Ray Tracing (Part 2)

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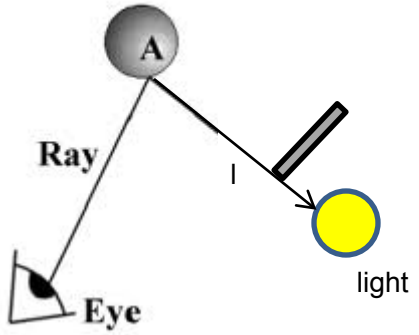
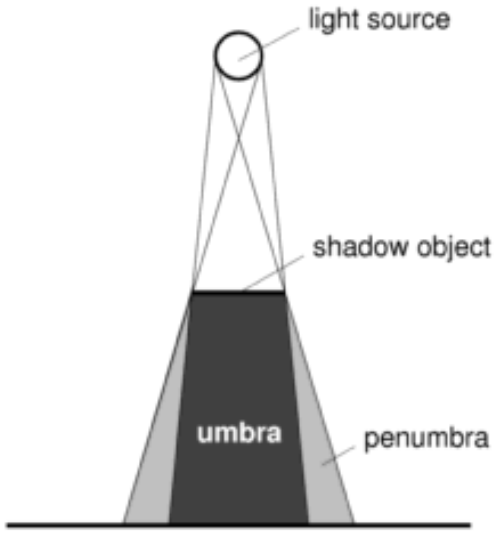
(Hard) Shadows

- If ray l is unoccluded from surface point to light source, then surface point is illuminated (i.e., not in shadow)
- Use same recursive rayTrace function but cast ray from surface point to light



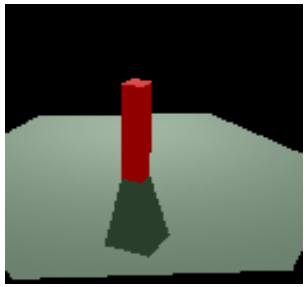
Soft Shadows

- Lights are actually areas, so use area light sources
- Using areas enables both umbra and penumbra to appear

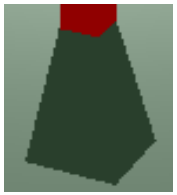


Soft Shadows

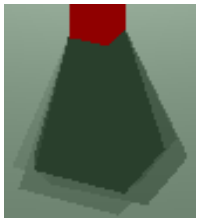
- Lights are actually areas, so use use area light sources
- *Distributed Ray Tracing*
  - Replace light with a collection of point light sources (e.g., up to 50 rays jittered samples)



Example Scene



1 light ray



Uniformly sampled light rays

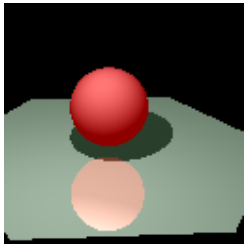
10 light rays

20 light rays

50 light rays

Distributed Ray Tracing

- Soft shadows (previous slide)
- Glossy Reflections



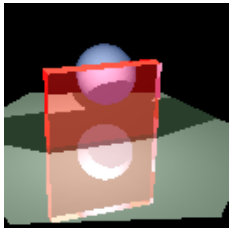
1 ray

10 rays

20 rays

50 rays

- Fuzzy Transluceny

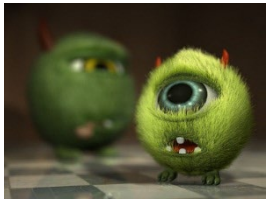


1 ray

10 rays

20 rays

- Defocus

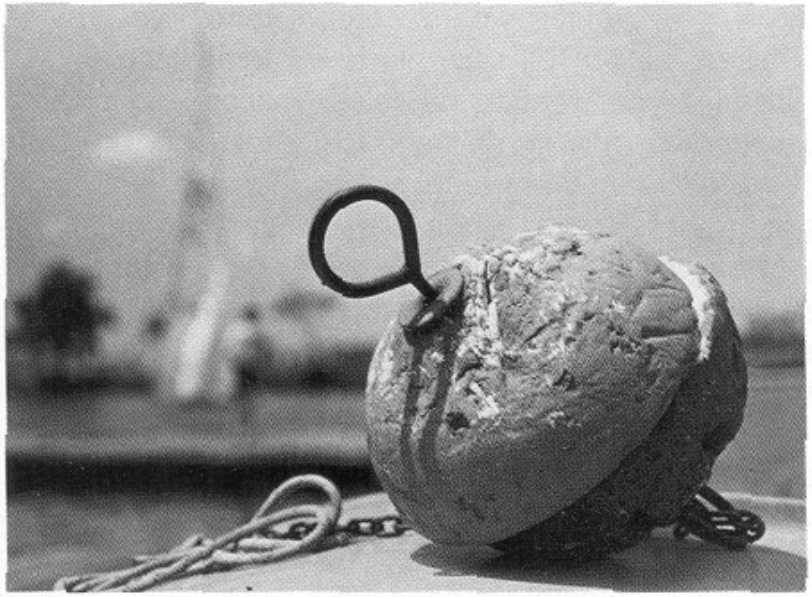



(examples using per-pixel and ray tracing logic)

Depth of Field

- The area in front of your camera where everything looks sharp and in focus.
  - objects falling within that area will be acceptably-sharp and in focus;
  - objects falling outside the area will be soft and out of focus.

