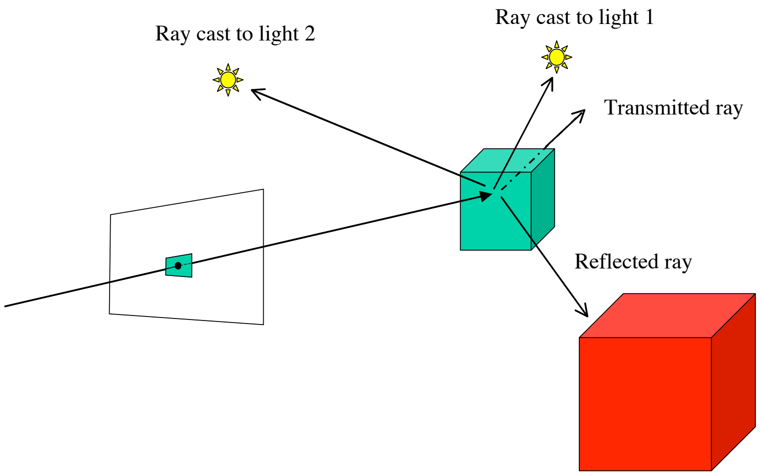
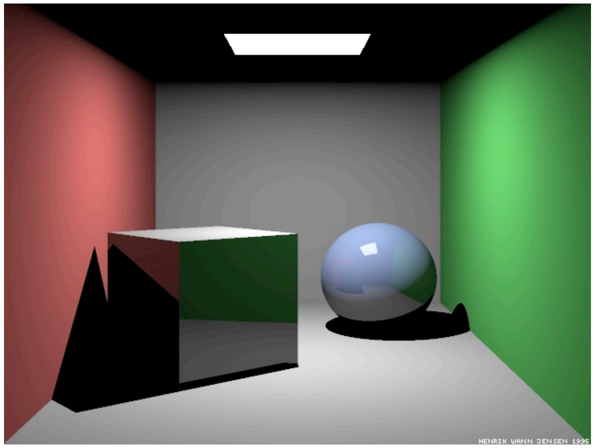
Recursive ray tracing

H&B, page 597





Ray-traced Cornell box, due to Henrik Jensen,
http://www.gk.dtu.dk/~hwj

PCKTWTCH by Kevin Odhner, POVRay

6Z4.JPG - A Philco 6Z4 vacuum tube by Steve Anger

Issues

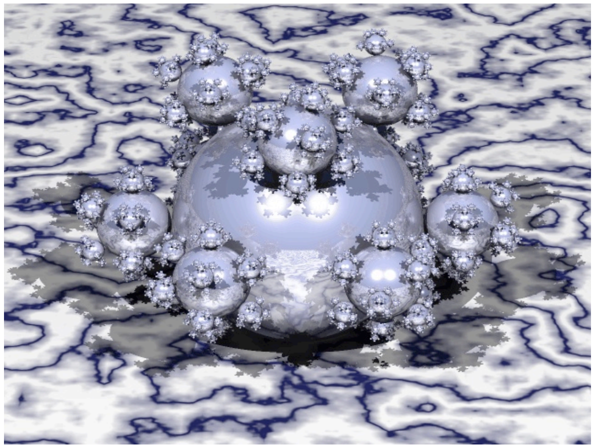
- Sampling (aliasing)
- Very large numbers of objects
  - Need making intersections efficient, exclude as much as possible using clever data structures
- Surface detail
  - bumps, texture, etc.
- Illumination effects
  - Caustics, specular to diffuse transfer
- Camera models

Sampling

- Simplest ray-tracer is one ray per pixel
  - This gives aliasing problems
- Solutions
  - Cast multiple rays per pixel, and use a weighted average
  - Rays can be on a uniform grid
  - It turns out to be better if they are “quite random” in position
    - “hard-core” Poisson model appears to be very good
    - different patterns of rays at each pixel

Efficiency - large numbers of objects

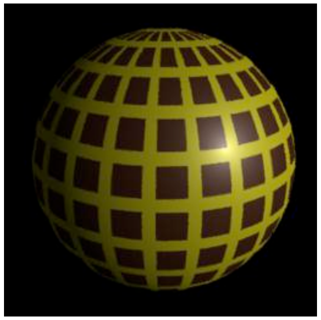
- Construct a space subdivision hierarchy of some form to make it easier to tell which objects a ray might intersect
- Uniform grid
  - easy, but many cells
- Bounding Spheres
  - easy intersections first
- Octtree
  - rather like a grid, but hierarchical
- BSP tree



