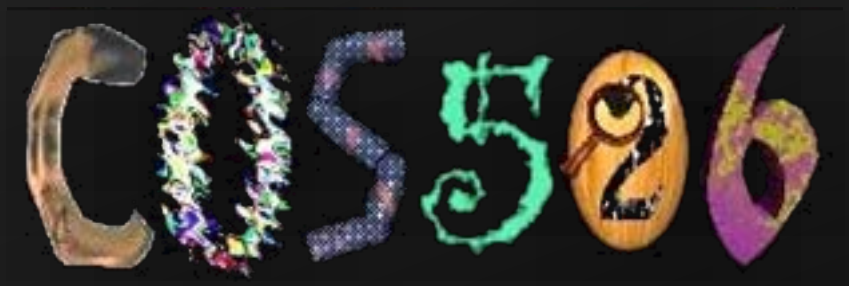


Advanced Computer Graphics

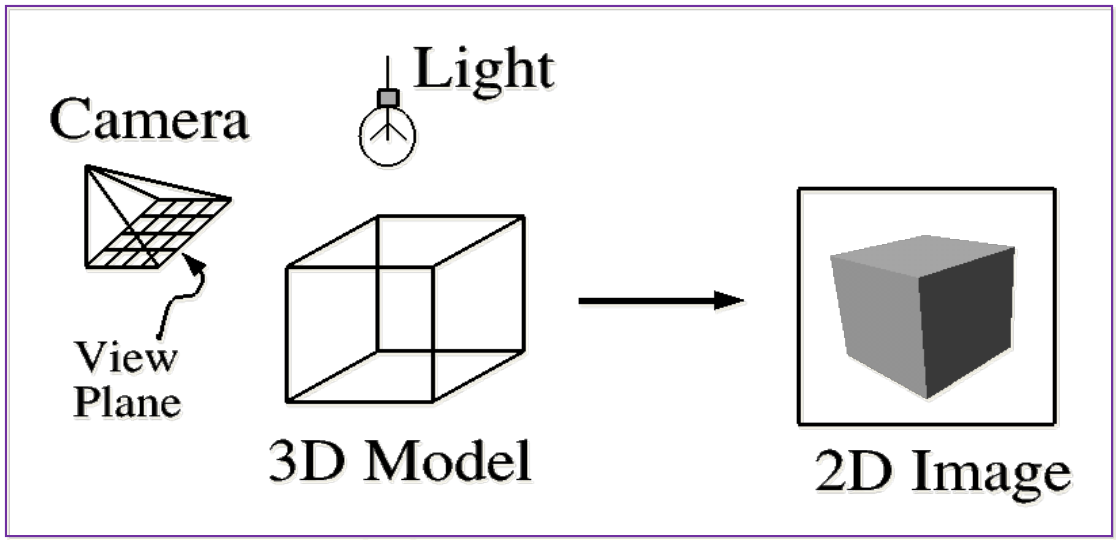
Szymon Rusinkiewicz

Fall 2018

Slide credits: Ravi Ramamoorthi and Tom Funkhouser

Introduction

- Elements of computer graphics
  - Imaging – *representing 2D images*
  - Modeling – *representing 3D objects*
  - Rendering – *constructing 2D images from 3D models*
  - Animation – *simulating changes over time*



Background

- Image Processing
  - Basic signal processing
  - Filtering, resampling, warping, ...
- Rendering
  - Polygon rendering pipeline
  - Ray tracing
- Modeling
  - Basic 3D object representations
  - Polygonal meshes
- Animation
  - Basic principles

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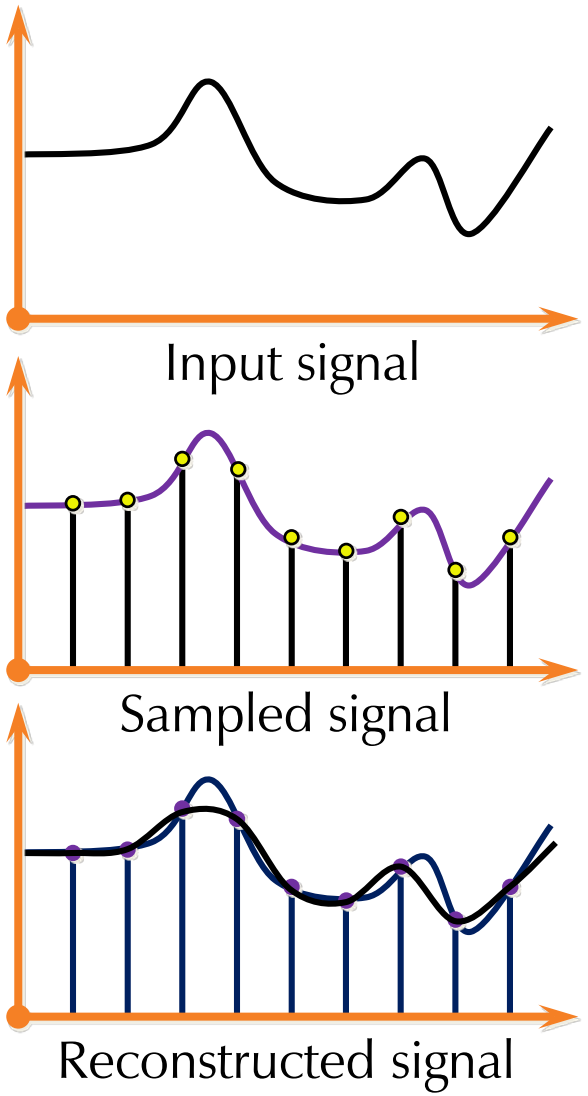

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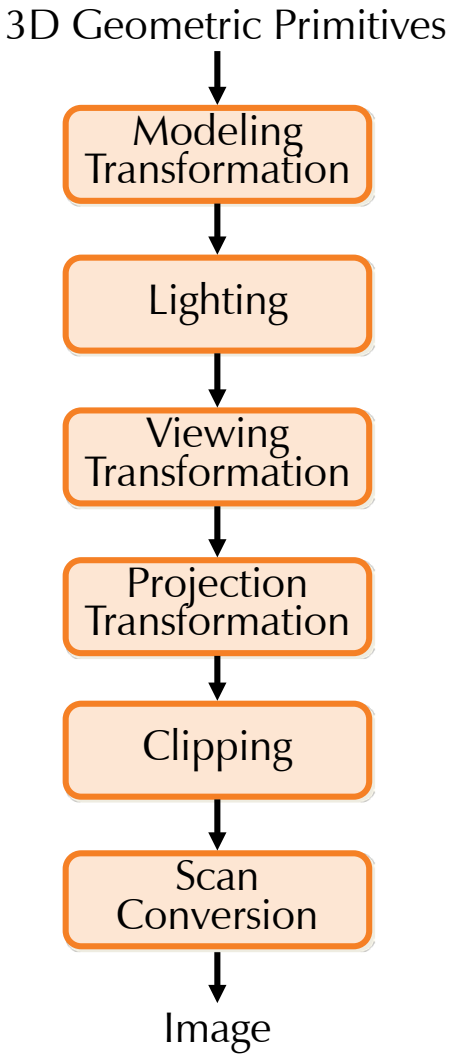

