Advanced Computer Graphics (Spring 2013)

CS 283, Lecture 1: Introduction and History

Ravi Ramamoorthi
http://inst.eecs.berkeley.edu/~cs283/sp13

Demo

- Precomputed relighting: Vase
- Interactive Global Illumination Video

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 advanced ugrads and beginning PhD students
- Regular lecture class but less rigid than CS 184
- Encourage you to take other CS 28x, 29x in graphics

Administrivia

- Website http://inst.eecs.berkeley.edu/~cs283/sp13
- Lectures Tu-Th 12:30-2:00pm in Soda 320
- E-mail instructor directly for questions, meetings …
  - ravir@cs.berkeley.edu
  - Generally available after class as well
- Piazza newsgroup
- Grader: Brandon Wang, brandonwang@berkeley.edu
- No books. Lecture slides online, reading as needed
- **TODO: E-mail HW 0 (basic info for roster) by Thu**

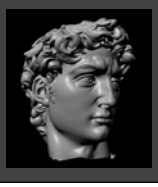
Course Logistics

- Graded on basis of 4 mostly programming homeworks
  - Can be done in groups of two (or individually)
- Turned in by creating website, sending e-mail
  - Do not modify site after deadline
  - May schedule demo sessions
- No late days. We assume you start early, work steady
  - Aimed at mature students, assignments 3-4 week duration
- *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

Geometry

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

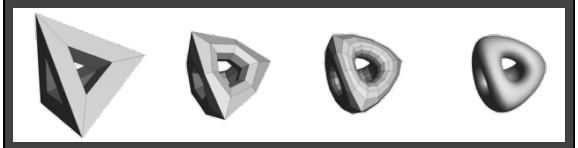
- More recently: Triangle meshes often acquired from real objects



Progressive Mesh Simplification

Subdivision Surfaces

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



- Video

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

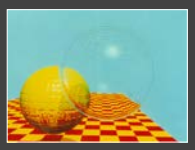
Images from FvDFH, Pixar's Shutterbug
Slide ideas for history of Rendering courtesy Marc Levoy

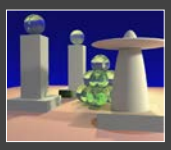
Rendering: 1970s (lighting)

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





Outline

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

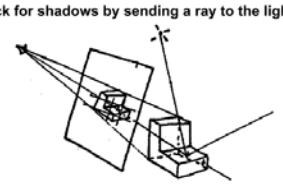
Ray Tracing History

Ray Tracing in Computer Graphics

Appel 1968 - Ray casting

1. Generate an image by sending one ray per pixel

2. Check for shadows by sending a ray to the light



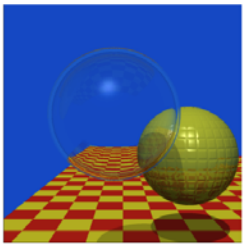
CS348B Lecture 2 Pat Hanrahan, Spring 2009

Ray Tracing History

Ray Tracing in Computer Graphics

"An improved Illumination model for shaded display," T. Whitted, CACM 1980

Resolution:
512 x 512
Time:
VAX 11/780 (1979)
74 min.
PC (2006)
6 sec.



Spheres and Checkerboard, T. Whitted, 1979

CS348B Lecture 2 Pat Hanrahan, Spring 2009

Heckbert's Business Card Ray Tracer

```
typedef struct{double x,y,z}vec;vec U,black,amb=[.02,.02,.02];struct sphere{ vec cen,color;
double rad,kd,ks,kt,kl,ir}*s,*best,sph[]=[0.,6.,.5,1.,1.,1.,.9, .05,.2,.85,0.,1.7,-1.,8.,-.5,1.,.5,.2,1.,
.7,.3,0.,.05,1.2,1.,8.,-.5,.1,.8,.8, 1.,.3,.7,0.,0.,1.2,3.,-6.,15.,1.,.8,1.,7.,0.,0.,0.,.6,1.5,-3.,-3.,12.,
.8,1., 1.,5.,0.,0.,0.,.5,1.5,];yx;double u,b,tmin,sqrt(),tan();double vdot(A,B)vec A ,B;{return A.x
*B.x+A.y*B.y+A.z*B.z;}vec vcomb(a,A,B)double a;vec A,B;{B.x+=a* A.x;B.y+=a*A.y;B.z+=a*A.z;
return B;}vec vunit(A)vec A;{return vcomb(1./sqrt( vdot(A,A)),A,black);}struct sphere*intersect
(P,D)vec P,D;{best=0;tmin=1e30;s= sph+5;while(s--->sph)b=vdot(D,U=vcomb(-1.,P,s->cen)),
u=b*b-vdot(U,U)+s->rad*s ->rad,u=u>0?sqrt(u):1e31,u=b-u>1e-7?b-u:b+u,tmin=u>=1e-7&&
u<tmin?best=s,u: tmin;return best;}vec trace(level,P,D)vec P,D;{double d,eta,e;vec N,color;
struct sphere*s,*l;if(!level--)return black;if(s=intersect(P,D));else return amb;color=amb;eta=
s->ir;d= -vdot(D,N=vunit(vcomb(-1.,P=vcomb(tmin,D,P),s->cen )));if(d<0)N=vcomb(-1.,N,black),
eta=1/eta,d= -d;l=sph+5;while(l-->sph)if((e=l ->kl*vdot(N,U=vunit(vcomb(-1.,P,l->cen))))>0&&
intersect(P,U)==l)color=vcomb(e ,l->color,color);U=s->color;color.x*=U.x;color.y*=U.y;color.z
*=U.z;e=1-eta* eta*(1-d*d);return vcomb(s->kt,e>0?trace(level,P,vcomb(eta,D,vcomb(eta*d-
sqrt (e),N,black))):black,vcomb(s->ks,trace(level,P,vcomb(2*d,N,D)),vcomb(s->kd, color,vcomb
(s->kl,U,black))));}main(){printf("%d %d\n",32,32);while(yx<32*32) U.x=yx%32-32/2,U.z=32/2-
yx++/32,U.y=32/2/tan(25/114.5915590261),U=vcomb(255., trace(3,black,vunit(U)),black),printf
("%.0f %.0f %.0f\n",U);}/*minray!*/
```

