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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 UCSD online 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: I teach CSE 168 (Rendering continues)
- Next winter: CSE 169 (Animation)
- CSE 165 (VR)
- Graduate: CSE 274 (Topics), many 291s, 273 (Computational Photography)

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To Do

- Look at website
- Various policies for course. E-mail if confused.
- Sign up for UCSD Online, Piazza, etc.
- Skim assignments if you want. All are ready
- Assignment 0, Due Jan 17 next week (see website). [both parts needed, total 10 points]
- Set up compilation framework in HW 0, feedback
  - Also test HW1, HW 2, HW 3 (curves)
  - Make sure you can compile multi-file from scratch (HW4)
- Any questions?

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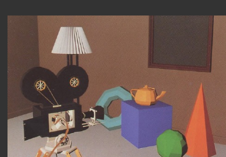
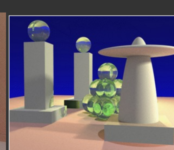
History

- 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)

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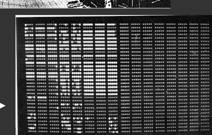
How far we've come: TEXT

Manchester Mark I



Display

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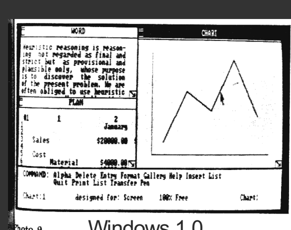
From Text to GUIs

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



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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

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Paint Systems

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

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

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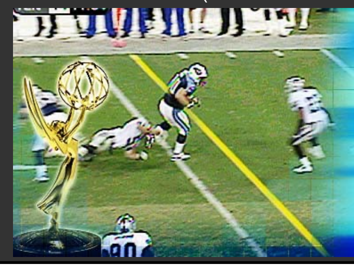
Image Processing

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



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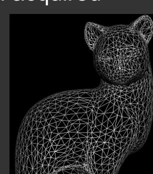
Modeling

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

- More recently: Triangle meshes often acquired from real objects

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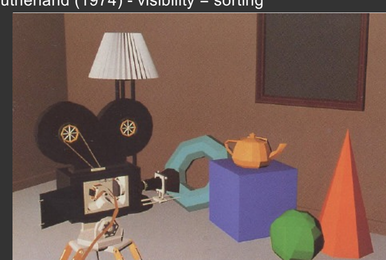
Rendering: 1960s (visibility)

- 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

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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

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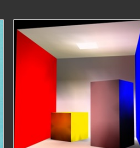
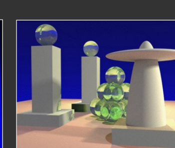
Rendering (1980s, 90s: Global Illumination)

early 1980s - global illumination

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

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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)

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