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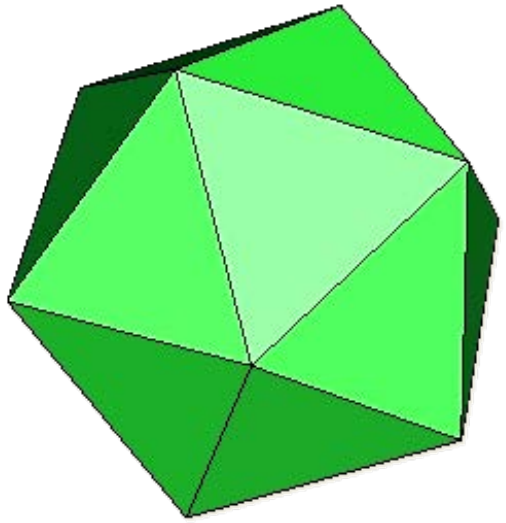

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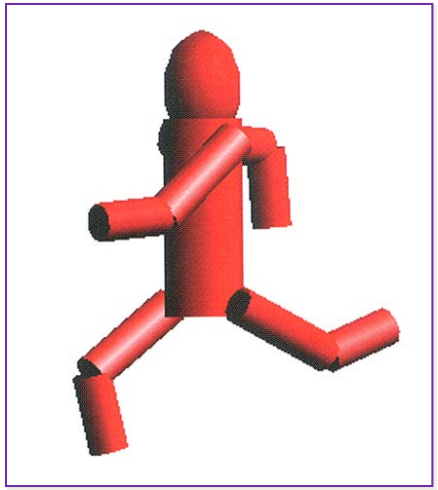


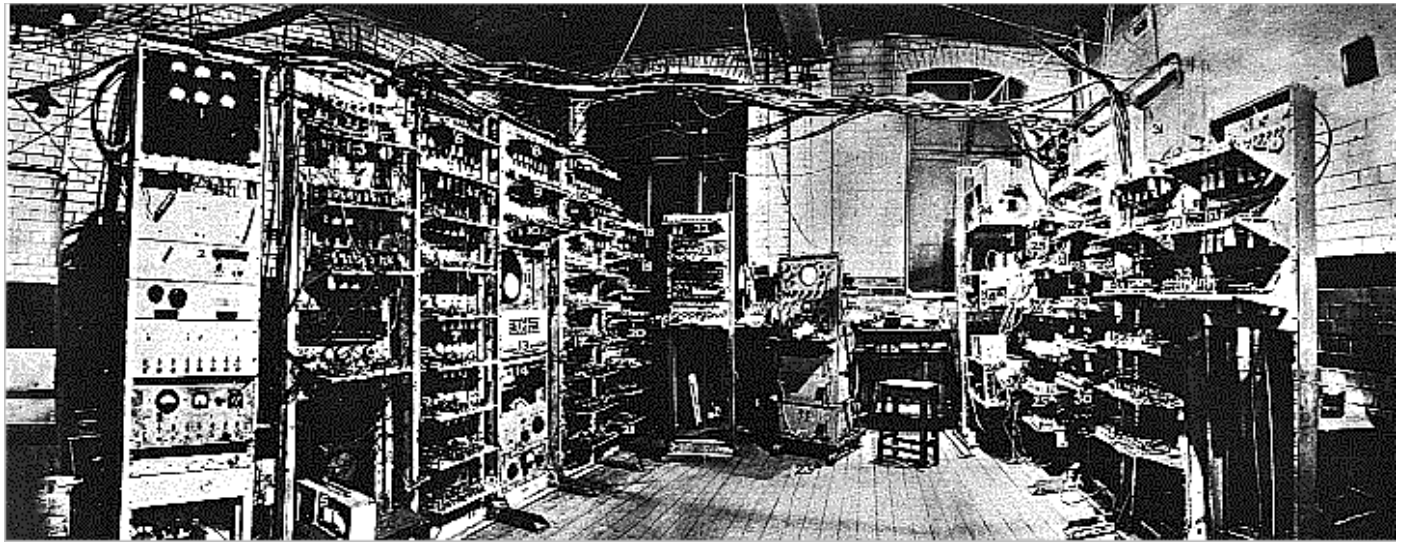
Angel, Plate I

COS 526

- Topics:
  - Image processing and computational photography
  - Geometry processing and mesh manipulation
  - Global illumination
  - Real-time rendering
  - Selected other topics
- Mechanics:
  - O(3) short written assignments
  - O(3) Programming assignments
  - Final project

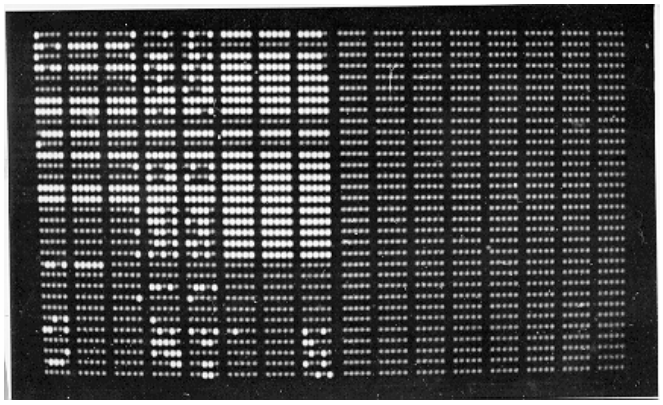
http://www.cs.princeton.edu/courses/archive/fall18/cos526/

How Far We've Come!