less depth of field

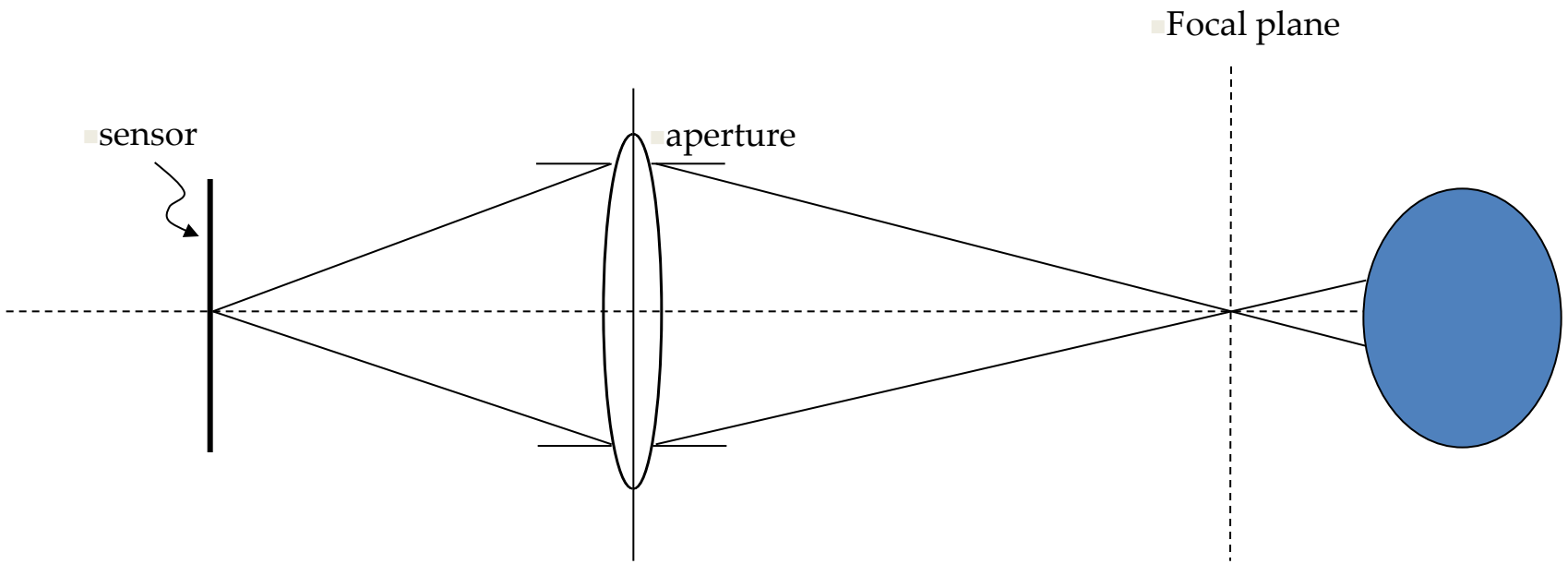


wider aperture

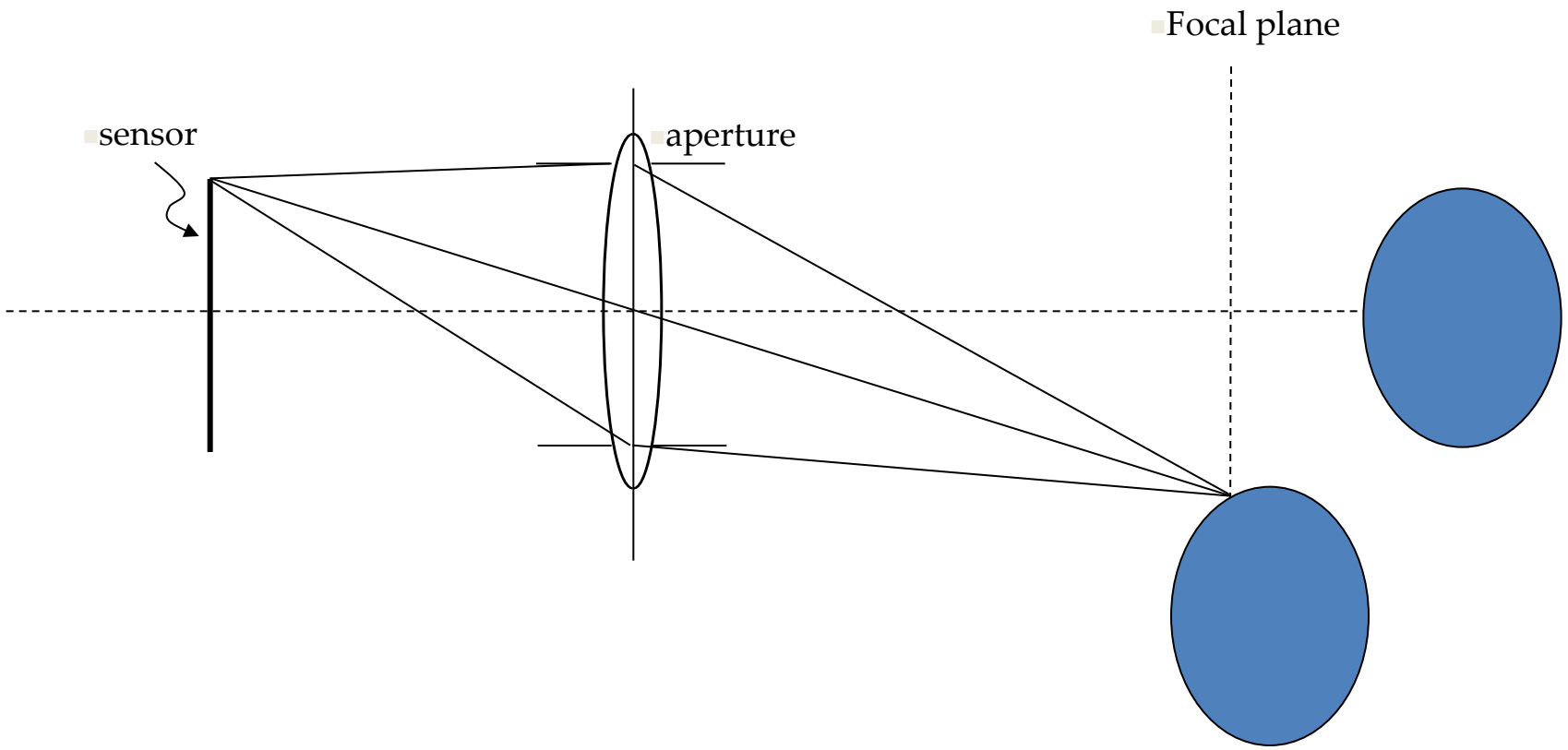
more depth of field

smaller aperture

Depth of Field

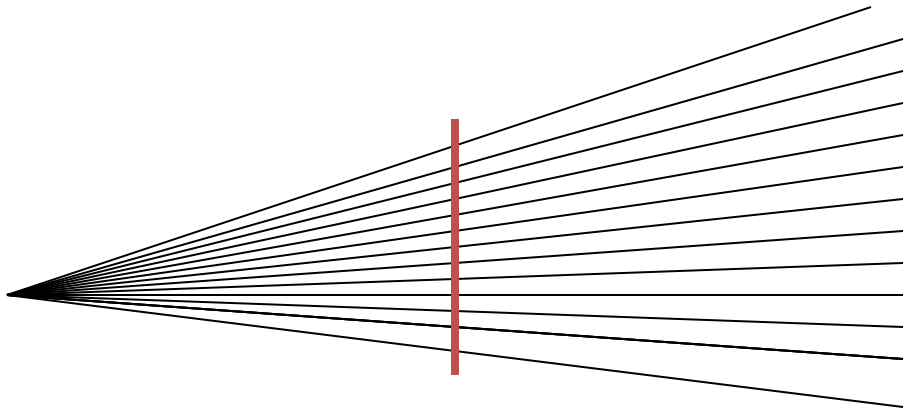


Depth of Field



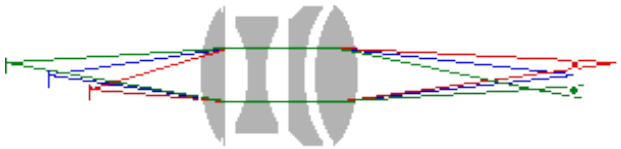
Computer Graphics
Camera Models

- Pinhole – ideal camera
- All rays go through single point
- Everything in focus -- unrealistic

