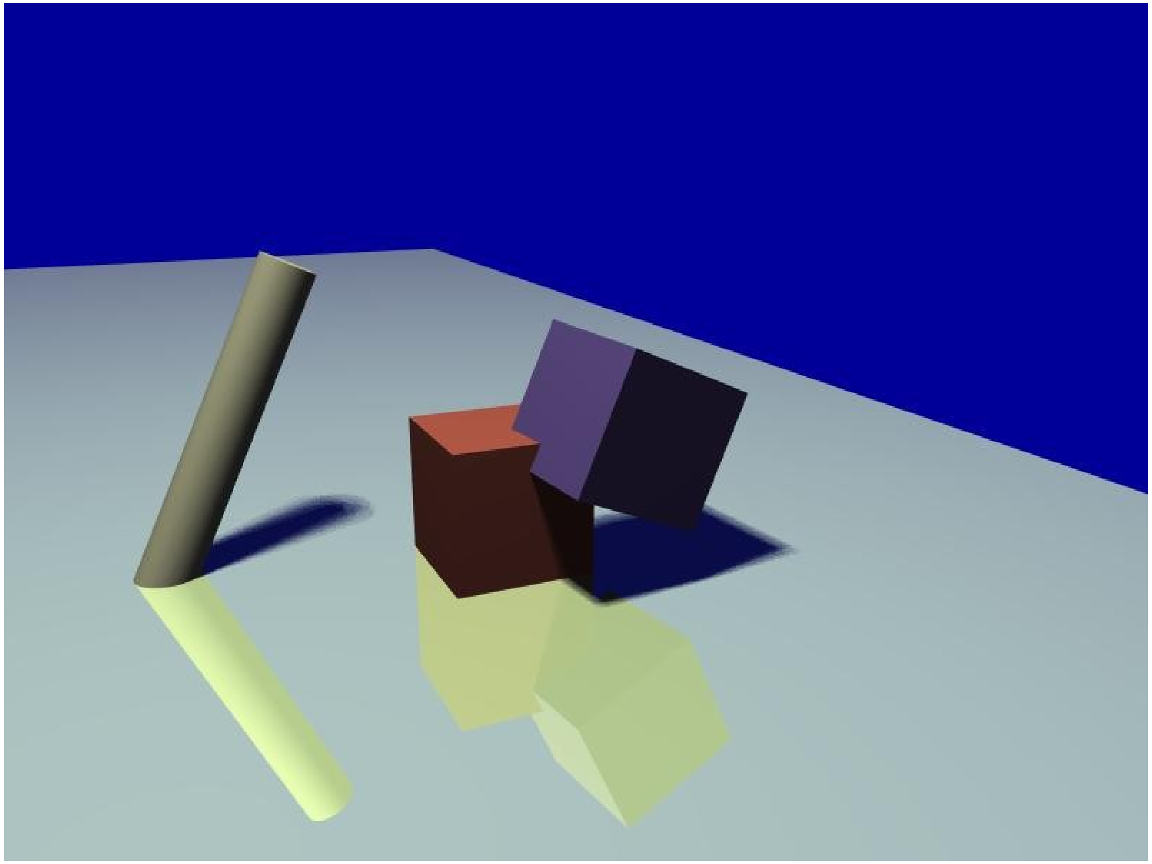
EECS 487
December 6, 2006

- project 5 concepts
- Pat Hanrahan: future of CG?



support code

- not jot
- written by Prof. Guskov
- command line raytracer:
  srt scene.sce rendering.tga
- “srt” = simple ray tracer
- scene: lights, camera, objects, ...
- output: targa image (see spec)