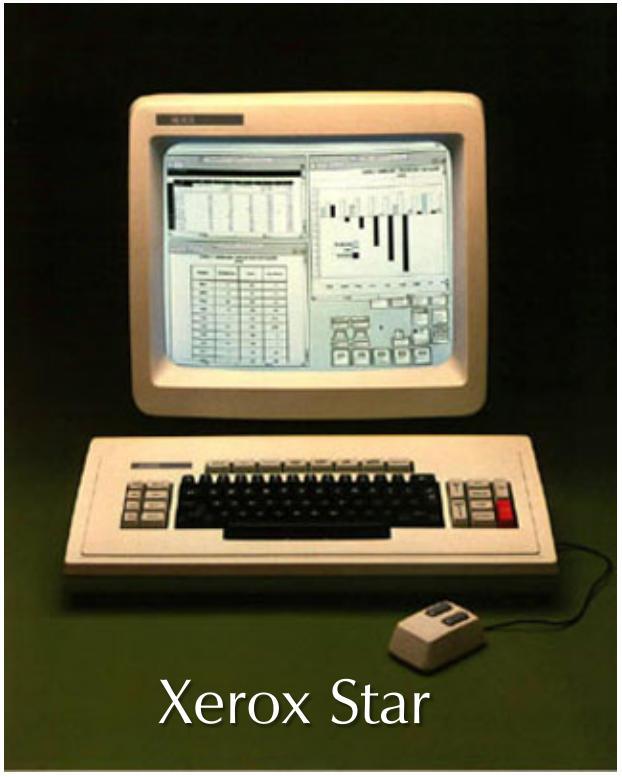
Manchester Mark I

Display ⟶



From Text to GUIs

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



Xerox Star

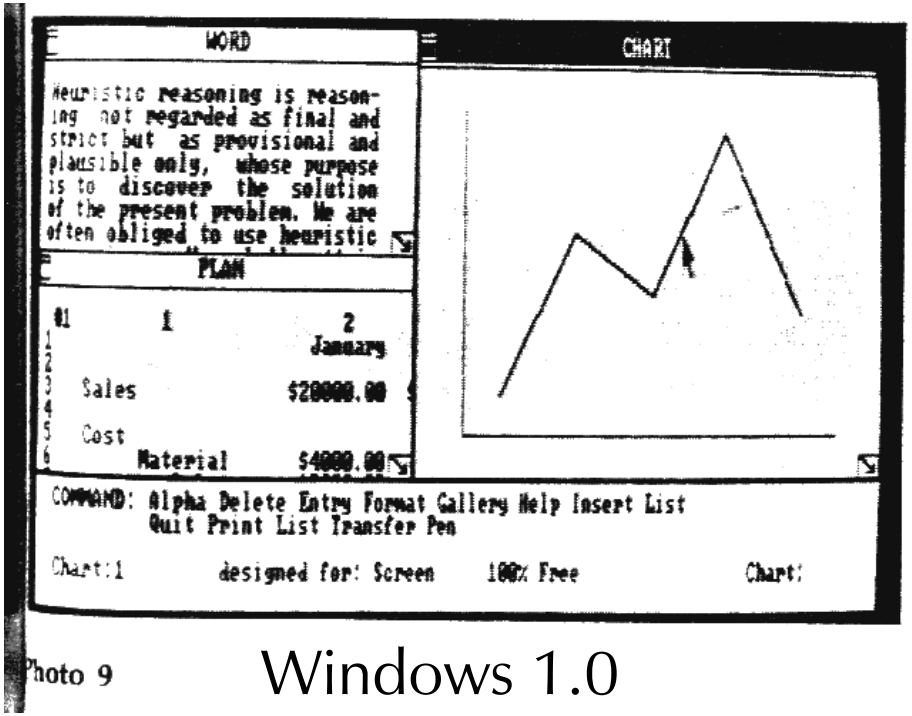


Photo 9

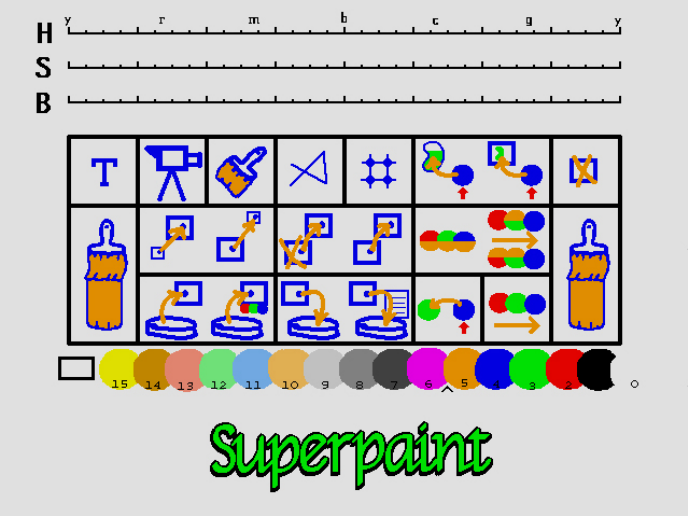
Windows 1.0

Drawing: Sketchpad (1963)

- Sketchpad (Sutherland, MIT 1963)
- First interactive graphics system (VIDEO)
- Source 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)

