RAY TRACER

Winter 2013 Help Slides

OUTLINE

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

WELCOME TO THE RAYTRACER PROJECT

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

RAY CLASS

Start position

r.at(t)

- A 3D ray is a 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), returns the position end point of the ray r
  - *t:* the distance from the start position

VEC.H, MAT.H: MATH FUNCTIONS

- vec.h gives useful tools for 2D, 3D, and 4D vectors:
  - Easy Vector Construction
    - eg. Vec3d x = Vec3d(0,0,0);
  - Basic operators are overrided
    - +,-,arithmetic, Vec3d v3 = v1 + v2
    - *, multiply by constant, Vec3d   v3 = 2*v1;
    - *, dotproduct, eg.   double dot = v1 * v2;
    - ^, crossproduct, eg.   Vec3d cross = v1 ^ v2;
  - Other useful functionality, read vec.h for complete details
    - normalize(), length(), iszero()

ISECT CLASS

- An isect represents the location where a ray intersects an 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
```

REQUIREMENT: 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).

REQUIREMENT: 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] ];
```

- return *true* if ray r intersects the triangle.
- More Help? See page linked to on project website
  - https://www.cs.washington.edu/education/courses/csep557/handouts/triangle_intersection.pdf

REQUIREMENT:
BLINN-PHONG SPECULAR-REFLECTION MODEL

- Fill in Material::shade in material.cpp:
- Refer to the RayTracing lecture:
  - https://www.cs.washington.edu/education/courses/csep557/handouts/RayTracing.pdf
- To sum over the light sources, use an iterator as described in the comments of the code.
- Need to implement Phong normal interpolation

REQUIREMENT: MULTIPLE LIGHT SOURCES

- Fill in PointLight::distanceAttenuation in light.cpp (DirectionalLight::distanceAttenuation is 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.

REQUIREMENT: 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 vec.h).
- Extra Credit: Better shadow handling (caustics, global illumination, etc.)

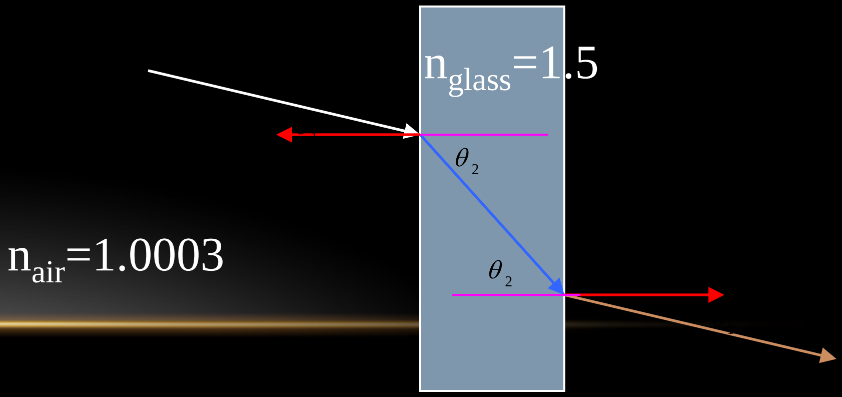
REQUIREMENT: REFLECTION

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

- See lecture notes.

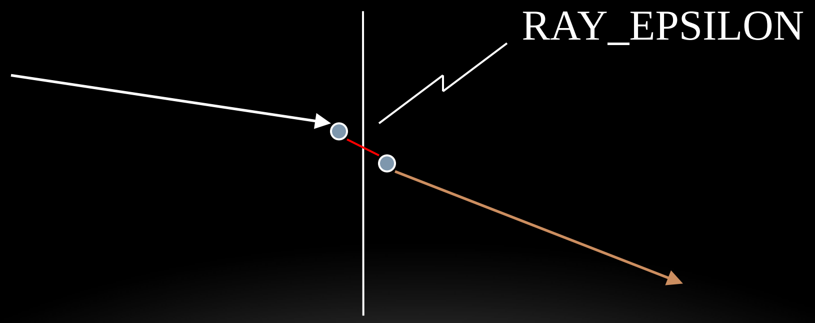
REQUIREMENT: REFRACTION

- Modify RayTracer::traceRay in RayTracer.cpp
  - create refracted rays.
- Remember Snell’s law, be careful about total internal refraction and the normal direction when the ray is exiting a material into air
- You can test with simple/cube_transparent.ray
- Unlike reflection, this routine has several cases to consider:
  - an incoming ray
  - an outgoing ray
  - totally internally refracted ray.