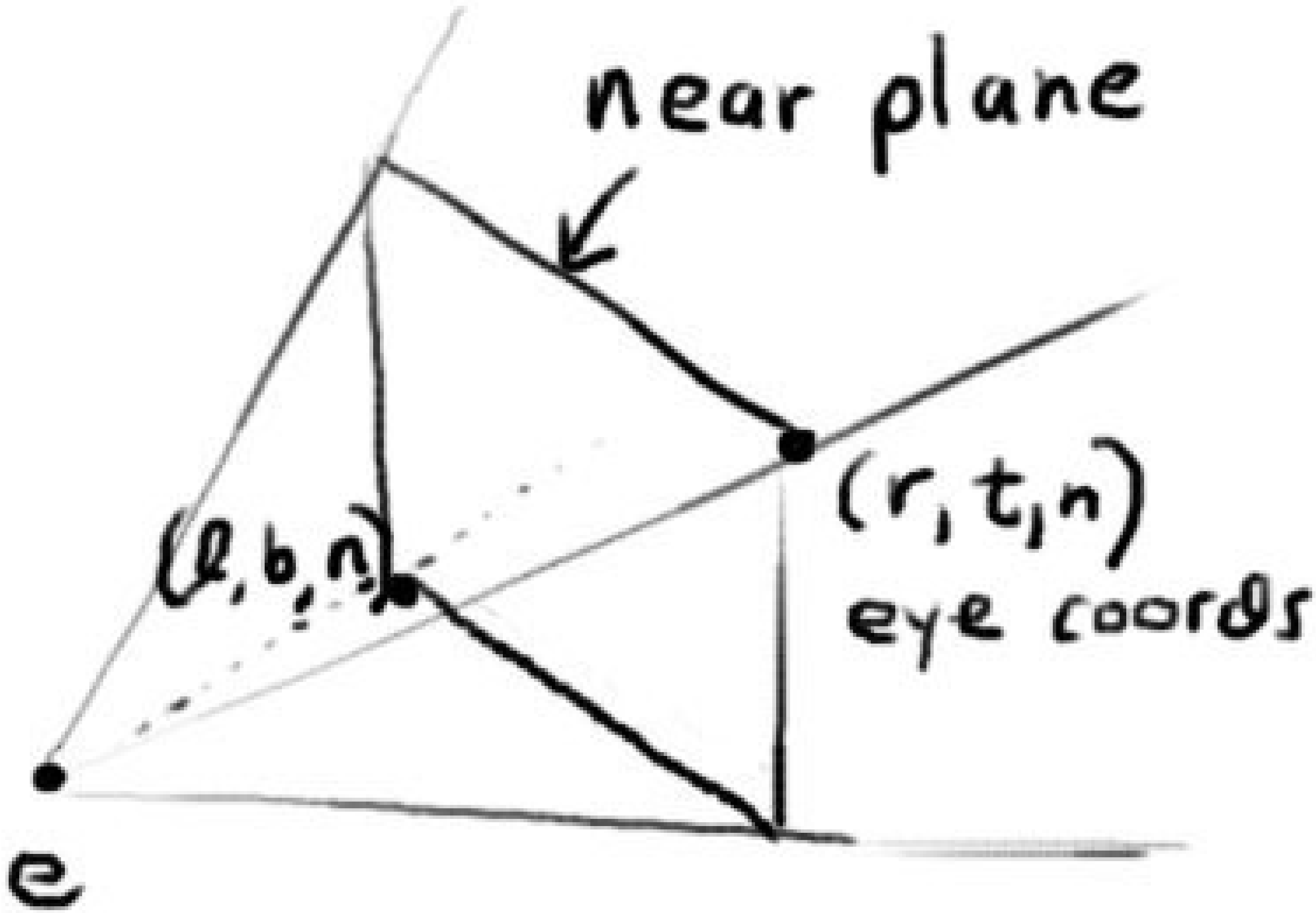
tasks

1. ray generation code
2. shading computations
3. interpolated normals for smooth shading
4. specular reflections
5. cylinder primitive
6. anti-aliasing
7. area lights
8. optimization: bounding sphere test