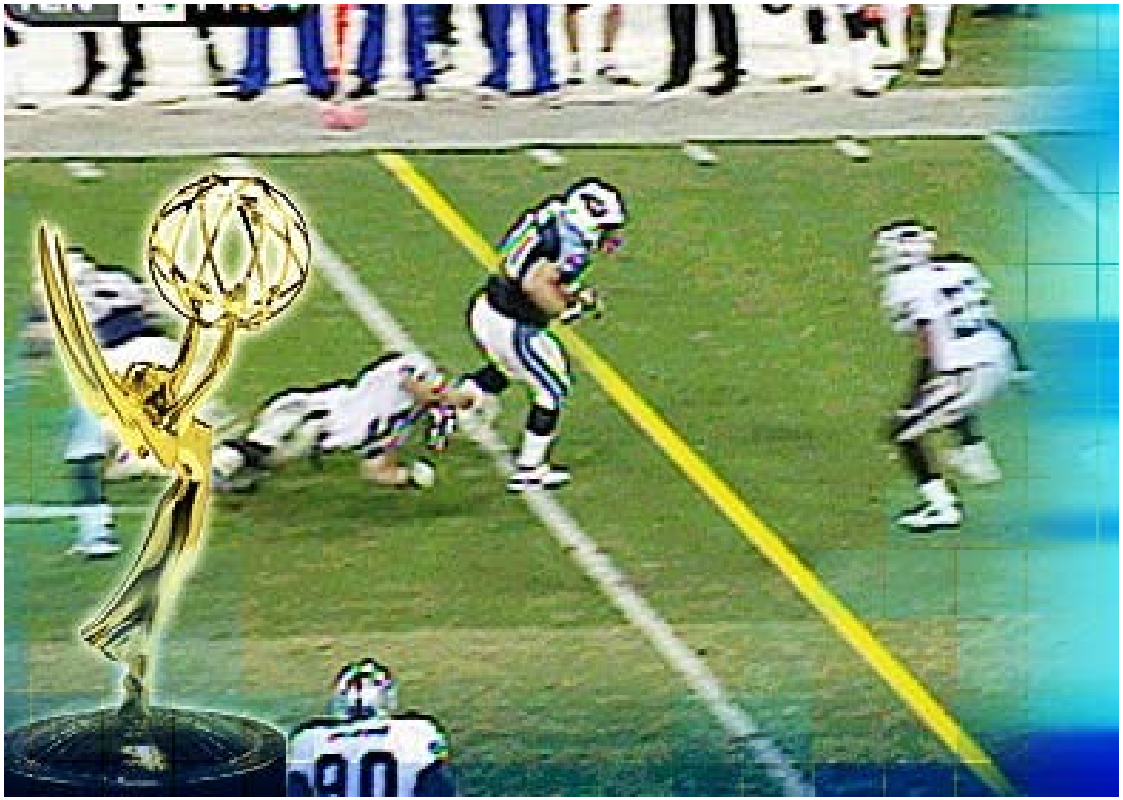


Image Processing

- Processing of images still an 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

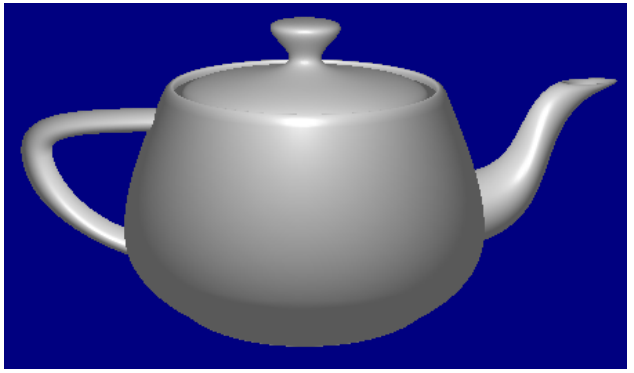
Texture Synthesis

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

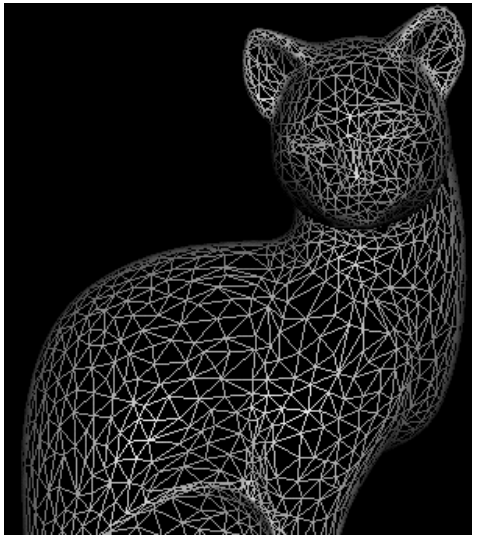
Efros and Leung 99, Efros and Freeman 01. This example from Wikipedia