500,000 spheres, Henrik Jensen, http://www.gk.dtu.dk/~hwj

Surface detail

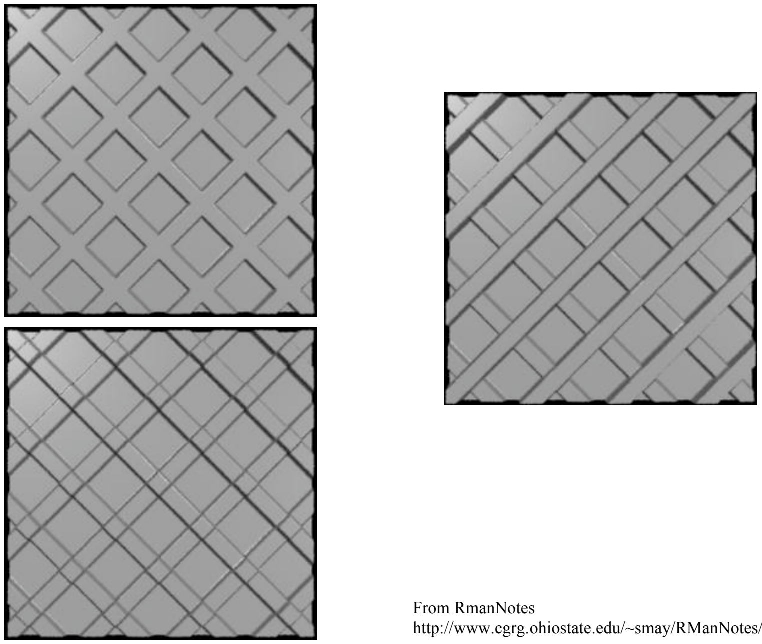
- Knowing the intersection point gives us a position in intrinsic coordinates on the surface
  - e.g. for a triangle, distance from two of three bounding planes
- This is powerful - we could attach some effect at that point
- Texture maps:
  - Make albedo (or color) a function of position in these coordinates
  - Rendering: when intersection is found, compute coordinates and get albedo from a map
  - This is not specific to ray-tracing



From RmanNotes: http://www.cgrg.ohio-state.edu/~smay/RManNotes/index.html

Surface detail, II

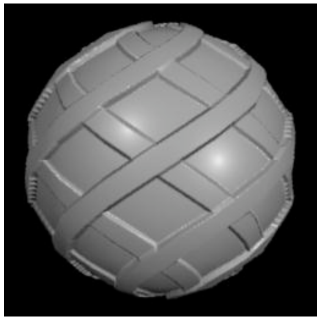
- Bumps
  - we assume that the surface has a set of bumps on it
    - e.g. the pores on an orange
  - these bumps are at a fine scale, so don’t really affect the point of intersection, but do affect the normal
  - strategy:
    - obtain normal from “bump function”
    - shade using this modified normal
    - notice that some points on the surface may be entirely dark
    - bump maps might come from pictures (like texture maps)



From RmanNotes
http://www.cgrg.ohiostate.edu/~smay/RManNotes/index.html

Surface detail, III

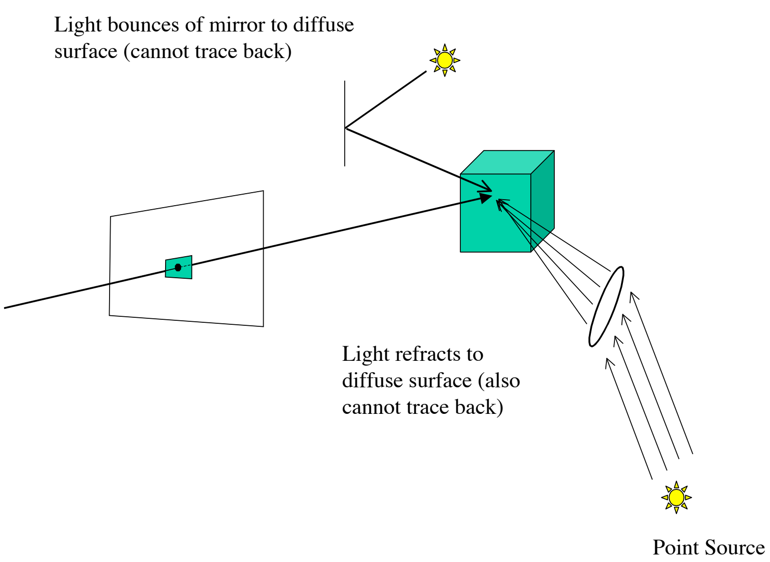
- A more expensive trick is to have a map which includes **displacements** as well
- Must be done **before** visibility