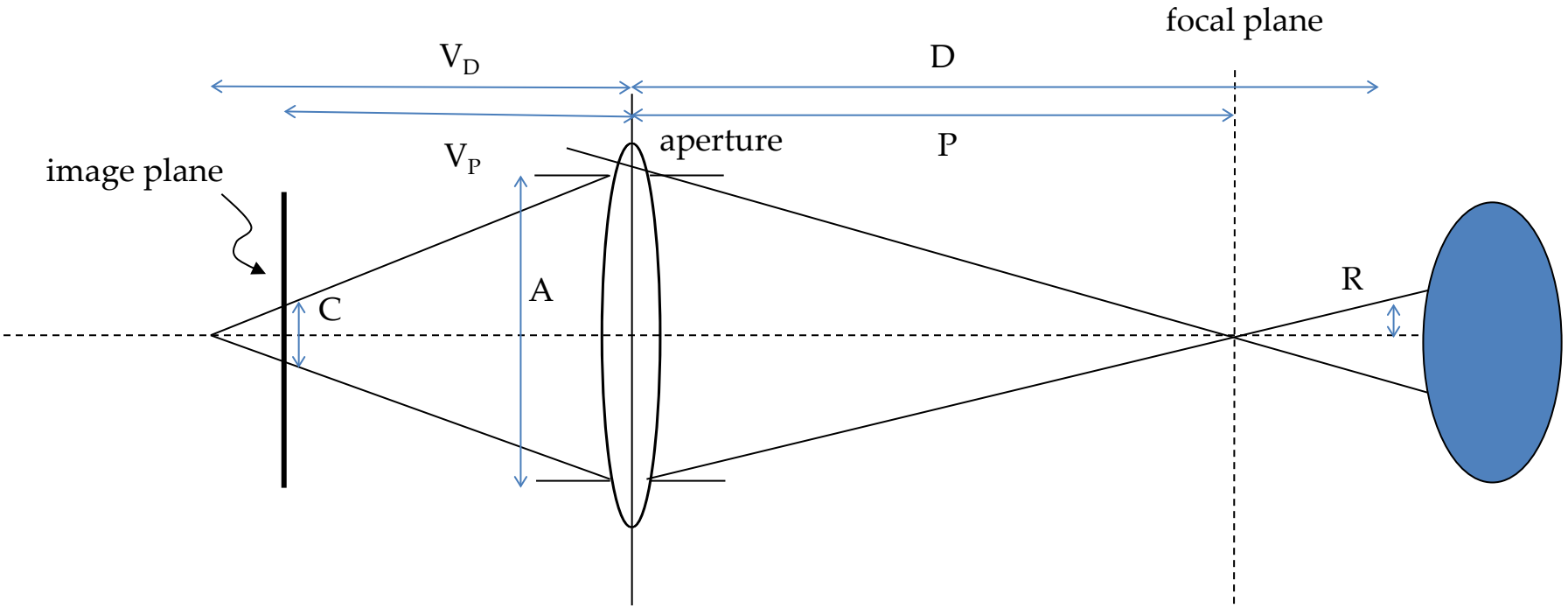


More Realistic Model

- Lenses with spherical surfaces
- Depth of field control



Depth of Field

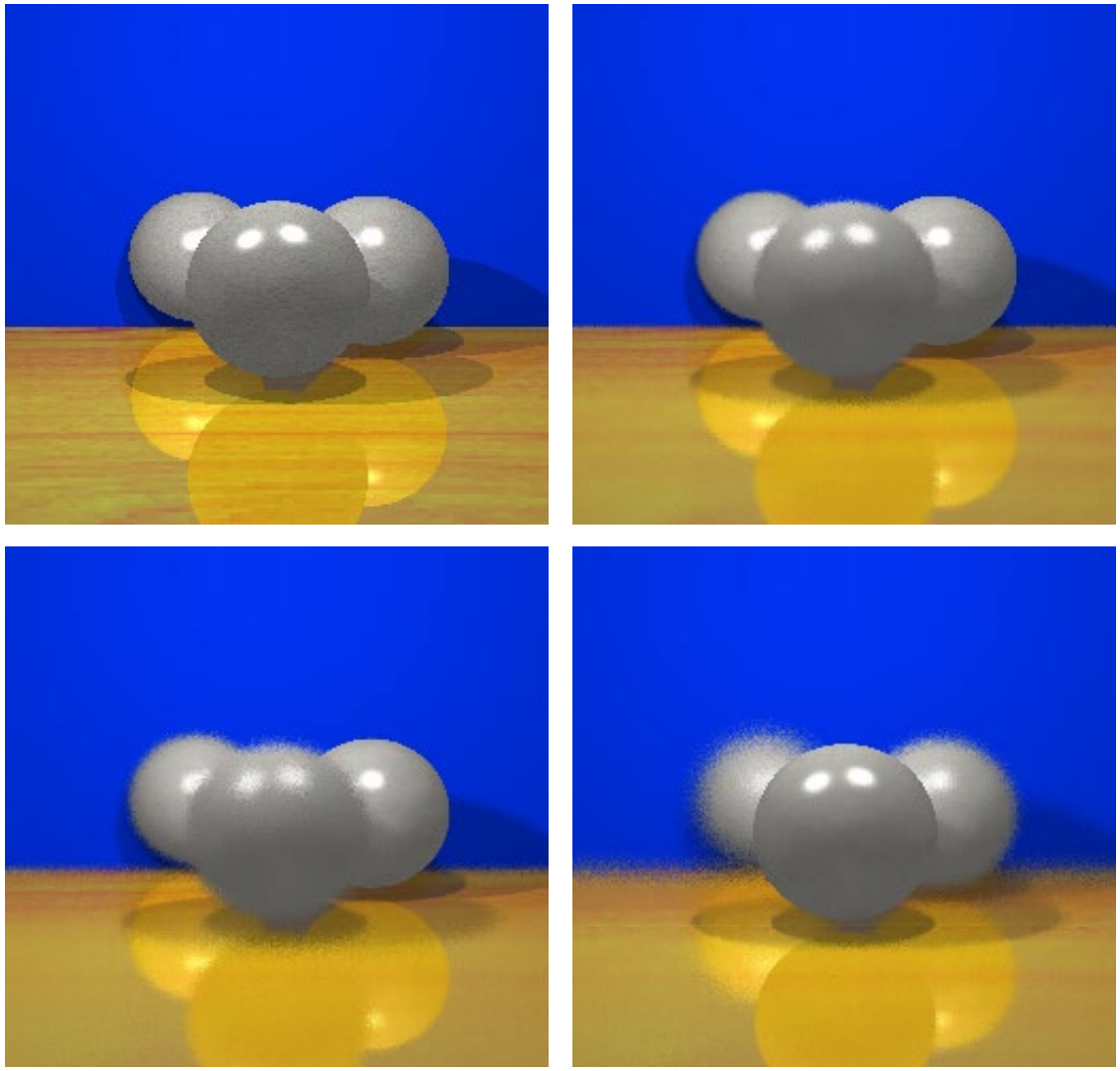


$V_P = AP/(P-A)$ for $P>A$ $\quad C = |V_D - V_P| \, (A/V_P)$ "=circle of confusion"

$V_D = AD/(D-A)$ for $D>A$ $\quad R = 0.5\, A\, (\, |D-P| \,/\, P\,)$

Depth of Field

Example Results



Depth of Field: Out of Focus Blur