Geometry

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

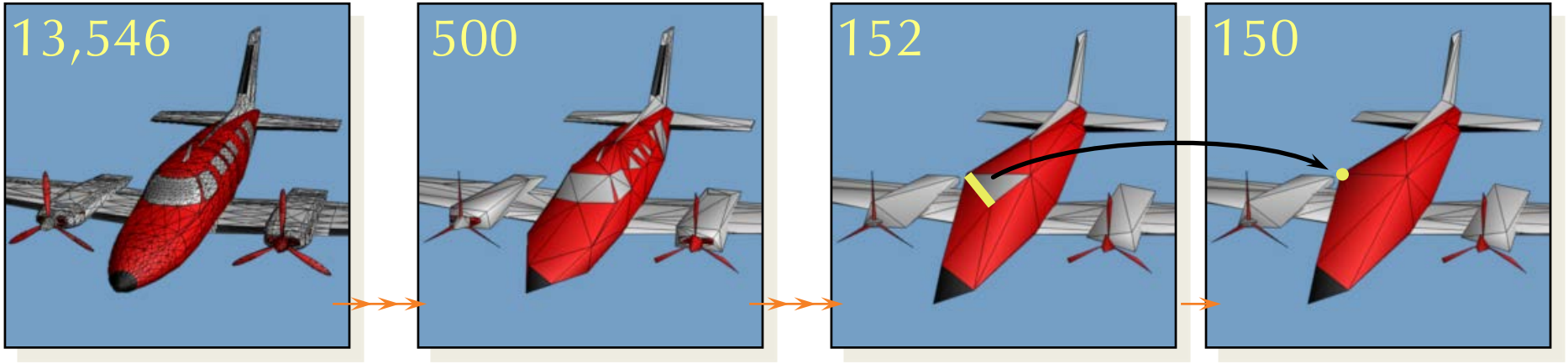


- More recently: Triangle meshes often acquired from real objects



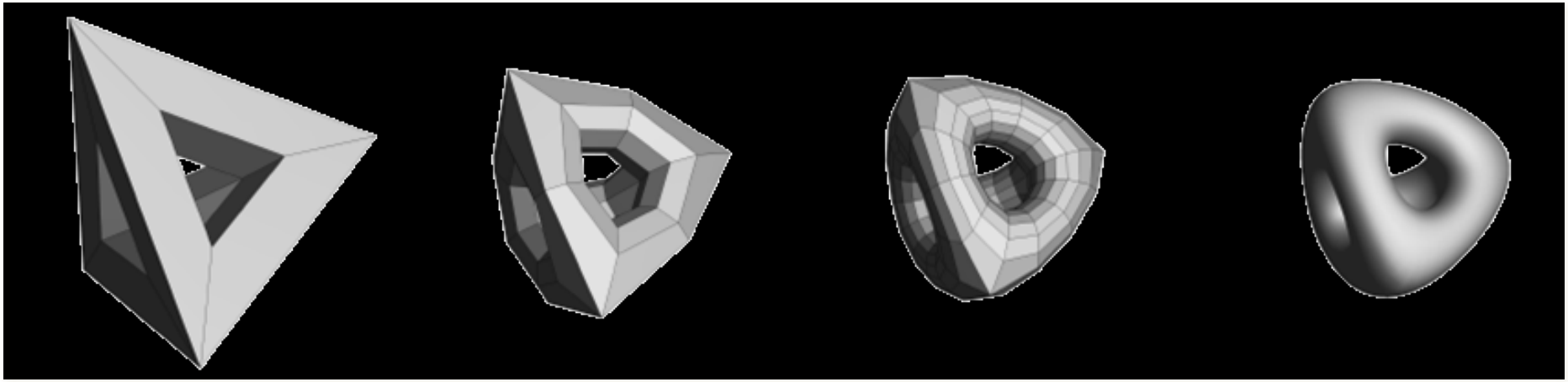
Progressive Meshes

- Start with fine mesh, produce coarser versions



Subdivision Surfaces

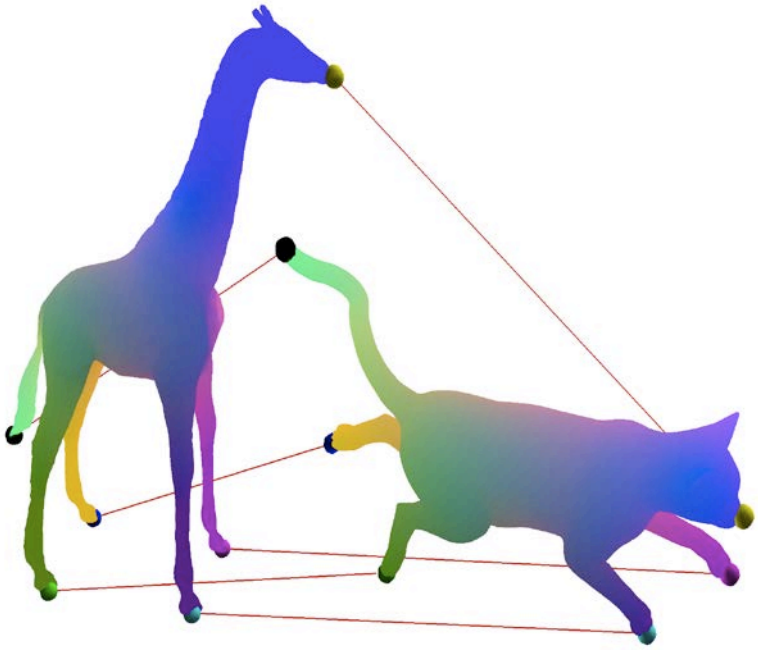
- Coarse mesh + subdivision rule
  - Smooth surface = limit of sequence of refinements

