Foundations of Computer Graphics

Online Lecture 1: Overview and History

Motivation: Why do we study 3D Graphics?

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Ravi Ramamoorthi

Instructor

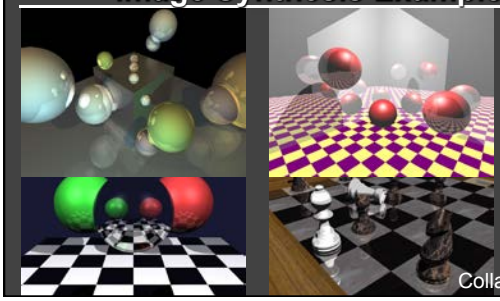
Ravi Ramamoorthi http://www.cs.berkeley.edu/~ravir

- 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 since Jan 2009
- Awards for research: White House PECASE (2008), SIGGRAPH Significant New Researcher (2007)
- http://www.cs.berkeley.edu/~ravir/RaviR.wmv
- Have taught Computer Graphics 10+ times

Goals

- **Systems:** Write complex 3D graphics programs (real-time scene viewer 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 like Maya, Alias, DirectX but about the concepts underlying them. You will write programs in OpenGL/GLSL

Image Synthesis Examples



Collage from 2007

Why Study 3D Computer Graphics?

- Applications (discussed next)
- Fundamental Intellectual Challenges

Applications

- Movies
- Games
- Computer Aided Design (CAD)
- Lighting Simulation (Interiors, Automobiles, …)
- Visualization (Scientific, Medical)
- Virtual Reality

Digital Visual Media

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

Why Study 3D Computer Graphics?

- 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, hardware

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Course Outline and Logistics

Ravi Ramamoorthi

3D Graphics Pipeline

Modeling → Animation → Rendering

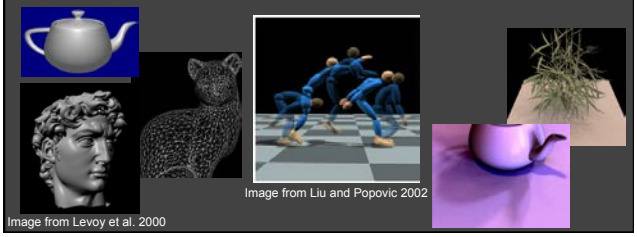

Image from Levoy et al. 2000

Image from Liu and Popovic 2002

3D Graphics Pipeline

Modeling → Animation → Rendering

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

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

HW 3: RayTracer
Realistic images with ray tracing
(two basic approaches: rasterize
And raytrace images [HW 2,3])

Assignment Logistics

- HW 0 immediately to check compilation etc.
- Feedback/Grading servers for all HW
- Submit images, compared with originals
  - Program generates images automatically for you
  - Can submit multiple times for feedback
- Skeleton code in C++/OpenGL/GLSL
  - Programming background in C/C++/Java needed
  - No prior knowledge of 3D graphics/OpenGL required

Workload

- Lots of fun, rewarding but may involve significant work
- 3 programming projects; almost all are time-consuming
- Course will involve understanding of mathematical, geometrical concepts taught (tested on final)
- Prerequisites: Solid C/C++/Java programming.
- Linear algebra (review next lecture) and basic math skills

A Note on GPU Programming

- Modern 3D Graphics Programming with GPUs
- GLSL + Programmable Shaders in HW 0,1,2
- Should be very portable, but need to set up your environment, compilation framework (HW 0)

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Brief History of Computer Graphics

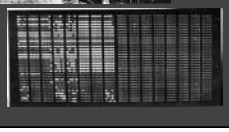
Ravi Ramamoorthi

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

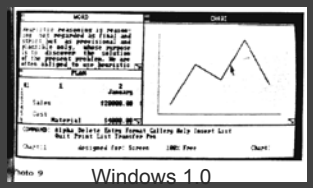
Display →



From Text to GUIs

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

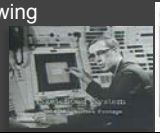
Xerox Star



Windows 1.0

Drawing: Sketchpad (1963)

- Sketchpad (Sutherland, MIT 1963)
- First interactive graphics system
  - http://www.youtube.com/watch?v=mOZqRJzE8xg
- 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)

Black Girl by Fritz Fisher
http://www.rgshoup.com/prof/SuperPaint

- Precursor to Photoshop: general image processing

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)

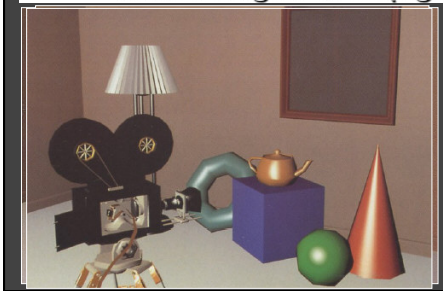
Hidden Line Algorithms:
Roberts (63), Appel (67)

Hidden Surface Algorithms:
Warnock (69), Watkins (70)

Visibility = Sorting
Sutherland (74)

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

Rendering: 1970s (lighting)



Diffuse Lighting
(Gouraud 1971)

Specular Lighting
(Phong 1974)

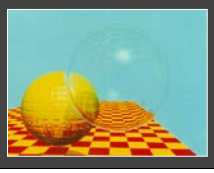
Curved Surfaces, Texture
(Blinn 1974)

Z-Buffer Hidden Surface
(Catmull 1974)

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