- How to approximate without actually creating an entire physically based rendering system?
- Basic idea:
  - You want something at distance “P” to be have its rays converge
  - So think backwards: how can you distort multiple rays per pixel so that they converge at distance P but not otherwise?

Example Real-Time Ray Tracer

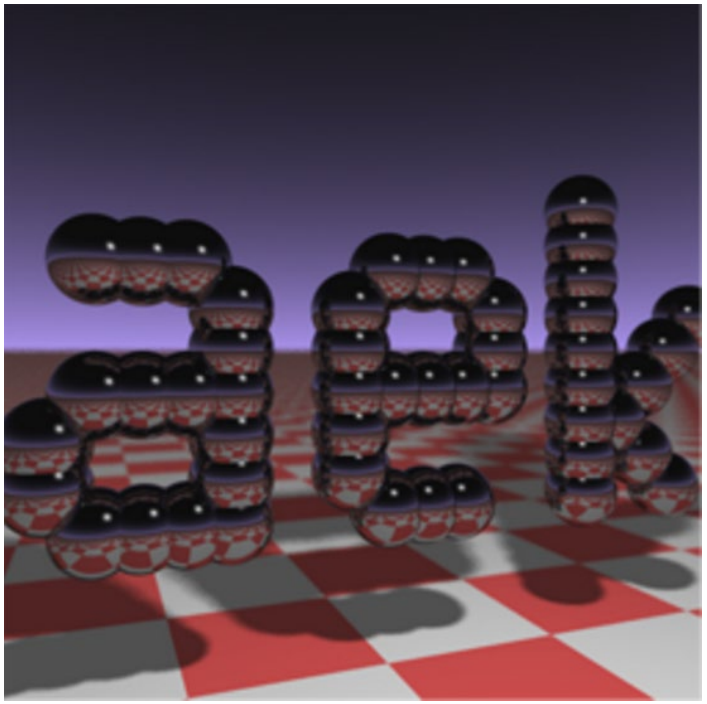
- Large Scale Voxel Renderer using Ray Tracing