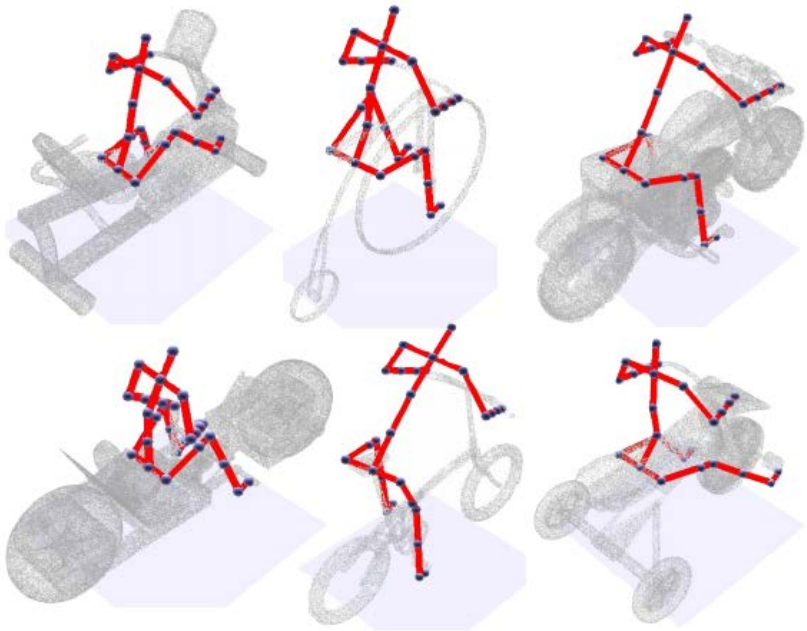


- Video

Modern Geometry Processing

- Spectral analysis, correspondence, functionality





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

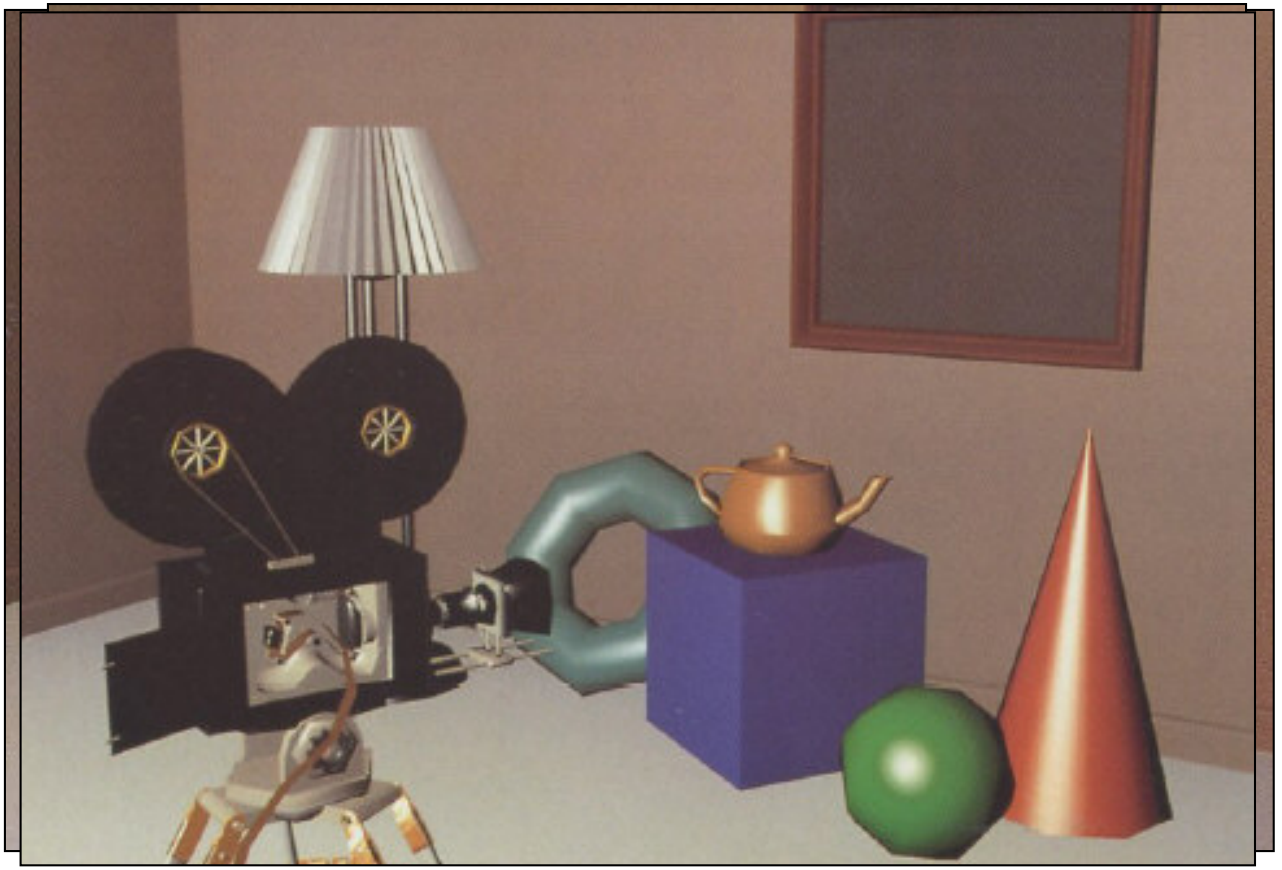
Rendering: 1960s (visibility)

- Roberts (1963), Appel (1967) - hidden-line algorithms
- 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

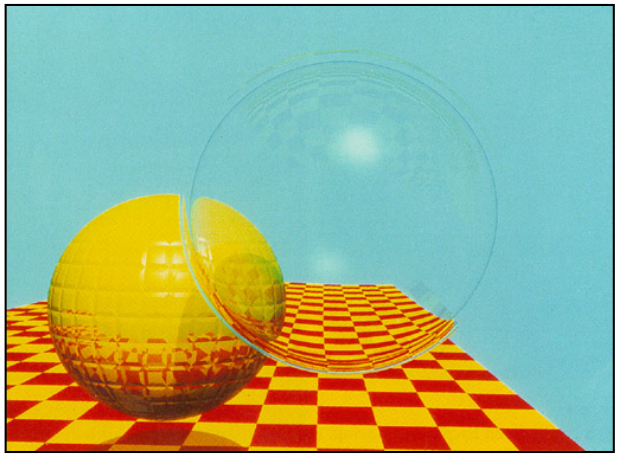
Rendering: 1970s (lighting)

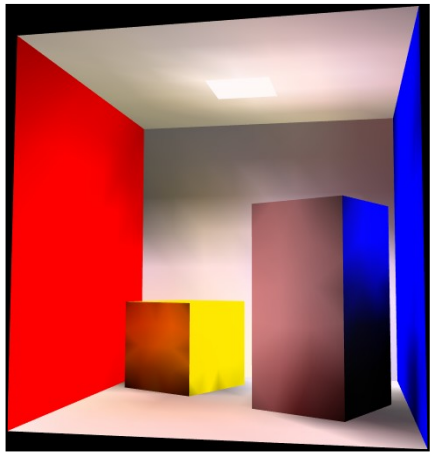
- Gouraud (1971) - diffuse lighting, Phong (1974) - specular lighting
- Blinn (1974) - curved surfaces, texture
- Catmull (1974) - Z-buffer hidden-surface algorithm

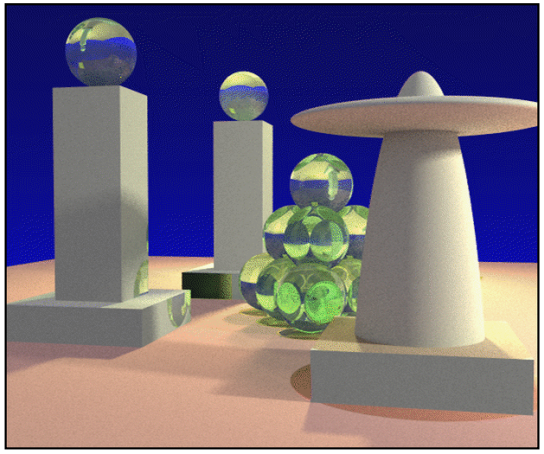


Rendering (1980s – today: Global Illumination)

