## Advanced Computer Graphics

CSE 163 [Spring 2018], Lecture 1

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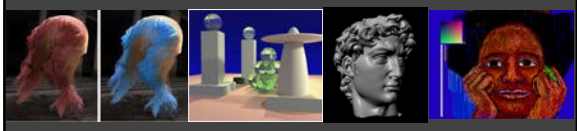


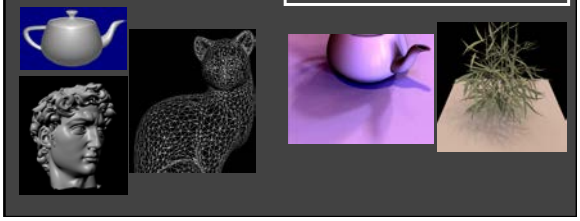
## Goals

- **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)



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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**

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

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

Unit 3: Advanced Rendering
Weeks 6 – 7, 8-9. **(Final Project)**

Unit 4: Animation, Imaging
Weeks 7-8, 10. **(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

## Overview

- 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

## Administrivia

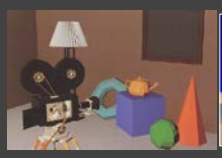
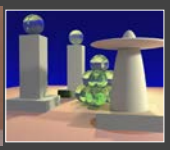
- Web: http://viscomp.ucsd.edu/classes/cse163/sp18/163.html
- Lectures Tu-Thu In EBU3B 2154
- E-mail instructor directly for questions, meetings …
  - ravir@cs.ucsd.edu
  - Off. Hours before class in EBU3B, 4118, 11-12
- Teaching Assistants: Jiyang Yu jiy173@eng.ucsd.edu , tutor: Ziyang Li zil150@ucsd.edu 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

## To Do

- Look at website
- Various policies etc. for course. Send me e-mail if confused
- Skim assignments if you want. All are ready
- Assignment 1, due Apr 27. Start working on it immediately (START EARLY). For today, make sure download/compile
- Find partners for assignment 1 and possibly later (can switch partners or switch individual/group of two between assignments if you want). Tell instructor/TA if need help
- 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)

## 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

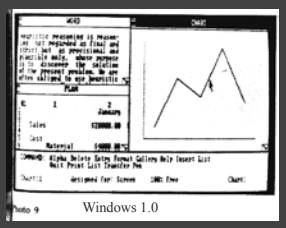
Manchester Mark I

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)

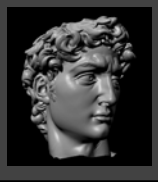
## Relevance to Course

- 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: $70^s$ – $80^s$
- Utah teapot: Famous 3D model

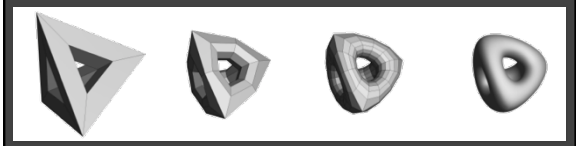
- More recently: Triangle meshes often acquired from real objects



## Progressive Mesh Simplification

## Subdivision Surfaces

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



- Video

## 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 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)

## Rendering: 1960s (visibility)

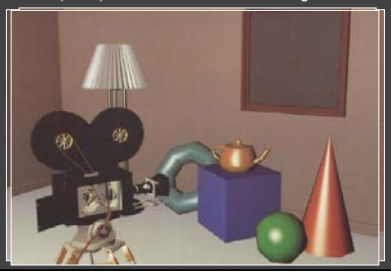
- Roberts (1963), Appel (1967) - hidden-line algorithms
- Warnock (1969), Watkins (1970) - hidden-surface
- Sutherland (1974) - visibility = sorting