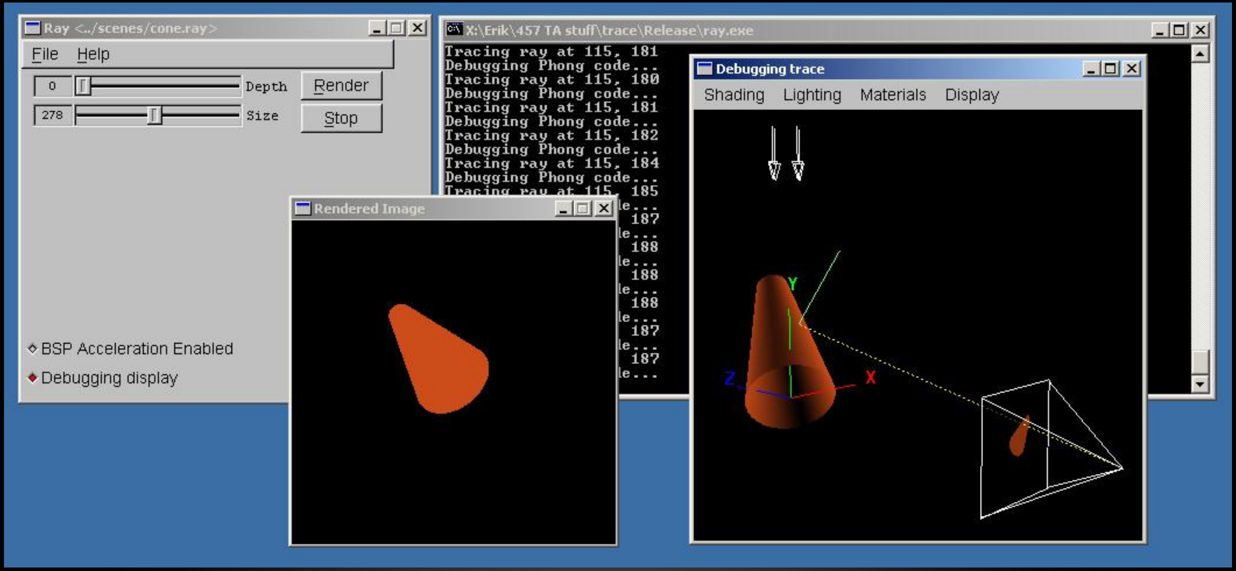
TIPS

- 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



THE DEBUGGER TOOL

- shipped with the skeleton code
- http://www.cs.washington.edu/education/courses/csep557/13wi/projects/trace/extra/debug.html



```
Tracing ray at 115, 181
Debugging Phong code...
Tracing ray at 115, 180
Debugging Phong code...
Tracing ray at 115, 181
Debugging Phong code...
Tracing ray at 115, 182
Debugging Phong code...
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```

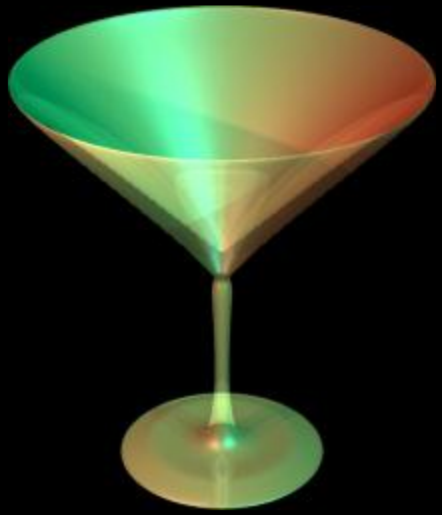
ARTIFACT REQUIREMENT

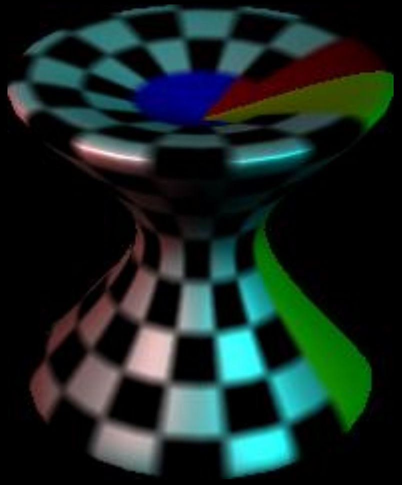
- Draw a pretty picture!
- One JPEG/PNG image traced with your Ray Tracer submitted for voting.
- Has to be a (somewhat) original scene
- For each image submitted for voting, a short .txt description of the scene or special features.
- Examples of each bell/whistle implemented with an accompanying readme.txt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

RAY TRACING YOUR SURFACE OF REVOLUTION