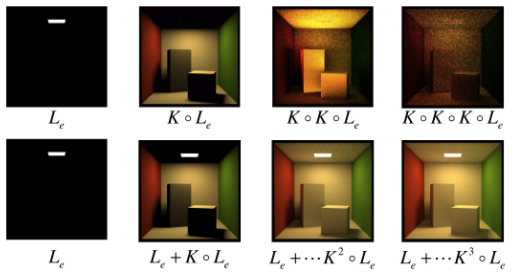
Outline

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

Global Illumination

Radiosity

Successive Approximation



Rendering Equation (Kajiya 86)

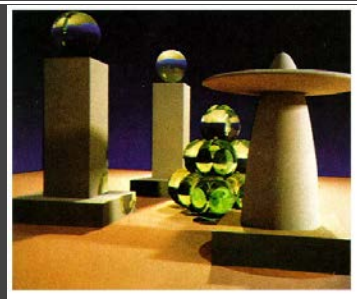
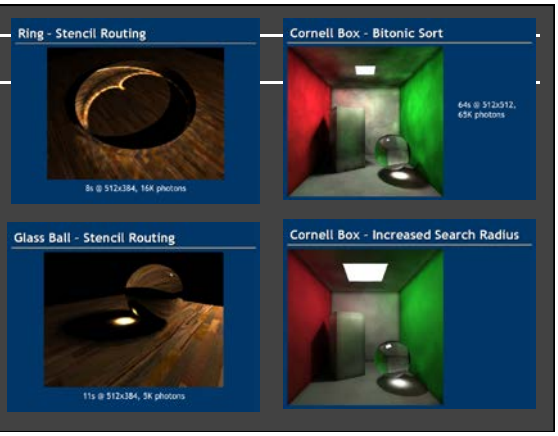


Figure 6. A sample image. All objects are neutral grey. Color on the objects is due to caustics from the green glass balls and color bleeding from the base polygon.