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

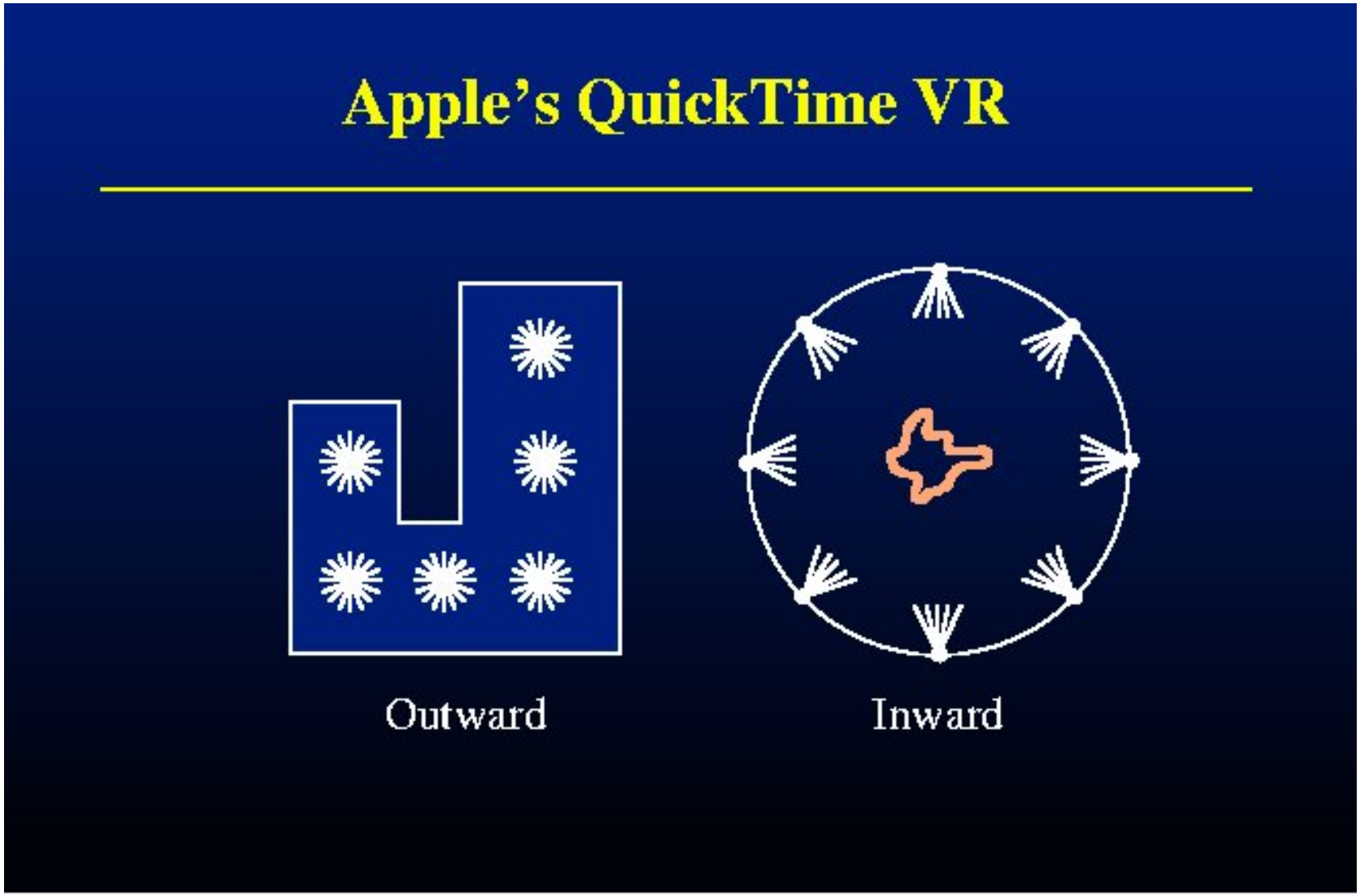






PDF

Image-Based Rendering



Dual Interpretation of Light Field

Plenoptic Light Field
Field radiance

UV Array of ST Images

Surface Light Field
Surface radiance

ST Array of UV Images

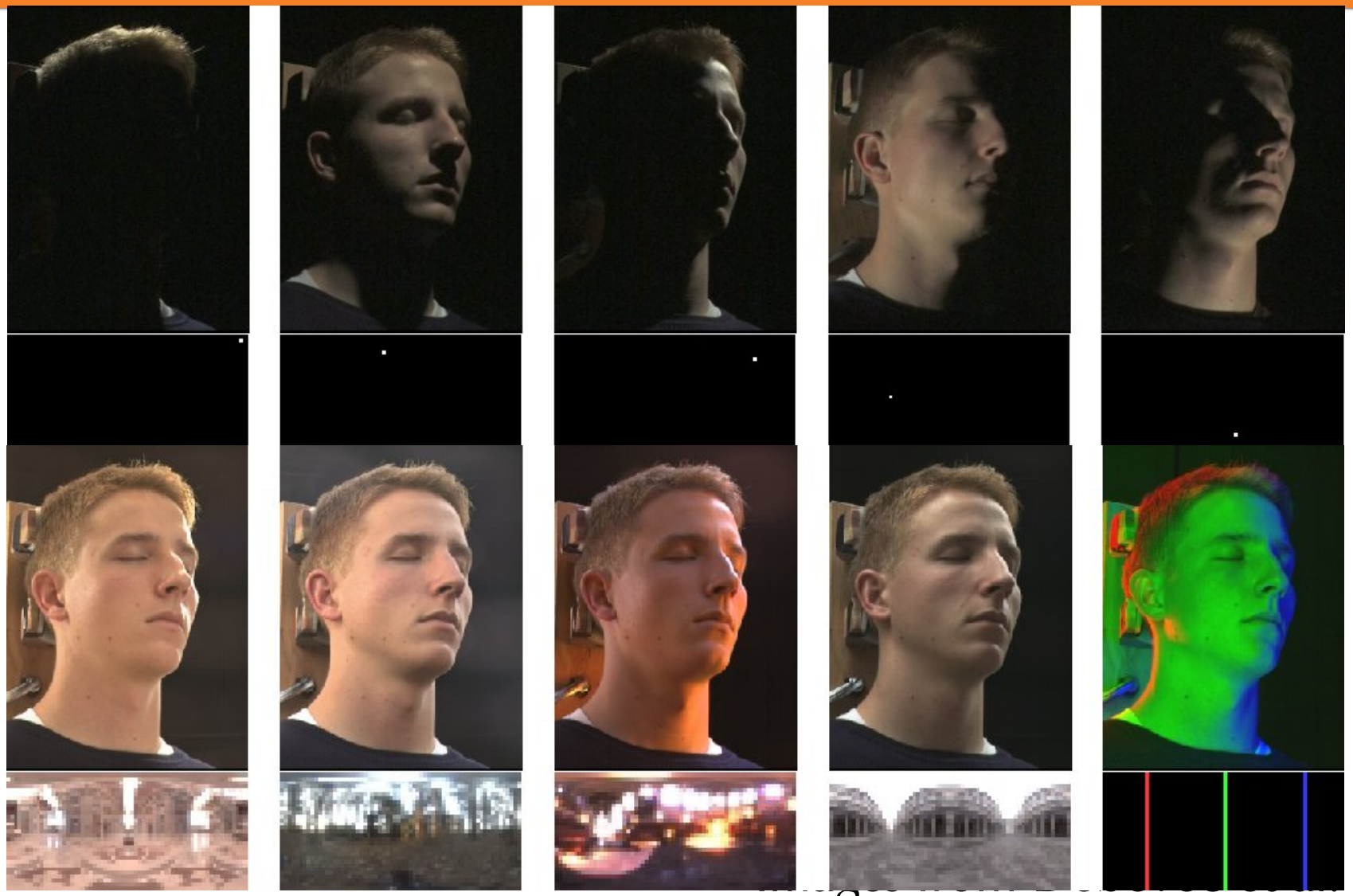
Lytro Light Field Camera

Demo refocus, perspective

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

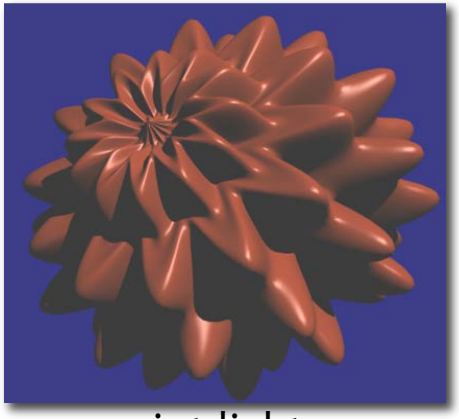
Illuminate subject from many incident directions

