Ray Tracer

Spring 2008 Help Session

Outline

- Project Web Resources
- What do you have to do for this project?
- Ray Class
- Isect Class
- Requirements
- Tricks
- Artifact Requirement
- Bells and Whistles

Project Web Page

http://www.cs.washington.edu/education/courses/cse457/CurrentQtr/projects/trace/

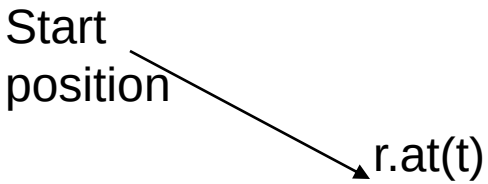
- Roadmap
  - Overview of files
  - STL Information
- List of useful equations
- File format description
- Debugging display documentation
- Triangle intersection handout

Welcome to the Raytracer Project

- Basically, you are given a raytracer;

  and you have to implement:

  - Shading (has multiple parts)
  - Sphere Intersection Code
  - The ability to intersect triangles
    - Complex objects consist of a 3D mesh made up of many of these triangles
  - Reflection and Refraction



ray Class

- A 3D ray is the fundamental component of a raytracer.
- ray r (start position, direction, RayType)
  - enum RayType{VISIBILITY, REFLECTION, REFRACTION, SHADOW};
  - example: ray r(foo, bar, ray::SHADOW);
- r.at(t), a method that determines the position of the ray r as a function of *t*, the distance from the start position (t*direction vector)
  - r.at(t) => where the end of the ray points at (a distance t away from the start point)

Dot Product & Cross Product

- DotProduct and CrossProduct are provided by vec.h
  - * - dotproduct
    - (e.g. double dot = v1 * v2;)
  - ^ - crossproduct
    - (e.g. Vec3d cross = v1 ^ v2;)

isect Class

- An isect represents the location where a ray intersects a specific object.
- Important member variables:

```
const SceneObject     *obj;  // the object that was intersected.
double t;                    // the distance along the ray where it occurred.
Vec3d N;                     // the normal to the surface where it occurred
Vec2d uvCoordinates;         // texture coordinates on the surface. [1.0,1.0]
Material *material;          // non-NULL if exists a unique material for this intersect.
const Material &getMaterial() const; // return the material to use
```

- This data structure is used to record the details of a ray's intersection with an object. (Filled-out in an object's intersection routine)

Requirements

Sphere Intersection

Fill in Sphere::intersectLocal in SceneObjects\Sphere.cpp:

Return *true* if ray r intersects the canonical sphere (sphere centered at the origin with radius 1.0) in positive time.

Set the values of isect i:

- i.obj = this
- i.setT(time of intersection)
- i.setN(normal at intersection).

Requirements

Triangle Intersection

Fill in TrimeshFace::intersectLocal in SceneObjects\trimesh.cpp:

Intersect r with the triangle abc:

```
Vec3d &a = parent->vertices[ ids [0] ];
Vec3d &b = parent->vertices[ ids [1] ];
Vec3d &c = parent->vertices[ ids [2] ];
```

Set up isect i as in the sphere intersection and return *true* if ray r intersects the plane containing triangle abc and the intersection is within the triangle.

See
http://www.cs.washington.edu/education/courses/457/CurrentQtr/projects/trace/extra/triangle_intersection.pdf

Requirements

Blinn-Phong specular-reflection model

Fill in Material::shade in material.cpp:

Refer to the raytracing lecture:

http://www.cs.washington.edu/education/courses/457/CurrentQtr/lectures/ray-tracing.pdf

To sum over the light sources, use an iterator as described in the comments of the code.

Remember, if you are inside an object, the object's normal will point outside. You will need to flip that normal for any shading, reflection, or refraction.
(Unless of course you like funky images and less points…)

Requirements

Contribution from multiple light sources

Fill in PointLight::distanceAttenuation in light.cpp (DirectionalLight::distanceAttenuation is already done for you). Use the alternative described in the ray-tracing lecture where

a = constantTerm

b = linearTerm

c = quadraticTerm

These terms are defined in light.h.