  "Efficient Sparse Voxel Octrees", Samuli and Karras, ACM I3D, 2010

  Paper = http://www.tml.tkk.fi/~samuli/publications/laine2010i3d_paper.pdf

  Video = http://www.tml.tkk.fi/~samuli/publications/laine2010i3d_video.avi

Minimalistic Ray Tracer



```
#include <stdlib.h> // card > aek.ppm #include <stdio.h>
#include <math.h> typedef int i;typedef float f;struct v{f x,y,z;v
operator+(v r){return v(x+r.x,y+r.y,z+r.z);}v operator*(f r){return
v(x*r,y*r,z*r);}f operator%(v r){return x*r.x+y*r.y+z*r.z;}v(){}v
operator^(v r){return v(y*r.z-z*r.y,z*r.x-x*r.z,x*r.y-y*r.x);}v(f a,f
b,f c){x=a;y=b;z=c;}v
operator!(){return*this*(1/sqrt(*this%*this));}};i
G[]={247570,280596,280600,249748,18578,18577,231184,16,1
6};f R(){return(f)rand()/RAND_MAX;}i T(v o,v d,f&t,v&n){t=1e9;i
m=0;f p=-o.z/d.z;if(.01<p)t=p,n=v(0,0,1),m=1;for(i k=19;k--;)for(i
j=9;j--;)if(G[j]&1<<k){v p=o+v(-k,0,-j-4);f b=p%d,c=p%p-1,q=b*b-
c;if(q>0){f s=-b-
sqrt(q);if(s<t&&s>.01)t=s,n=!(p+d*t),m=2;}}return m;}v S(v o,v
d){f t;v n;i m=T(o,d,t,n);if(!m)return v(.7,.6,1)*pow(1-d.z,4);v
h=o+d*t,l=!(v(9+R(),9+R(),16)+h*-1),r=d+n*(n%d*-2);f
b=l%n;if(b<0||T(h,l,t,n))b=0;f
p=pow(l%r*(b>0),99);if(m&1){h=h*.2;return((i)(ceil(h.x)+ceil(h.
y))&1?v(3,1,1):v(3,3,3))*(b*.2+.1);}return v(p,p,p)+S(h,r)*.5;}i
main(){printf("P6 512 512 255 ");v g=!v(-6,-
16,0),a=!(v(0,0,1)^g)*.002,b=!(g^a)*.002,c=(a+b)*-256+g;for(i
y=512;y--;)for(i x=512;x--;){v p(13,13,13);for(i r=64;r--;){v
t=a*(R()-.5)*99+b*(R()-.5)*99;p=S(v(17,16,8)+t,!(t*-
1+(a*(R()+x)+b*(y+R())+c)*16))*3.5+p;}printf("%c%c%c",(i)p.x,(i
)p.y,(i)p.z);}}
```

Evan's Demos

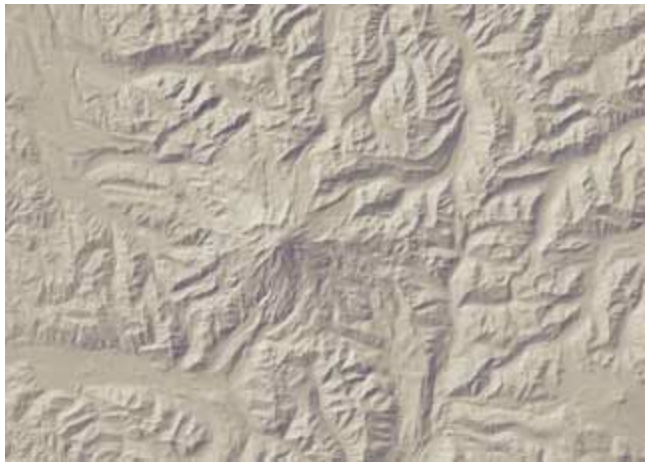
- PathTracer (not quite a ray tracer but almost, and its pretty cool):
  - http://madebyevan.com/webgl-path-tracing/
- Water (pretty cool preview of what next):
  - http://madebyevan.com/webgl-water/

Ray Tracing Explained

- https://www.youtube.com/watch?v=gBPNO6ruevk

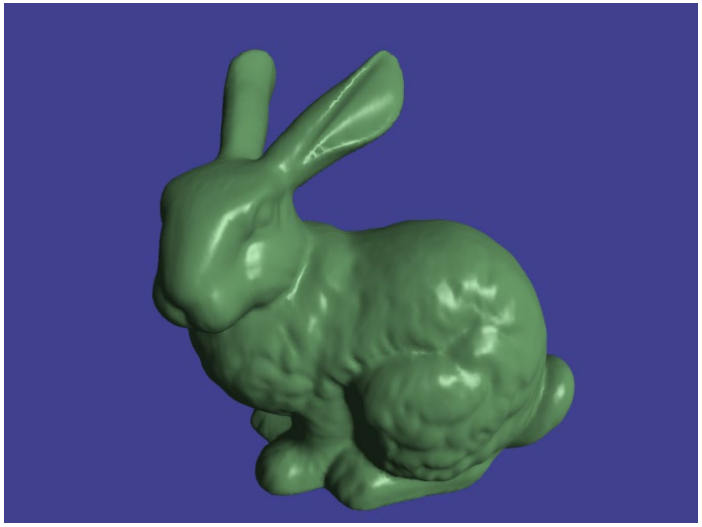
- By Eric Haines, author of “Real-time Rendering” and current NVIDIA researcher
- (9 minutes)