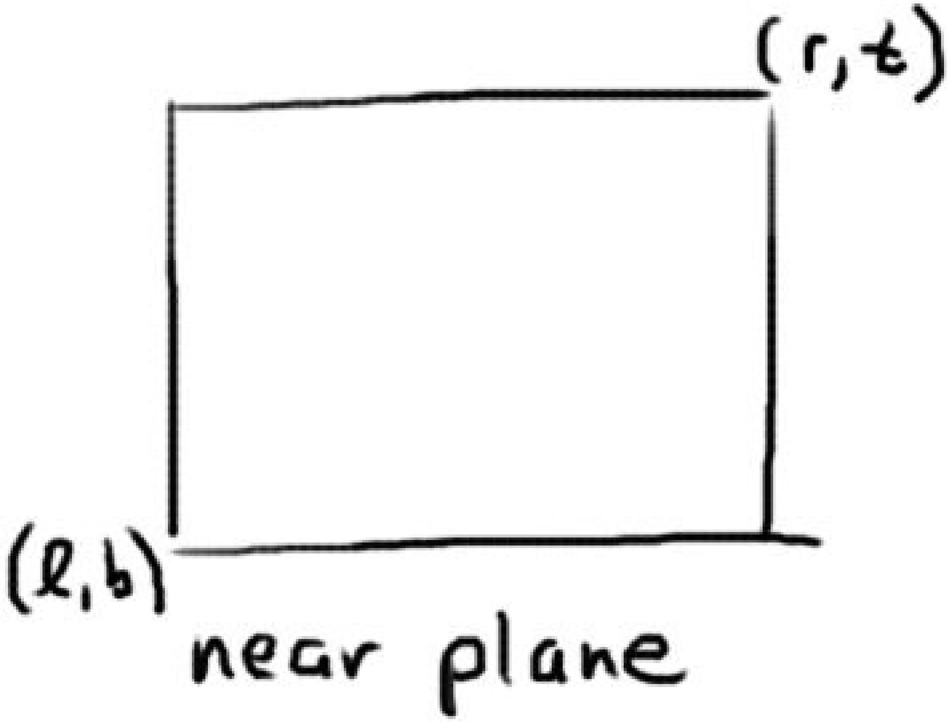
ray generation

- same camera model we've seen before
- parameters:
  e: eye location
  u: unit vector pointing right
  v: unit vector pointing up
  w: unit vector pointing behind us
  rendering window width, height in pixels
  field of view angle (in vertical direction)
  distance to near plane

ray generation

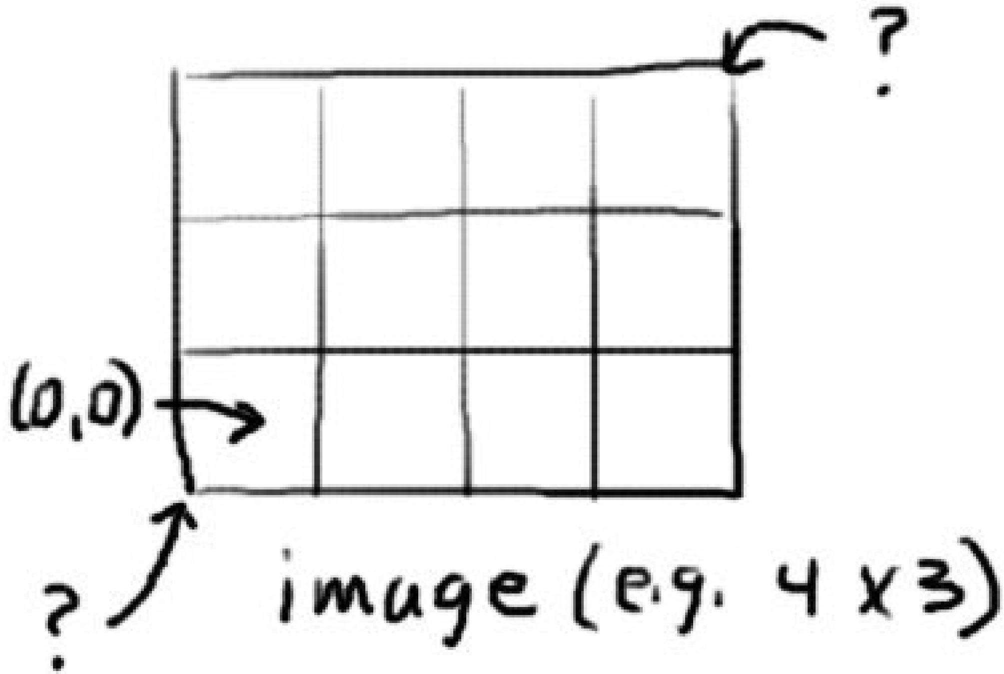


ray generation



- image maps to rectangle in near plane
- assume center of rectangle is (0,0)
- Q: what are (l,b) in terms of (r,t)?

ray generation



- say (0,0) is *center* of lower left pixel
- Q: what are coordinates at corners?

ray generation

- convert pixel coordinates (i,j) to eye coords (u,v,n) describing location on near clipping plane (n is coordinate of near plane)
- e.g. (-½, -½) in pixels maps to (l,b,n) in eye coordinates
- world-space location **s** is then:
  $\mathbf{s} = \mathbf{e} + \mathbf{u}u + \mathbf{v}v + \mathbf{w}n$
- Q: what is the ray?