Requirements

Shadow Attenuation

Fill in DirectionalLight::shadowAttenuation and PointLight::shadowAttenuation in light.cpp.

The ray-tracing lecture shows you where to insert this factor into the Blinn-Phong equation (A_shadow for each light).

Rather than simply setting the attenuation to 0 if an object blocks the light, accumulate the product of k_t's for objects which block the light (use the `prod` function from the vector package). Count each intersection with an object by the shadow ray (which may include entering and exiting).

See Foley, et. al. Section 16.12 in course reader – this particular method is not really covered in lecture slides

Better ways to handle shadows (caustics, global illumination, etc.) get extra credit

Here's a link to the ray-tracing lecture:

http://www.cs.washington.edu/education/courses/457/CurrentQtr/lectures/ray-tracing.pdf

Requirements

Reflection

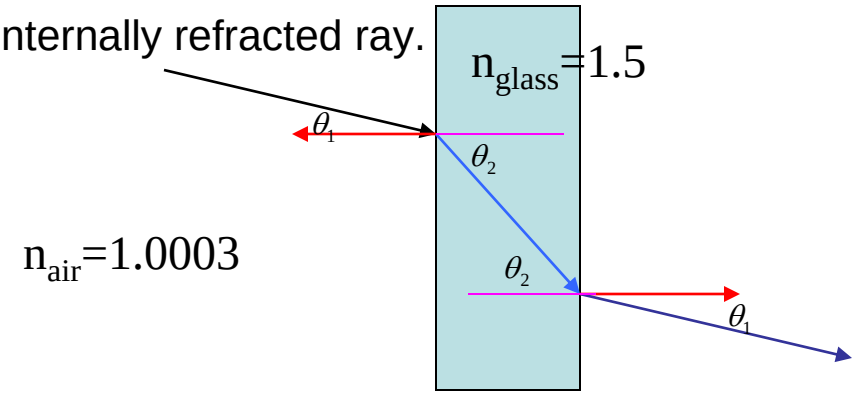
Modify RayTracer::traceRay in RayTracer.cpp to implement recursive ray tracing which takes into account reflected rays.

See Foley, et. al. and lecture slides.

Requirements

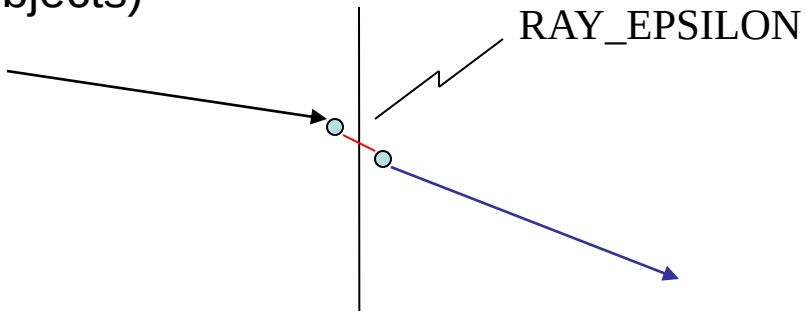
Refraction

- Modify RayTracer::traceRay in RayTracer.cpp to implement recursive ray tracing which takes into account refracted rays.
- Remember Snell's law, watch out for total internal refraction, and consider the case when the ray is exiting a material into air (think about the direction of the normal)
- You can test with simple/cube_transparent.ray
- Warning: Unlike reflection, this routine has several cases to consider: an incoming ray, an outgoing ray and a totally internally refracted ray.



Tricks

- Use the sign of the dot product r.getDirection() with i.N to determine whether you're entering or exiting an object
- Use **`RAY_EPSILON`** (which is defined as 0.00001) to account for computer precision error when checking for intersections (dark scattered dots appearing on objects)



