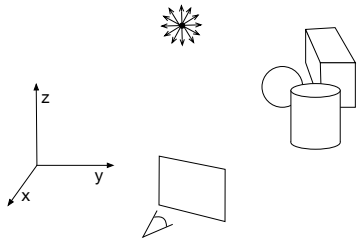
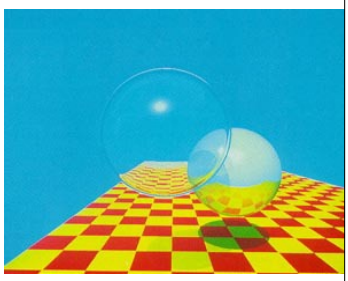
Global Illumination

- Ray Tracing
- Radiosity



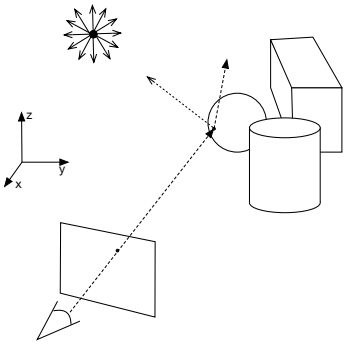
Ray Tracing

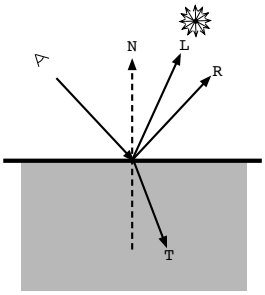
- a generalization of ray casting
- why?
  - visible surface
  - shadows
  - reflection
  - refraction



Whitted, 1980

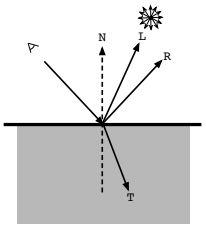
Ray Tracing How



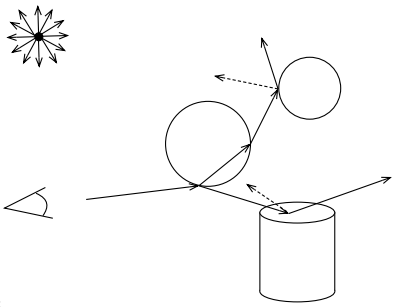


Ray Tracing How

$$I = ambient + \sum^{lights} (diffuse + specular) + K_r \cdot I_R + K_t \cdot I_T$$

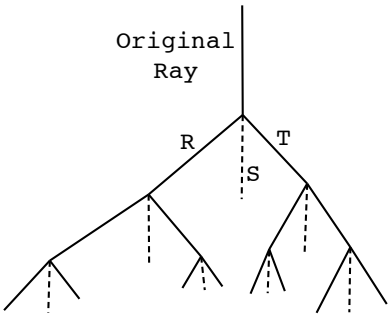


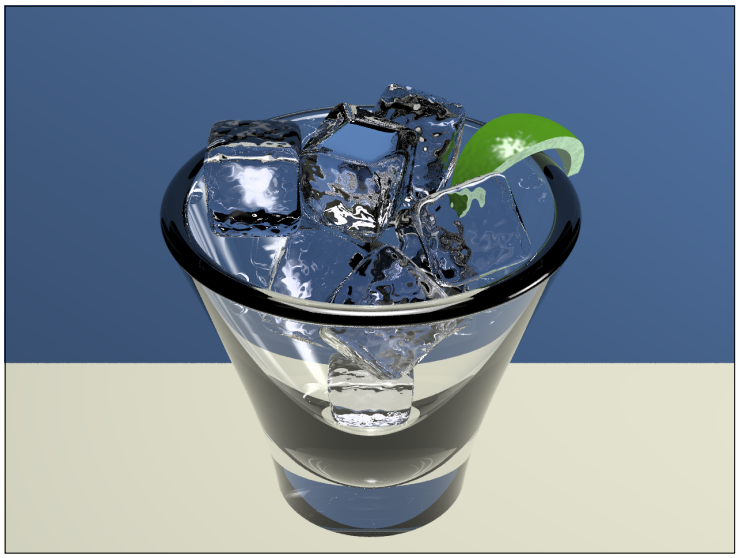
Multiple Reflections and Refractions



- Recursion!
- when to stop?
  - max # of bounces
  - ray contribution < threshold