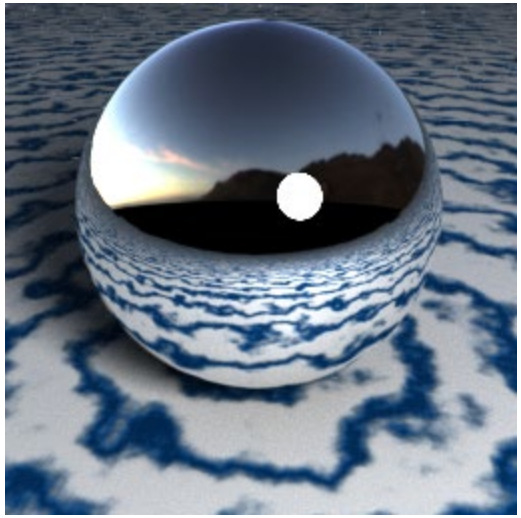
Diffuse



(mostly)

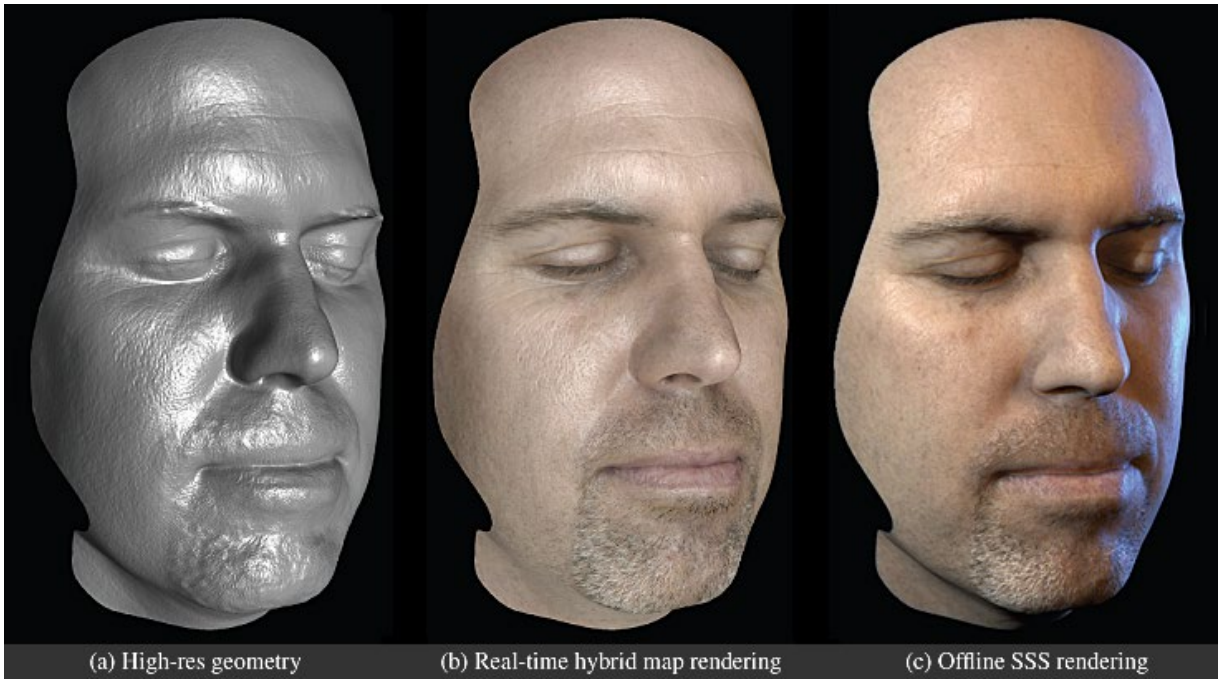
Specular++





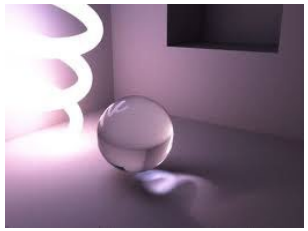
Environment Mapping

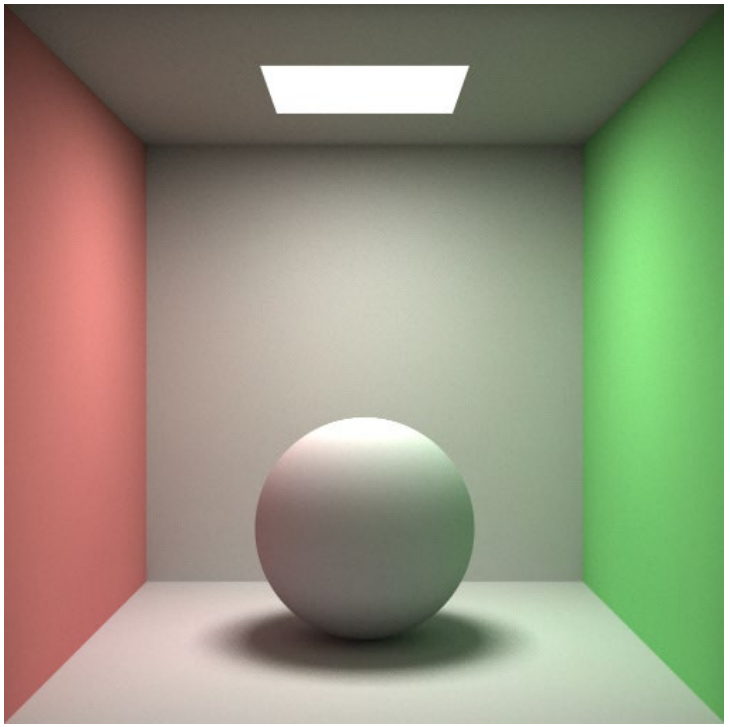
Subsurface Scatterring



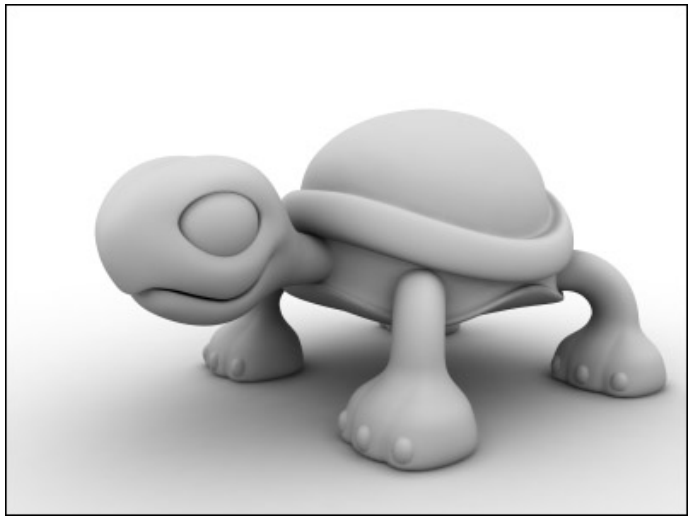
Others

Transparency



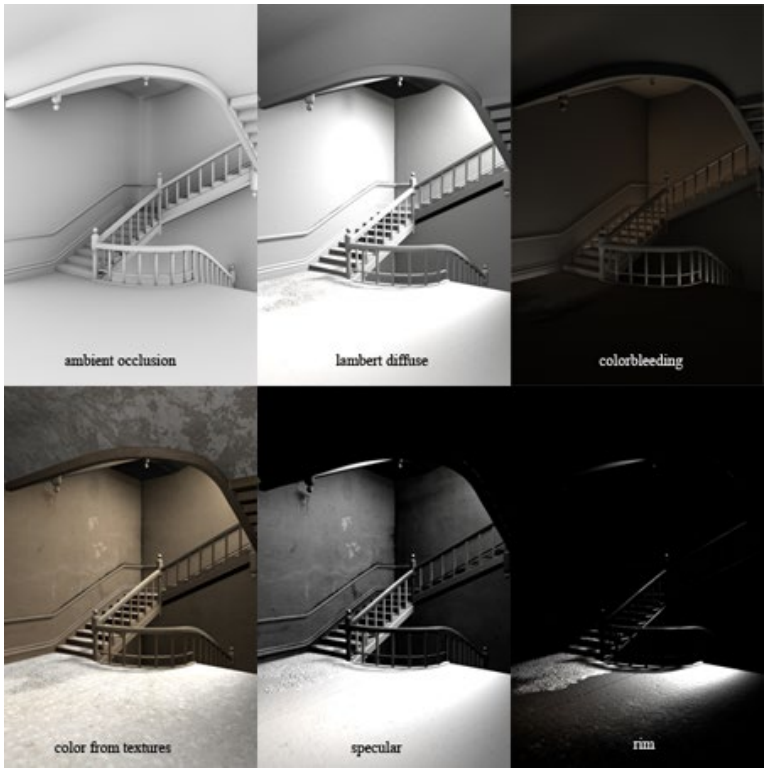


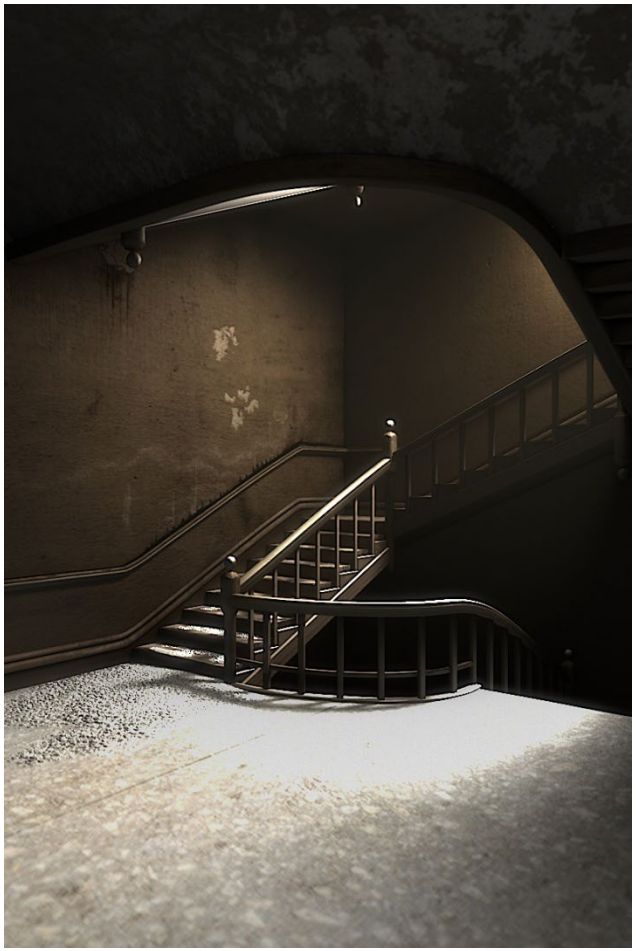
Radiosity



Ambient occlusion

Others


ambient occlusion
lambert diffuse
colorbleeding
color from textures
specular
rim



Lighting and Shading

- Light sources
  - Point light
    - Models an omnidirectional light source (e.g., a bulb)
  - Directional light
    - Models an omnidirectional light source at infinity
  - Spot light
    - Models a point light with direction
- Light model
  - Ambient light
  - Diffuse reflection
  - Specular reflection