- Render your surface of revolution to earn one easy extra point
- Using this code snippet to write triangle mesh into a file
  - http://www.cs.washington.edu/education/courses/csep557/13wi/projects/trace/code/write_revolution_rayfile.c
- Using this .ray file as a template
  - http://www.cs.washington.edu/education/courses/csep557/13wi/projects/trace/code/revolution.ray
  - It contains default lighting of modeler
  - Replace polymesh{} part with your own surface of revolution
- Render your new .ray file in tracer

SAMPLE RESULTS



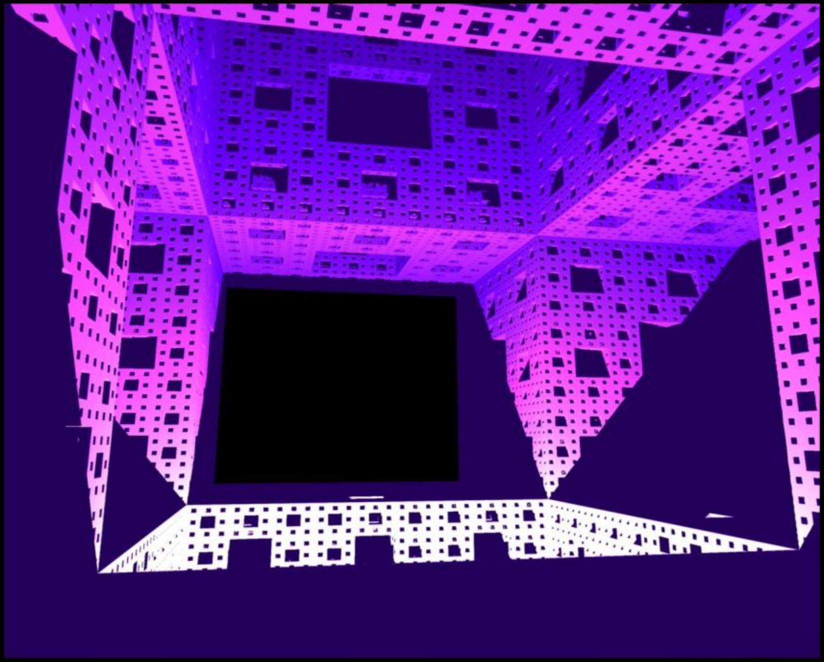


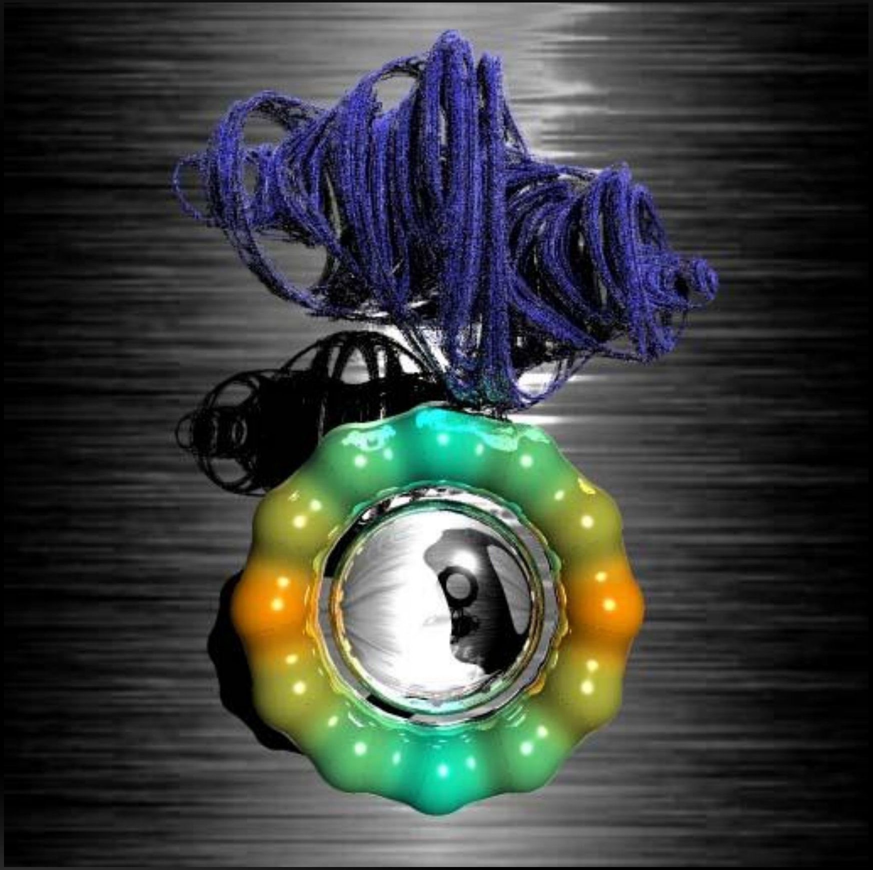
With texture mapping

BELLS AND WHISTLES

- **TONS of Awesome Extra Credit!!!**
- 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
- Depth of field, Soft shadows, Motion blur, Glossy reflection – most images we’re used to have at least one of these effects
- **NOTE**: Please add control boxes for substantial ray tracing modifications so the required extensions are easily gradable
  - see sample solution style