Example Images



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



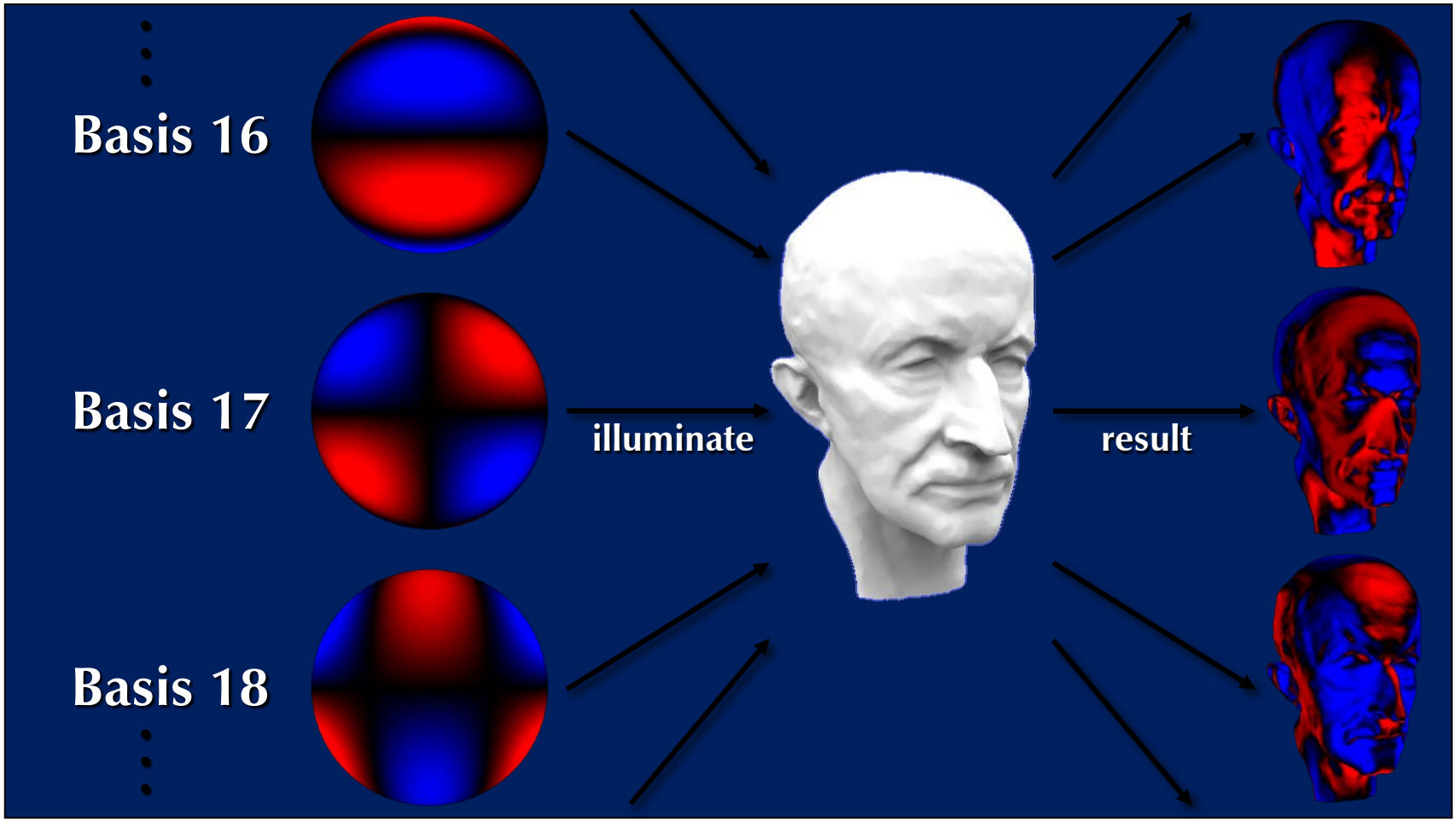
point light

area light

area lighting, no shadows

area lighting, shadows

Precomputation: Spherical Harmonics



Diffuse Transfer Results

No Shadows/Inter

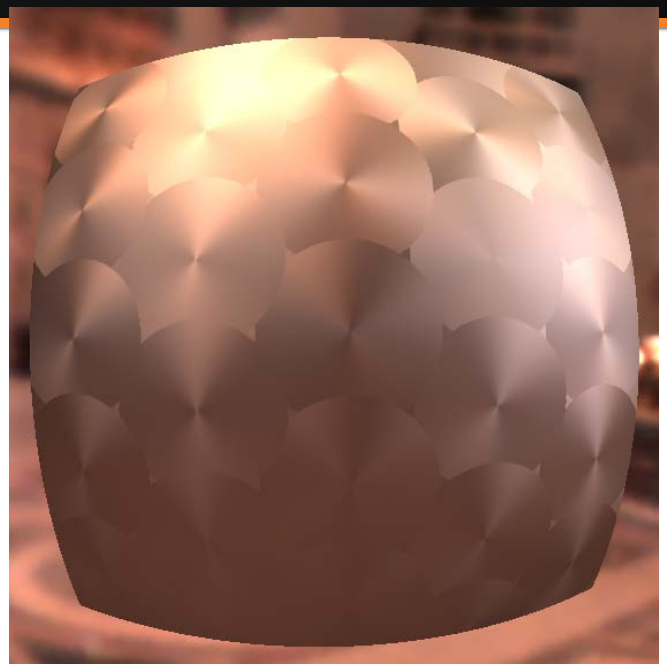
Shadows

Shadows+Inter

Arbitrary BRDF Results

Anisotropic BRDFs

Other BRDFs



Spatially Varying

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)

http://www.cs.princeton.edu/courses/archive/fall18/cos526/