Ray Tree



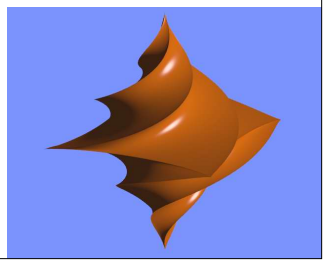


Ray Tracing Main Topics

- intersection algorithms
- reducing intersections
- anti-aliasing
- advanced optical effects

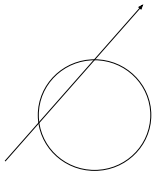
Intersection Algorithms

- implicit surfaces: F(x,y,z)=0
  spheres, conic sections, planes, blobs, etc
- cubes, triangles, triangular meshes
- Constructive Solid Geometry (CSG)



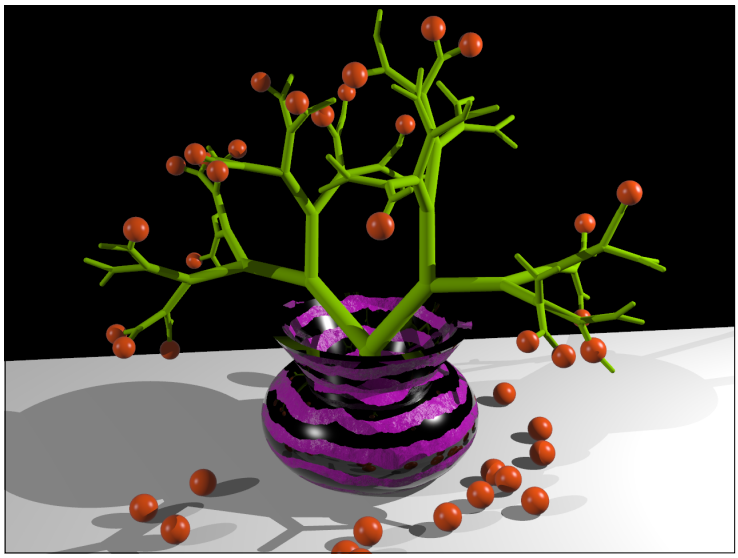
Implicit Surfaces

- ray: $p_t = o + t \cdot \vec{d}$
- sphere: $x^2 + y^2 + z^2 - 1 = 0$

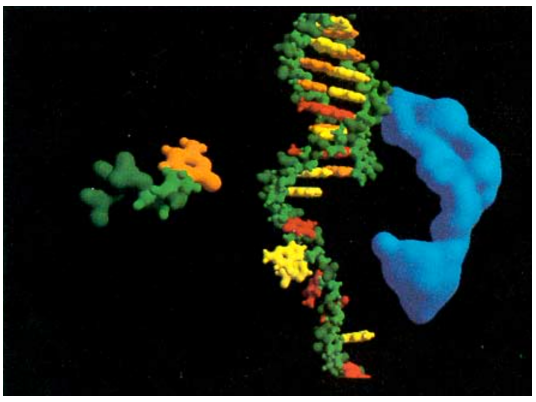


$$(o_x + t \cdot \vec{d}_x)^2 + (o_y + t \cdot \vec{d}_y)^2 + (o_z + t \cdot \vec{d}_z)^2 - 1 = 0$$
$$(o_x^2 + 2 \cdot o_x \cdot t \cdot \vec{d}_x + t^2 \cdot \vec{d}_x^2) + (o_y^2 + 2 \cdot o_y \cdot t \cdot \vec{d}_y + t^2 \cdot \vec{d}_y^2) + (o_z^2 + 2 \cdot o_z \cdot t \cdot \vec{d}_z + t^2 \cdot \vec{d}_z^2) - 1 = 0$$
$$(\vec{d}_x^2 + \vec{d}_y^2 + \vec{d}_z^2)t^2 + 2(o_x \cdot \vec{d}_x + o_y \cdot \vec{d}_y + o_z \cdot \vec{d}_z)t + (o_x^2 + o_y^2 + o_z^2) - 1 = 0$$
$$dot(d,d)t^2 + 2dot(o,d)t + dot(o,o) - 1 = 0$$
$$at^2 + bt + c = 0$$