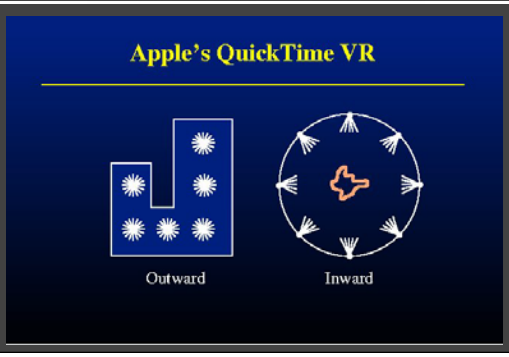
Caustics



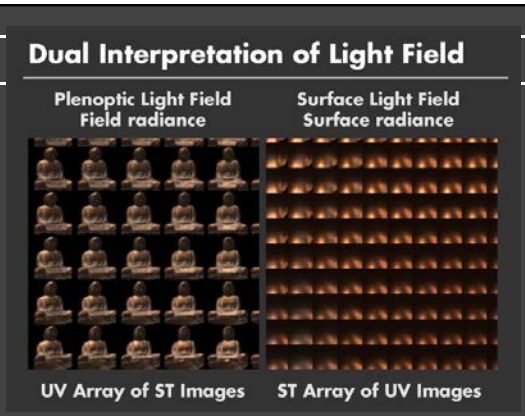
Outline

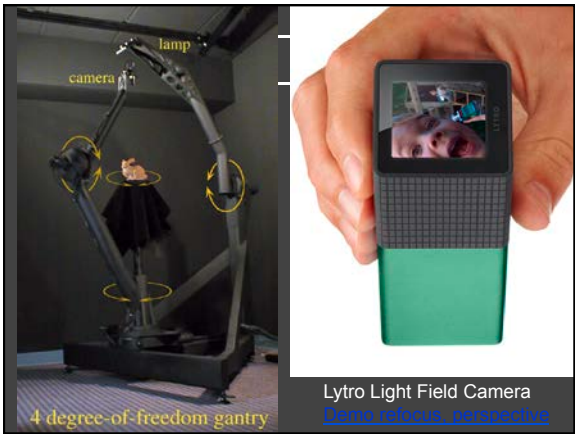
- Basic Ray Tracing
- Global Illumination
- *Image-Based Rendering*
- Real-Time Rendering

Image-Based Rendering



Dual Interpretation of Light Field



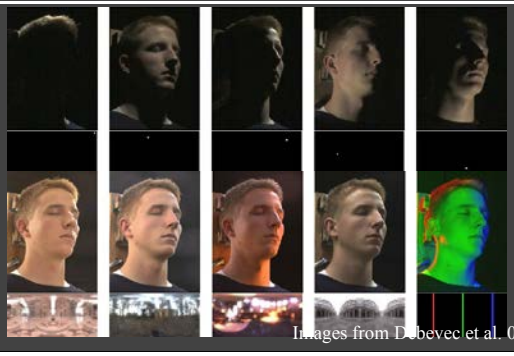


Lytro Light Field Camera
Demo: refocus, perspective

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

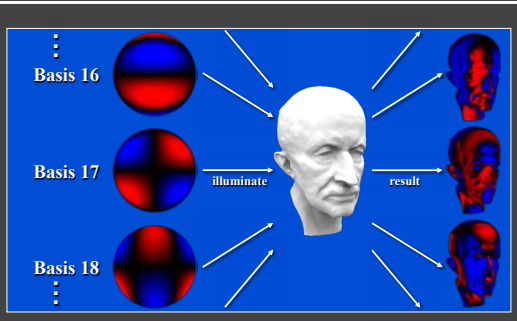
Outline

- 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

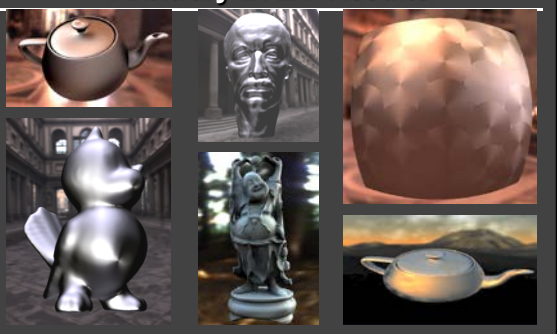
Precomputation: Spherical Harmonics



Diffuse Transfer Results

No Shadows/Inter | Shadows | Shadows+Inter

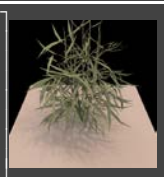
Arbitrary BRDF Results



Anisotropic BRDFs | Other BRDFs | Spatially Varying

Relighting as a Matrix-Vector Multiply

$$\begin{bmatrix} P_1 \\ P_2 \\ P_3 \\ \vdots \\ P_N \end{bmatrix} = \begin{bmatrix} T_{11} & T_{12} & \cdots & T_{1M} \\ T_{21} & T_{22} & \cdots & T_{2M} \\ T_{31} & T_{32} & \cdots & T_{3M} \\ \vdots & \vdots & \ddots & \vdots \\ T_{N1} & T_{N2} & \cdots & T_{NM} \end{bmatrix} \begin{bmatrix} L_1 \\ L_2 \\ \vdots \\ L_M \end{bmatrix}$$



Physical Simulation and Animation

- Recent clothing animation video

Game footage recorded from Xbox 360 version of

Star Wars: The Force Unleashed

Imaging

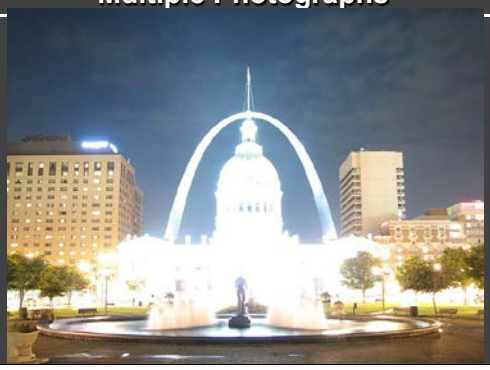
- Processing of images important part of graphics
- Especially in context of photography: Combine photos, manipulate images
  - Recent video on automatic cinemagraph portraits
- Computational photography. Examples flash/no-flash, fluttered shutter, new light field cameras
- Community and Internet photo 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!