ray generation

- Q: what is the ray?
- A: $r(t) = \mathbf{e} + t(\mathbf{s} - \mathbf{e})$

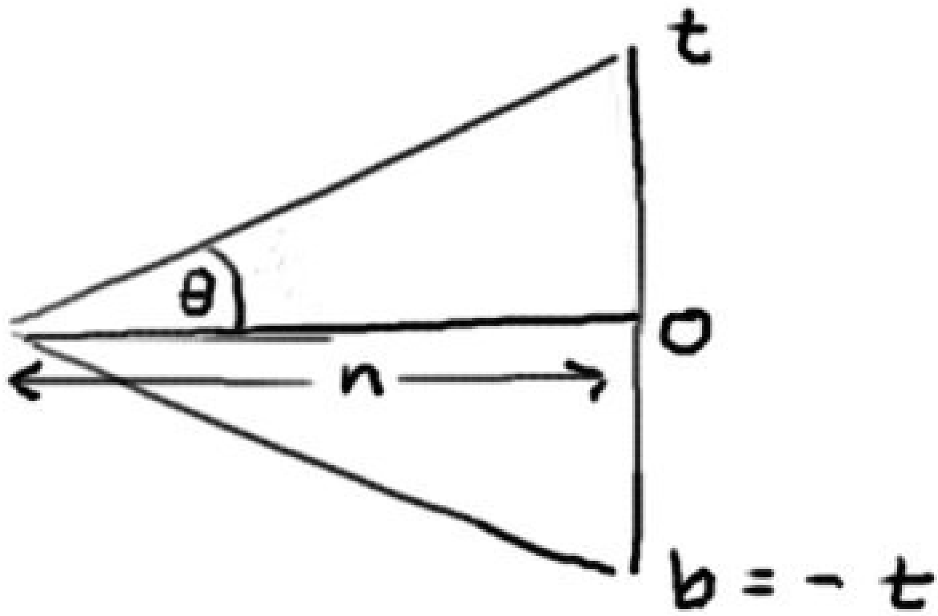
ray generation

- Q: how to get l, r, t, b, n, f?
- e.g. simple.sce:

```
# camera
eyepos 0 -2 1.5    // e
eyedir 0 1 -0.4    // -w
eyeup 0.0 0.0 1.0 // used to find v
wdist 1.0          // distance to near plane
fovy_deg 50        // field of view vertically
```

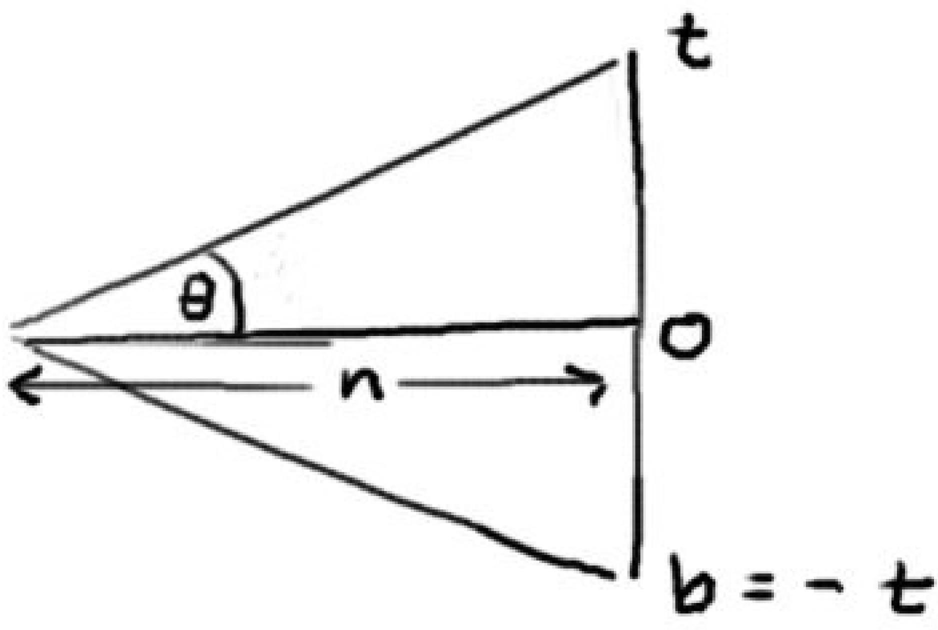
ray generation

- Q: how to get l, r, t, b, n, f?
- A: given n = wdist,
  and fovy θ = fovy/2, find t:



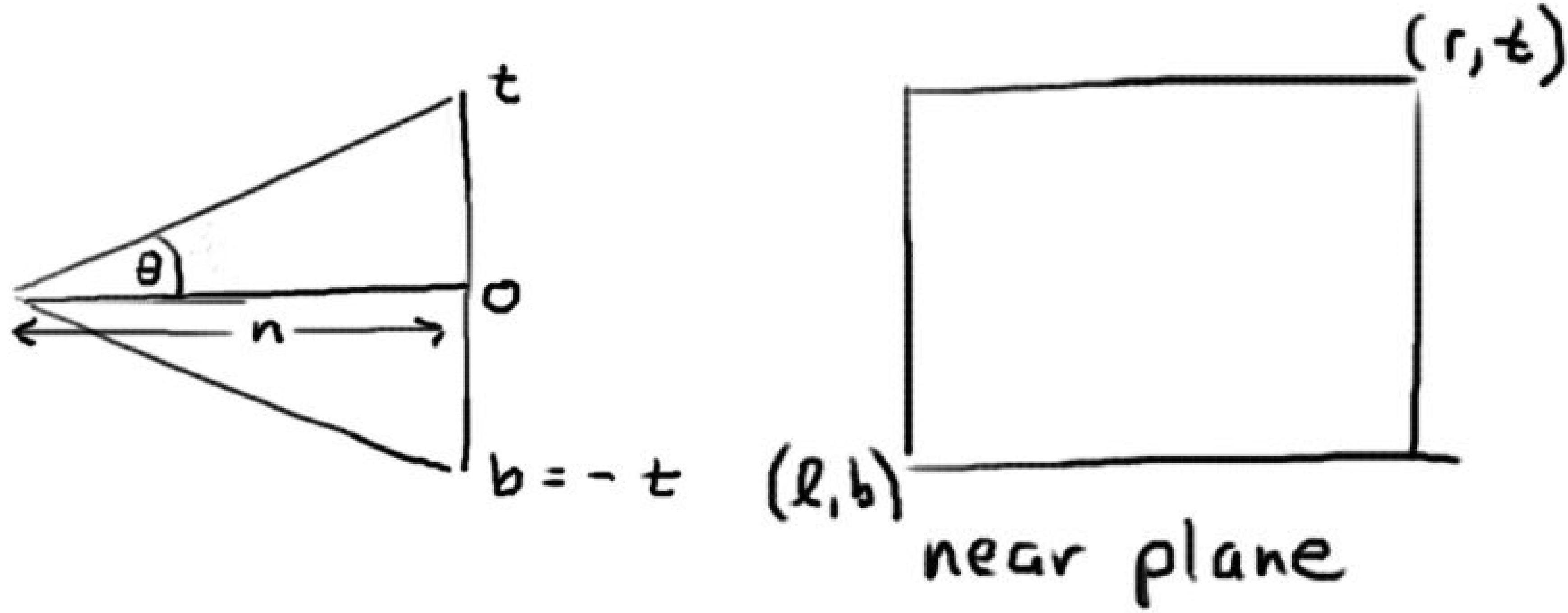
ray generation

- $\tan(\theta) = t/n$
- solve for t



ray generation

- aspect ratio a = image width/height
- r = a*t



shading

```
/// Returns the color from the shading computation using
/// the information in the hitinfo_t structure
/// level is the recursion level
XVecf RayTracerT::Shade(const hitinfo_t& hit, int level) {
  XVecf color(0.0f);

  // Ambient light contribution
  color = hit.m_mat.m_ca*hit.m_mat.m_cr;

  // YOUR CODE HERE
  // shading code here
  // iterate over the lights and collect their contribution
  // make a recursive call to Trace() function to get the reflections


  return color;
}
```

shading

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  // iterate over the lights and collect their contribution
  // make a recursive call to Trace() function to get the reflections

  SceneT::LightCt::const_iterator li;
  for(li=m_scene.BeginLights(); li!=m_scene.EndLights(); ++li) {
     ...
  }
  return color;
}
```

shading