in general: find roots of equation

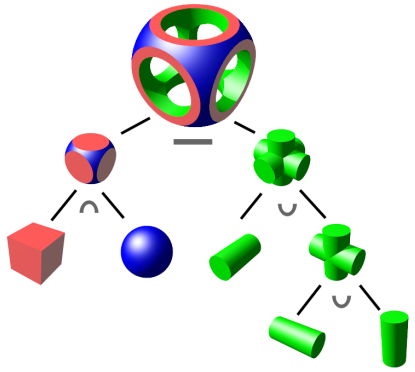


Blobs



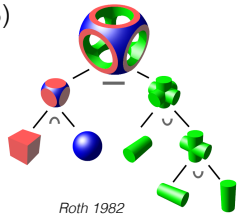
Blinn, 1982

Constructive Solid Geometry



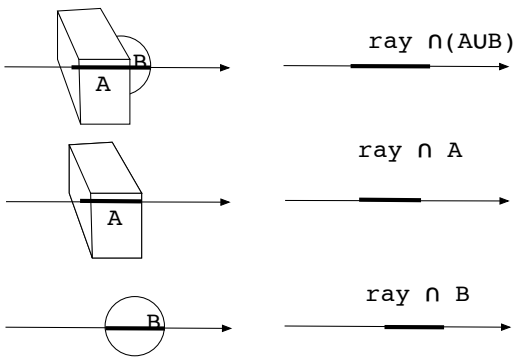
Constructive Solid Geometry

- Boolean set operations on simpler solids
- Union, Intersection, Difference, Negation
- ray ∩ (A ∪ B) = (ray ∩ A) ∪ (ray ∩ B)
- turn hard 3D problem into simpler 1D problem



Roth 1982

Ray tracing CSG

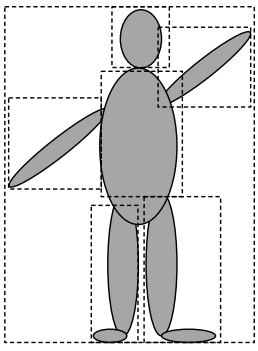


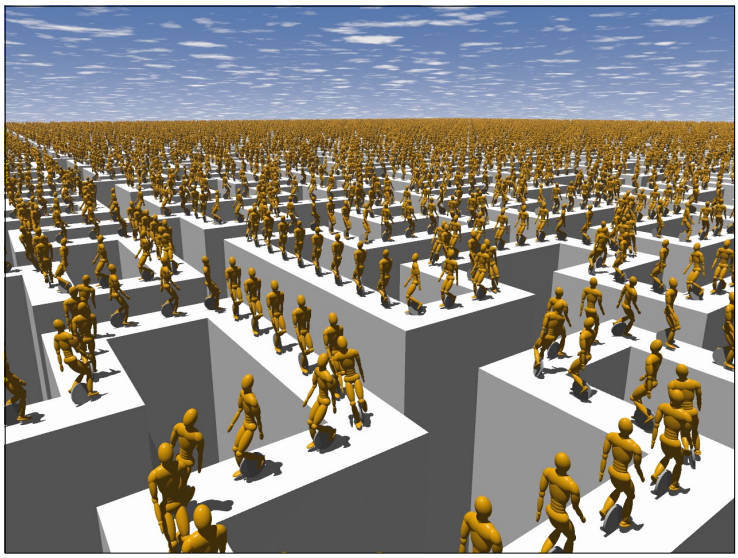
Ray Tracing Efficiency

- 1K * 1K * 1K objects = one billion intersection calc 😞
- improvements
  - hierarchical bounding volumes
  - spatial partitioning

Hierarchical Bounding Volumes

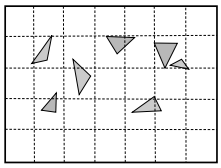
- Explicit creation of hierarchy
- Automatic creation
  - list of objects -> tree
  - intersection ∝ surface area





Spatial Partitioning

- 2-D



- 3-D
  - subdivide space
  - traverse grid one *voxel* at a time
  - uniform vs octree