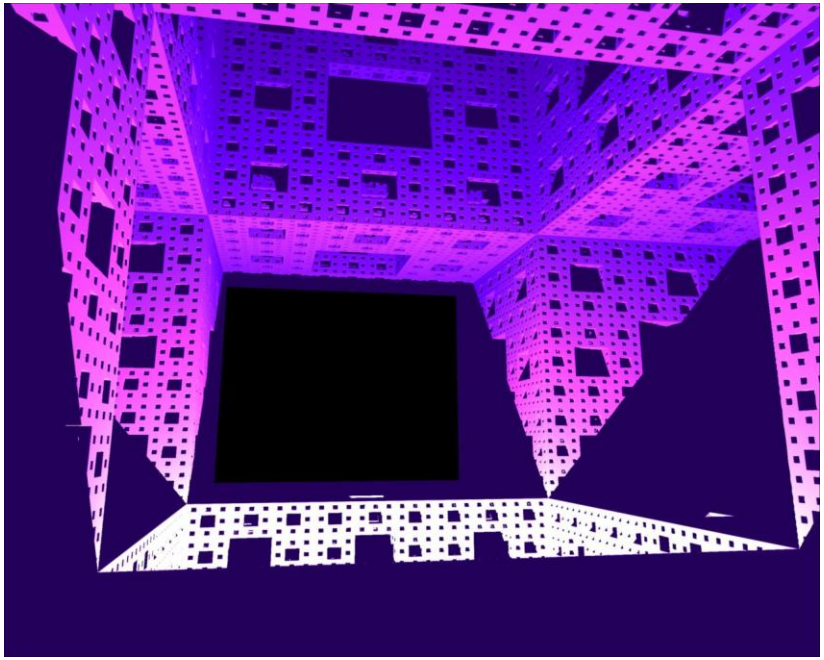
Artifact Requirements

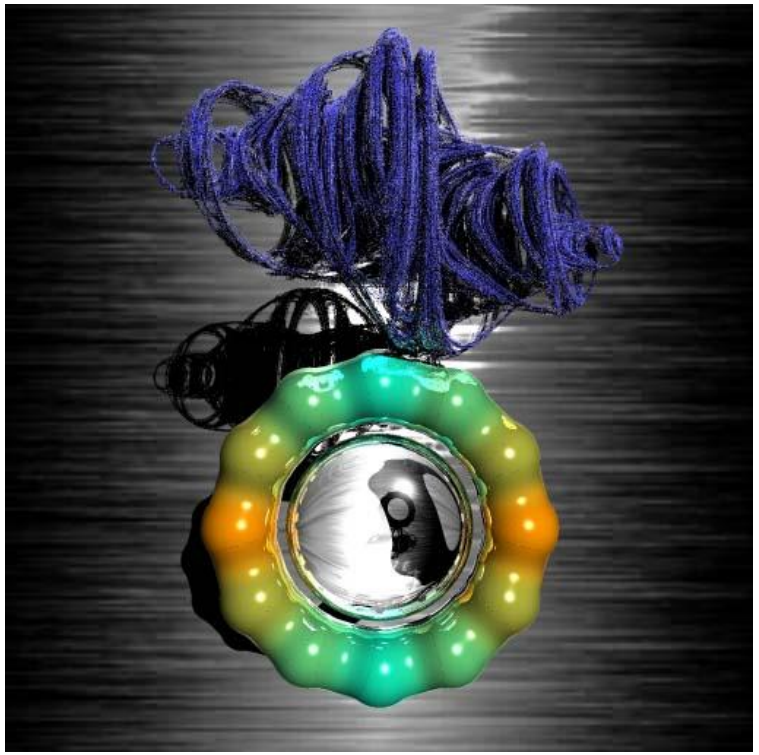
- One JPEG/PNG image per person traced with your Ray Tracer submitted for voting.
- Has to be a (somewhat) original scene
- For each image submitted for voting, a short .txt description of the scene or special features.
- Examples of each bell/whistle implemented with an accompanying readme.txt specifying which image demonstrates which feature (and where/how).

Bells and Whistles

- Antialiasing – A must for nice scenes (to render scenes without “jaggies”)
- Interpolate trimesh material properties – will make them look nicer
- Environment/Texture/Bump Mapping – Relatively easy ways to create complex, compelling scenes
- Single Image Random Dot Stereograms – I have no idea, but they look cool!
- Depth of field, Soft shadows, Motion blur, Glossy reflection – most images we’re used to have at least one of these effects

3D and 4D Fractals





Constructive Solid Geometry

- Allows for complex objects while still just intersecting simple primitives