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

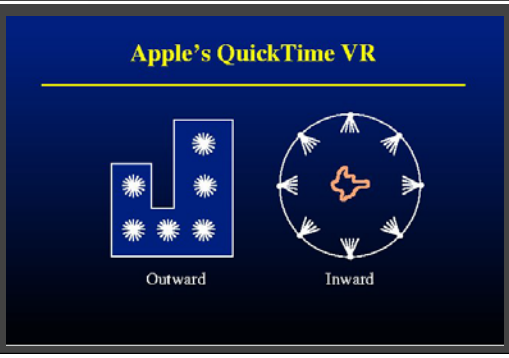


## Rendering (1980s, 90s: Global Illumination)

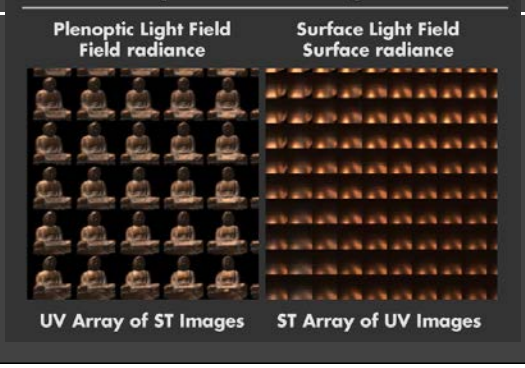
early 1980s - global illumination

- Whitted (1980) - ray tracing
- Goral, Torrance et al. (1984) radiosity
- Kajiya (1986) - the rendering equation
- This is basically what 168 covers

## Image-Based Rendering




## Dual Interpretation of Light Field



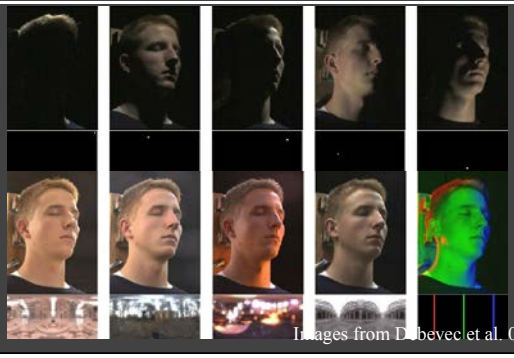


Lytro Light Field Camera
Demo refocus, perspective

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

Illuminate subject from many incident directions

## Example Images



Images from Debevec 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

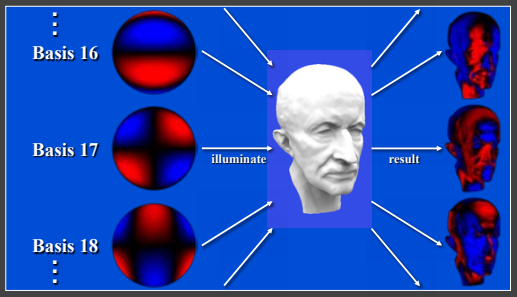
point light

area light

area lighting, no shadows

area lighting, shadows

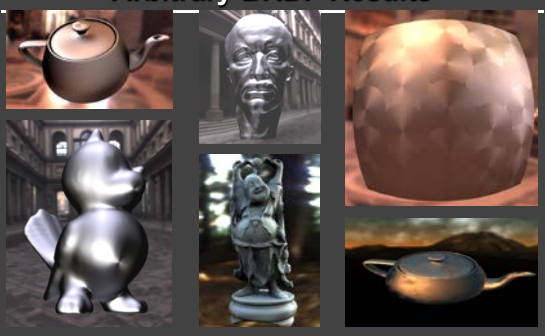
## Precomputation: Spherical Harmonics




## Diffuse Transfer Results

No Shadows/Inter | Shadows | Shadows+Inter

## Arbitrary BRDF Results



Anisotropic BRDFs | Other BRDFs | Spatially Varying

## Imaging

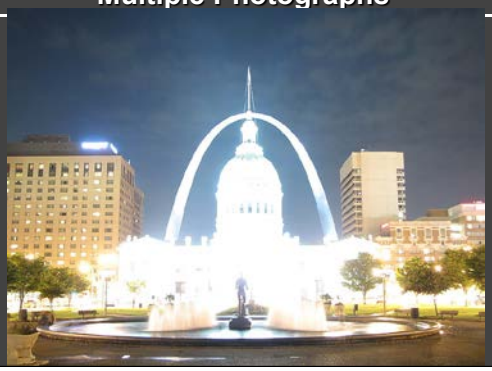
- Processing of images important part of graphics
- Especially in context of photography: Combine photos, manipulate images
- Computational photography. Examples flash/no-flash, fluttered shutter, new light field cameras
- Community and Internet photo collections
- Basic ideas like HDR and Texture Synthesis

## High Dynamic Range

- Photographs at multiple exposures
- Combine and tonemap

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

## History of Computer Animation

- 10 min clip from video on history of animation
- http://www.youtube.com/watch?v=LzZwiLUVaKo
- 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)