  - Especially things like anti-aliasing, glossy reflection, soft shadows, etc.

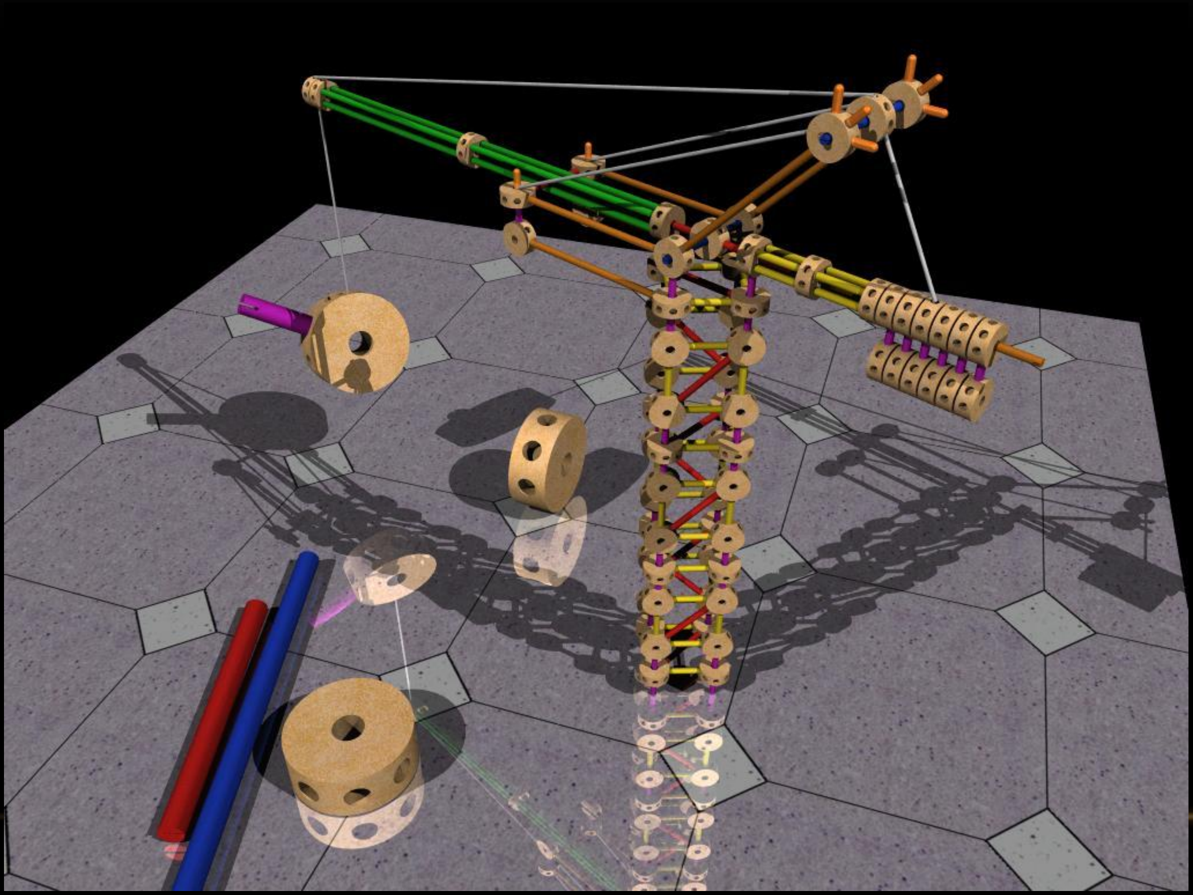
3D AND 4D FRACTALS





CONSTRUCTIVE SOLID GEOMETRY

- Allows for complex objects while still just intersecting simple primitives



USING PLY MODELS

- ply is one of the standard formats for 3D models

http://en.wikipedia.org/wiki/PLY_%28file_format%29

- There are a lot of ply models available online
- We provide a simple tool that converts ply models into .ray files.
- You still need to add lighting and material property.

THE DREADED MEMORY LEAK!!!

- A Memory Leak can (and probably will) ruin your night of rendering hours before the artifact is due.
- depth 10, Anti-Aliasing, HUGE Image ➔ ALL MEMORY CONSUMED BY ray.exe
  - at 1.8 GB on Hardware lab machines
- Cause: not calling free after allocating memory
  - Object constructors, vector (array) creation
- It is HIGHLY RECOMMENDED you have no memory leaks
- Solution: call the “delete [object]” on ANYTHING you create that temporarily
  - i.e. 3 byte temporary vectors in rayTrace function