Advanced Computer Graphics
CSE 163 [Spring 2018], Lecture 1
Ravi Ramamoorthi
http://www.cs.ucsd.edu/~ravir

Goals

- **Systems:** Write fairly complex programs for image processing, mesh algorithms, image synthesis
- **Theory:** Understand mathematical aspects and algorithms underlying modern 3D graphics

This course is a continuation of CSE 167, Introduction to Computer Graphics. It fills some gaps, provides a more advanced thorough overview.

Course Outline

- **3D Graphics Pipeline**
  - **Modeling** (Creating 3D Geometry)
  - **Rendering** (Creating, shading images from geometry, lighting, materials)

Unit 1: Foundations of Signal and Image Processing
Understanding the way 2D images are formed and displayed, the important concepts and algorithms, and to build an image processing utility like Photoshop. Weeks 1 – 3. Assignment 1

Assignment 1

Unit 2: Meshes, Modeling
Weeks 3 – 5. Assignment 2

Unit 3: Advanced Rendering
Weeks 6 – 7. Assignment 3 (Final Project)

Unit 4: Animation, Imaging
Weeks 7-8. Assignment 4 (Final Project)
Overview

- **CSE 163: Advanced Computer Graphics**
  - Prerequisite: Done well in CSE 167 or equivalent elsewhere
  - Strong interest in computer graphics
  - Advanced undergraduates, MS, PhD all welcome
  - Should count for relevant graphics/vision concentrations
  - Advanced topics in image processing, geometry, rendering, animation following on from CSE 167
  - Intended as a one quarter self-contained follow on
    - If you take only one advanced graphics course, full coverage
    - But can (encouraged) to take 163,190(VR) together
  - No significant overlap with CSE 165,168,169,190 VR
    - Image processing, meshes new material
    - Rendering coverage is real-time, image-based, not in 168

Regular lecture class but less rigid than CSE 167

- Advanced course, encourage class participation
- But also need more independence, self discipline
  - Grading entirely based on 3 large programming projects
  - Can be done individually (same requirements) or group of 2
  - Given 3-4 weeks, no extensions/late days. Turn in what you have. Need to START EARLY and work steadily.
  - Minimal handholding, skeleton code

Homeworks usually turned in by creating website

- Link to URL to submit + zip of code (new: upload TritonEd)
- Do not modify website after due date
- May schedule demos

Encourage you to take other CS 16x, 2xx in graphics

Overview

- Workload: Challenging course: Lots of fun, rewarding but may involve significant work However, given 3-4 weeks/project; work steadily
- Most will get high grades. Assume did well in 167, here to have fun learn more graphics
- Final project open ended (some detailed options)
- More flexibility on pass-fail (graduate students)
  - Must still do one (of two) regular assignment, 50% overall
  - Final project can be waived given research etc.
- Please see website for more details, assignments

Workload: Challenging course: Lots of fun, rewarding but may involve significant work However, given 3-4 weeks/project; work steadily

- Most will get high grades. Assume did well in 167, here to have fun learn more graphics
- Final project open ended (some detailed options)
- More flexibility on pass-fail (graduate students)
  - Must still do one (of two) regular assignment, 50% overall
  - Final project can be waived given research etc.
- Please see website for more details, assignments

Administrivia

- Web: [http://viscomp.ucsd.edu/classes/cse163/sp18/163.html](http://viscomp.ucsd.edu/classes/cse163/sp18/163.html)
- Lectures Tu-Thu In EBU3B 2154
- E-mail instructor directly for questions, meetings …
  - Off. Hours before class in EBU3B, 4118, 11-12
- Teaching Assistants: Jiyang Yu jiy173@eng.ucsd.edu , tutor: Ziyang Li zil159@ucsd.edu Also cse-163ta@eng.ucsd.edu
  - See website for office hours, e-mail for other times
- Piazza newsgroup: please sign up [note spr 2018] (piazza.com/ucsd/spring2018/cse163)
  - No books. Lecture slides online, reading as needed
  - [http://viscomp.ucsd.edu/classes/cse163/sp18/readings](http://viscomp.ucsd.edu/classes/cse163/sp18/readings)

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)
2D Graphics

Many of the standard operations you’re used to:

- Text
- Graphical User Interfaces (Windows, MacOS, …)
- Image processing and paint programs (Photoshop, …)
- Drawing and presentation (Powerpoint, …)

How far we’ve come: TEXT

From Text to GUIs

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

Drawing: Sketchpad (1963)

- Sketchpad (Sutherland, MIT 1963)
- First interactive graphics system
- Many of 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)
Relevance to Course

- In 167, didn’t focus on 2D
- But relevant broadly (not just for 2D), since ultimately 3D scene displayed as 2D image
- In 163, we cover image processing and many photoshop functions [assign. 1 to write a mini-version]

Geometry

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

Progressive Mesh Simplification

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

Subdivision Surfaces

- 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
- We focus on real-time, image-based (no overlap with 168 that focuses on basic offline rendering)

Relevance to Course

- Unit 2 is about mesh processing algs.
- Will learn to represent, work with meshes
- Do mesh simplification, progressive meshes for assignment 2
Rendering: 1960s (visibility)
- Roberts (1963), Appel (1967) - hidden-line algorithms
- Sutherland (1974) - visibility = sorting

Rendering: 1970s (lighting)
- 1970s - raster graphics
  - Blinn (1974) - curved surfaces, texture
  - Catmull (1974) - 2-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
  - This is basically what 168 covers

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
- Lytro Light Field Camera
  - 4 degree of freedom pan/tilt
  - 360 degree field of view
Acquiring Reflectance Field of Human Face [Debevec et al. SIGGRAPH 00]

Illuminate subject from many incident directions

Example Images

Images fromDebevec et al. 00

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

Diffuse Transfer Results

- No Shadows/Inter
- Shadows
- Shadows+Inter

Precomputation: Spherical Harmonics

Basis 16
Basis 17
Basis 18

Arbitrary BRDF Results

Anisotropic BRDFs
Other BRDFs
Spatially Varying
**Imaging**

- Processing of images important part of graphics
- Especially in context of photography: Combine photos, manipulate images
- Computational photography. Examples flash/no-flash, fluttered shutter, new light field cameras
- Community and Internet photo collections
- Basic ideas like HDR and Texture Synthesis

---

**High Dynamic Range**

- Photographs at multiple exposures
- Combine and tonemap

---

**Multiple Photographs**

---

**Combined and Tonemapped**

---

**Texture Synthesis**

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

---

**History of Computer Animation**

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

- Graphics is Modeling/Geometry, Rendering, Animation/Simulation, Imaging and much more
- Course looks at all of these. One stop follow on to CSE 167, no overlap with 165, 169 or 190
- 3 programming assignments (groups of 2)
  - Image Processing
  - Progressive Meshes
  - Project (eg Real-Time / Image-Based Rendering)