From RmanNotes: http://www.cgrg.ohio-state.edu/~smay/RManNotes/index.html

Illumination effects

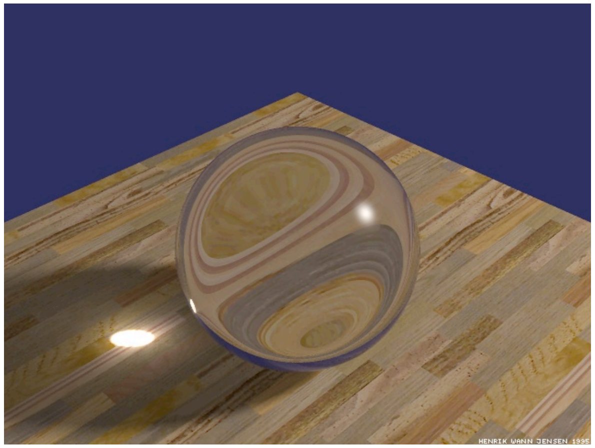
- Caustics:
  – refraction or reflection causes light to be “collected” in some regions.
- Specular-> diffuse transfer
  – source reflected in a mirror
- Can’t render this by tracing rays from the eye - how do they know how to get back to the source?



Illumination effects (cont)

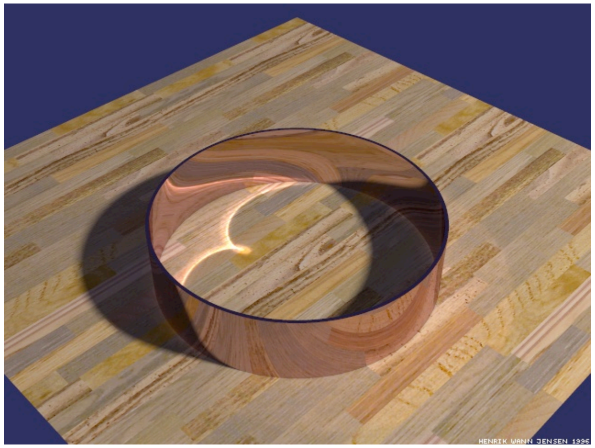
- To get the effect of light reflected and refracted from sources onto diffuse surfaces, we can trace rays **from** the light **to** the first diffuse surface
  - leave a note that illumination has arrived - an illumination map, or photon map
  - sometimes referred to as the forward ray
  - now retrieve this note by tracing eye rays
- Issues
  - efficiency (why trace rays to things that might be invisible?)
  - aliasing (rays are spread out by, say, curved mirrors)

Refraction caustic



Henrik Jensen, http://www.gk.dtu.dk/~hwj

Reflection caustic



Henrik Jensen, http://www.gk.dtu.dk/~hwj

Refraction caustics

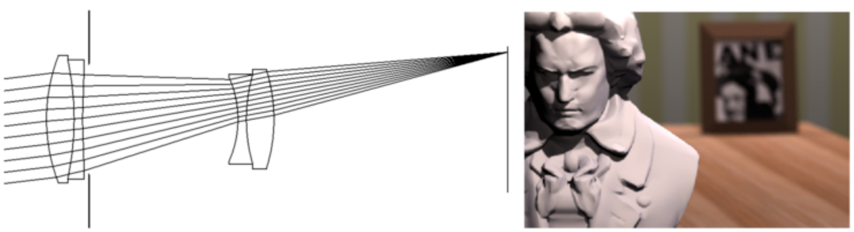
Henrik Jensen, http://www.gk.dtu.dk/~hwj

Lens Effects

Note that a ray tracer very elegantly deals with the projection geometry that we struggled with in earlier lectures which was based on a very simple and "ideal" camera model

We can go further and introduce a more interesting or realistic camera model

from
A Realistic Camera Model for Computer Graphics
Craig Kolb, Don Mitchell, and Pat Hanrahan
Computer Graphics (Proceedings of SIGGRAPH '95), ACM SIGGRAPH, 1995, pp. 317-324



Note limited depth of field, just like a real lens

from
A Realistic Camera Model for Computer Graphics
Craig Kolb, Don Mitchell, and Pat Hanrahan
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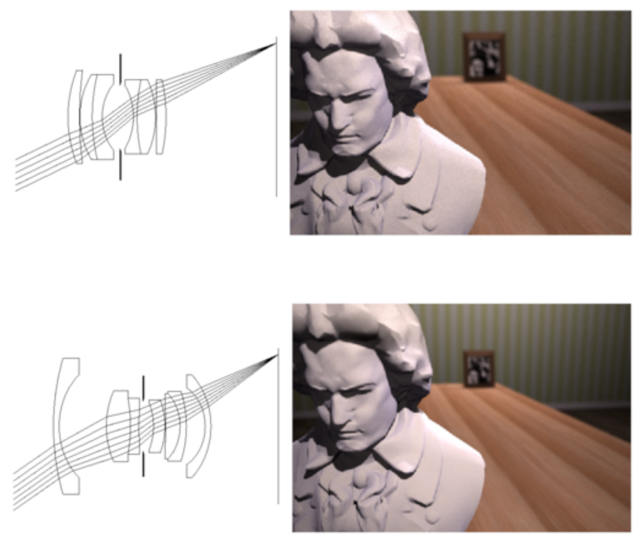

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