Lighting and Shading

- Diffuse reflection
  - Lambertian model

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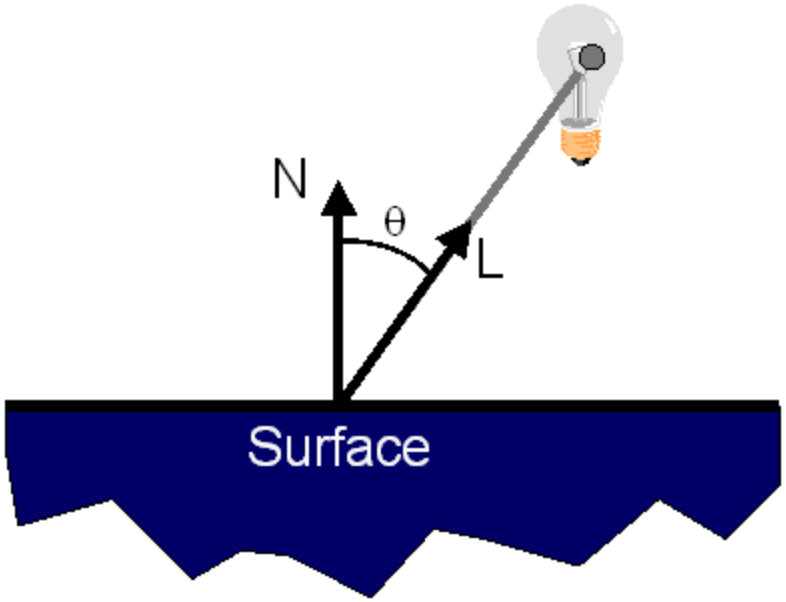

Lighting and Shading

- Diffuse reflection
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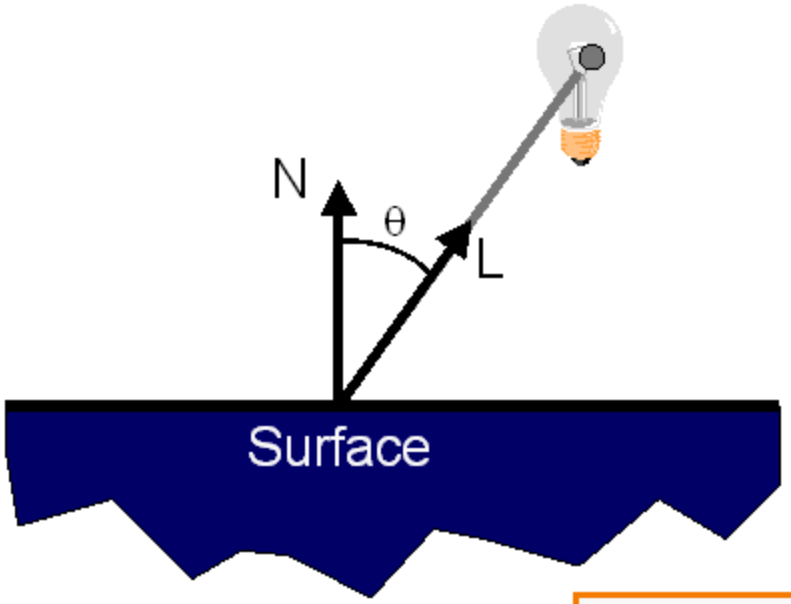


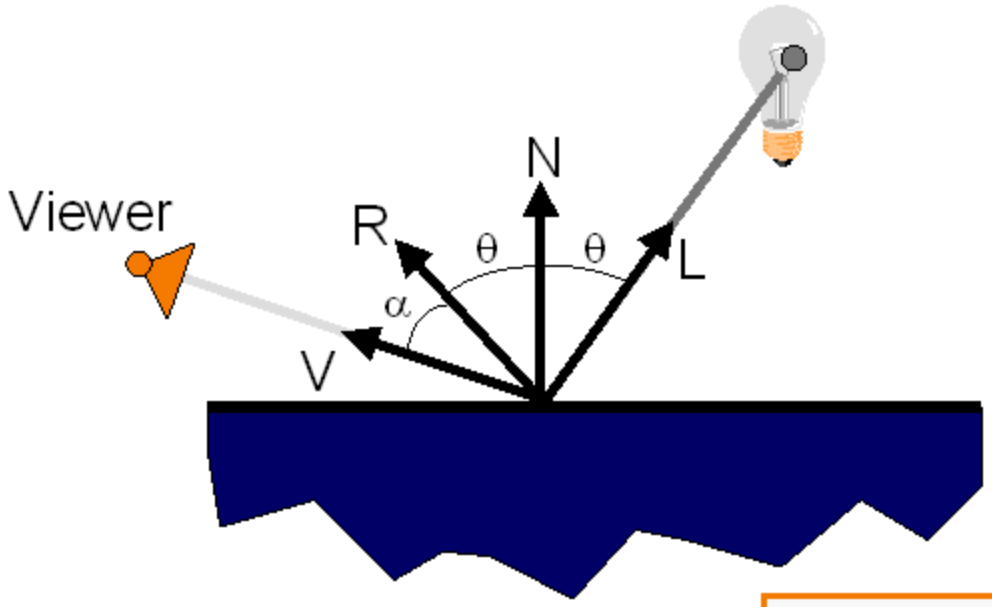
$$I_D = K_D(N \bullet L)I_L$$

Lighting and Shading

- Specular reflection
  - Phong model

Lighting and Shading

- Specular reflection
  - Phong model



$$I_S = K_S (V \bullet R)^n I_L$$

Lighting and Shading

- Specular reflection
  - Phong model