Advanced Computer Graphics
(Fall 2010)
CS 283, Lecture 1: Introduction and History

Ravi Ramamoorthi
http://inst.eecs.berkeley.edu/~cs283/fa10

Overview
- CS 283, Advanced Computer Graphics
  - Prerequisite: Done well in CS 184 or equivalent elsewhere
  - Strong interest in computer graphics
- Advanced topics in rendering/geometry-animation
  - Background for modern topics
  - Areas of current research interest
- Goal is background and up to research frontier
  - Aimed at beginning PhD students and advanced undergrads
- Regular lecture class but less rigid than CS 184
- Encourage you to take other CS 28x, 29x in graphics

Demo
- Precomputed relighting: Vase
- Real-Time complex shading (with area lights)

Administrivia
- Website http://inst.eecs.berkeley.edu/~cs283/fa10
- Lectures MW 1-2:30pm in Soda 310
- E-mail instructor directly for questions, meetings …
  - ravir@cs.berkeley.edu
  - Talk to me after class re issues, getting off waitlist etc.
- TA: Jiamin Bai (545), bjiamin@eecs.berkeley.edu
- No books. Lectures online, reading/refs as needed
- TODO: E-mail TA picture (small 120x160), name, e-mail, etc by tomorrow

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

Course Logistics
- Graded on basis of 4 mostly programming homeworks
- Can be done in groups of two
- Turned in by creating website, sending e-mail
  - Do not modify site after deadline
  - May schedule demo sessions
- Can substitute research or implementation project for one or more of assignments (encouraged to do so)
  - With instructor approval of specific plan
  - Allows you to focus on topics of interest and research
- See website for more details, assignments
Progressive Mesh Simplification

Subdivision Surfaces

Coarse mesh + subdivision rule
Smooth surface = limit of sequence of refinements

Video

Rendering and Appearance

- Core area in computer graphics
- Efficiently and easily create visual appearance
- Long history (1960s to current time): Variety of old and new topics
- From basic visibility and shading, to global illumination, to image-based rendering, to data-driven appearance and light fields
- Many links to physics, math, computer science

Rendering: 1960s (visibility)

- Roberts (1963), Appel (1967) - hidden-line algorithms
- 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
- Blinn (1974) - curved surfaces, texture

Rendering (1980s, 90s: Global Illumination)

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

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

- Basic Ray Tracing
- Global Illumination
- Image-Based Rendering
- Real-Time Rendering

Ray Tracing History

Ray Tracing in Computer Graphics

"An improved Illumination model for shaded display," T. Whitted, CACM 1979

Resolution: 512 x 512
Time: VAX 11/780 (1979)
74 min.
PC (2008)
6 sec.

Spheres and Checkerboard, T. Whitted, 1979

Heckbert’s Business Card Ray Tracer

Global Illumination

Ray Tracing in Computer Graphics

Apel 1968 - Ray casting
1. Generate an image by sending one ray per pixel
2. Check for shadows by sending a ray to the light

Radiosity
Successive Approximation

\[ I_s \quad K \cdot I_s \quad K \cdot I_s \quad K \cdot K \cdot K \cdot I_s \]

\[ I_s \quad I_s \cdot K \cdot I_s \quad I_s \cdot K^2 \cdot I_s \quad I_s \cdot K^3 \cdot I_s \]

Rendering Equation (Kajiya 86)

Outline

- Basic Ray Tracing
- Global Illumination
- Image-Based Rendering
- Real-Time Rendering

Caustics

Image-Based Rendering

Apple’s QuickTime VR

Outward

Inward
Dual Interpretation of Light Field

- Plenoptic Light Field
  - Field radiance

- Surface Light Field
  - Surface radiance

UV Array of ST Images
ST Array of UV Images

Acquiring Reflectance Field of Human Face [Debevec et al. SIGGRAPH 00]

Illuminate subject from many incident directions

Example Images

Outline

- Basic Ray Tracing
- Global Illumination
- Image-Based Rendering
- Real-Time Rendering

Precomputed Radiance Transfer

- Better light integration and transport
  - dynamic, area lights
  - self-shadowing
  - interreflections

- For diffuse and glossy surfaces
- At real-time rates
- Sloan et al. 02
**Precomputation: Spherical Harmonics**

**Diffuse Transfer Results**

No Shadows/Inter | Shadows | Shadows+Inter

**Arbitrary BRDF Results**

Anisotropic BRDFs | Other BRDFs | Spatially Varying

**Relighting as a Matrix-Vector Multiply**

\[
\begin{bmatrix}
T_{11} & T_{12} & \cdots & T_{1M} \\
T_{21} & T_{22} & \cdots & T_{2M} \\
\vdots & \vdots & \ddots & \vdots \\
T_{N1} & T_{N2} & \cdots & T_{NM}
\end{bmatrix}
\begin{bmatrix}
L_1 \\
L_2 \\
\vdots \\
L_M
\end{bmatrix}
= \begin{bmatrix}
L_1 \\
L_2 \\
\vdots \\
L_M
\end{bmatrix}
\]

**Physical Simulation and Animation**

- [Recent clothing animation video](#)

**Imaging**

- Processing of images important part of graphics
- Especially in context of photography: Combine photos, manipulate images
  - Video for image interpolation
- Computational photography. Examples flash/no-flash, fluttered shutter, new cameras
- Community and Internet photo collections
- Basic ideas like HDR and Texture Synthesis
  - Both largely developed at Berkeley
High Dynamic Range

- Photographs at multiple exposures
- Combine and tonemap

From Wikipedia. Debevec and Malik 97

Multiple Photographs

Combined and Tonemapped

Texture Synthesis

- From small image to larger (keep texture)
- Novel idea: Copy image patches (quilting)

Efros and Leung 99, Efros and Freeman 01. This example from Wikipedia

Summary

- Graphics is Modeling/Geometry, Rendering, Animation/Simulation, Imaging and much more
- Course looks at all of these
- Goal to develop modern ideas, understand topics at the research/industry frontier
- 4 programming assignments (groups of 2)
  - Progressive Meshes
  - Path Tracer
  - Real-Time / Image-Based Rendering
  - Project
- Can substitute research/implementation for any!