```
SceneT::LightCt::const_iterator li;
for(li=m_scene.BeginLights(); li!=m_scene.EndLights(); ++li) {
   // send ray to light
   // if hit any object before light, skip the light

   // get surface normal from hit
   // find n dot l
   // do diffuse computation using light color and
   //    material diffuse color

   // add specular contribution from light

   // if material specular color is not black,
   //    compute color along reflected ray via RayTracerT::Trace()
}
```

phong shading

- do per pixel normals
  - use barycentric coordinates (provided)
  - return interpolated normal within mesh triangle in `MeshT::Intersect()`
  - if: `m_shade == PHONG_SHADE`

Cylinder primitive

- To implement any object, just need to define `IGel::Intersect()`
- First step: map ray from world space to object space
- E.g. Sphere (provided in support code):
  - Given sphere center **c** and radius r, point **p** is on the sphere if $|\mathbf{p} - \mathbf{c}|^2 = r^2$.
  - Point **p** on the ray: $\mathbf{p} = \mathbf{e} + t\mathbf{d}$
  - Substitute in 1st equation, solve for t via quadratic formula

Cylinder primitive

- In object space the cylinder is "canonical", e.g. radius = 1, centered along z-axis, top at z = 1, bottom at z = 0
- to intersect: first intersect with infinite cylinder (no top or bottom)
- point **p** is on the cylinder if $|\mathbf{p}_{xy}|^2 = 1$.
- Substitute $\mathbf{p} = \mathbf{e} + t\mathbf{d}$, solve for t

Cylinder primitive

- If ray missed, skip (done).
- If 0 <= z <= 1, the ray hit the side (done).
- Else, check if ray hits top or bottom:
  - Find intersection with plane
  - See if result is inside unit circle

Antialiasing

- Modify RayTracerT::TraceAll():
- Outside of main loop over pixels:
  - `if (m_opts.m_aasample>0) {`
  - Create random samples within a generic pixel
  - Use jittered sampling (see text)
  - Create samples in [0,1]x[0,1] square representing locations within a pixel
  - For each area light:
    - Create random samples (similar method)

Antialiasing

- For each pixel:
  - `if (m_opts.m_aasample>0) {`
  - For each sample within a pixel
    - Create view ray
    - Compute color seen along the ray
    - Add up, divide by total number of rays

Area lights

- Define area light class in light.h
- Load area lights in loadscene.cpp
- Handle area lights in raytracer.cpp
  - For each pixel:
  - Before generating rays, shuffle the samples within each light (see text)
  - During loop over pixel samples, store current sample number in: `RayTracerT::m_current_sample`

Area lights

- In RayTracerT::Shade(), when iterating over lights, pass the current sample number to each light as a “hint”:
- `(*li)->HintSample(m_current_sample);`
- It uses the corresponding jittered sample
- Because of shuffling, there is no correlation of sampling pattern within a pixel to the sampling pattern within the light

Bounding sphere test

- In `MeshT::ComputeBV()`, compute a bounding volume
- Find average location, max distance to average location
- Use these as sphere center, radius
- When sphere is created, call `ComputeBV`
- Use `BallT` (add member variable to `MeshT` class)

Bounding sphere test

- In MeshT::Intersect(), compute the ray in object space, then before iterating over mesh triangles, check:

```
if(!m_bball.Intersect(ray, hitdummy))
  return false; // skip it!
// else check every triangle...
```

My problem

- Method for shuffling samples and passing around hints seems extra complicated
- At each pixel, we shuffle the samples in each light...
- Q: What is the point of all this?

My problem

- Q: What is the point of all this?
- A: So we can precompute the samples, and not have to call the random number generator too much.

My problem

- Q: But don't you have to call the random number generator a whole lot of times for the shuffling?
- A: Well... yes. D00d, I just work here!

My problem

- Q: And how expensive is it exactly to call the random number generator anyway?
- A: Um... I don't know, I never checked...
- Possible case of premature optimization?

Reasonable alternative

- Don't precompute any jittered samples
- Just compute random samples on the fly as needed

Pat Hanrahan keynote

- Realistic or Abstract Imagery:
  The Future of Computer Graphics?

  http://www.graphics.stanford.edu/~hanrahan/talks/realistic-abstract