6.837 Assignment 10 Presentations

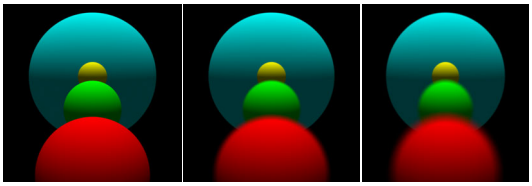
December 7th & 9th, 2004

Mike E.

Distributed Ray Tracing

- Effects created by sending many rays from a random distribution.
- Used for depth of field effects, glossy reflections, and soft shadows
- My implementation reused Sampler and Film objects for creating distribution average

Depth of Field results...



Normal Scene | Yellow Ball focus | Blue Ball Focus

Ning S.

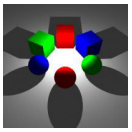
Distribution Raytracing

To be random is to be realistic.

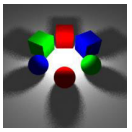
Ning Song
6.837 Assignment 10 Presentation
12/07/04

Soft Shadows

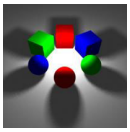
- Light sources in the real world have area.
- Represent light source as infinite number of points.
- For each shadow ray, sample a random point on light source.
- Be sure that pixel and shadow samples don't correspond.
- Note that number of samples has significant impact on image quality.



Point light, no soft shadows



Area light, soft shadows, 16 samples/pixel



Area light, soft shadows, 64 samples/pixel

Depth of Field

- Real world camera has area (vs. usual pinhole camera model)
- Model camera (eye) as square or circular disk with area *a*.
- Sample various eye positions on disk while maintaining line of focus (i.e., sample from focal plane). http://glasnost.itcarlow.ie/~powerk/Graphics/Notes/node12.html#SECTION00128000000000000000
- Larger lens size means more things out of focus, smaller lens size means more in focus.

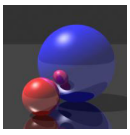
Perfect focus

Small lens size

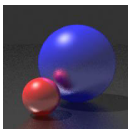
Large lens size

Glossy Reflection

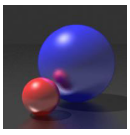
- Glossy surfaces have non-ideal reflections (i.e., blurry reflections).
- Implement by varying reflection rays (i.e., sampling reflection ray directions).
- For each surface hit point, perturb ideal reflection ray using perpendicular square with length *a*, which is degree of blurriness.



Perfect reflection



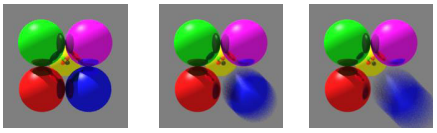
Glossy Reflection, 16 samples/pixel



Glossy reflection, 64 samples/pixel

Motion Blur

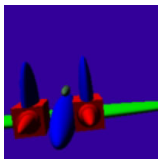
- Image is formed over non-zero span of time.
- For each ray, pick a random time between *t_start* and *t_end*, and intersect with moving primitive.
- Resulting image will again be blurred.
- Important to specify both start and end positions of object in order to calculate bounding boxes for ray acceleration.



T = 0 T = 5 T = 10

(1) James T.

TriangleMeshGroup & CSGs



James Tolbert, II

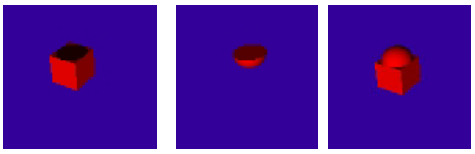
Assignment 10 Presentation

6.837

Triangle Mesh Group

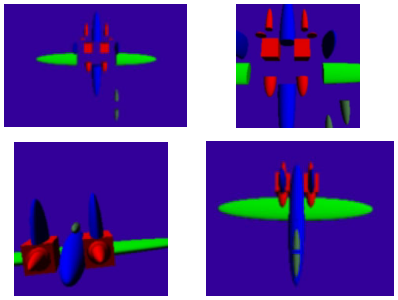
- No new Object3D, Group subclass
- Only Override the inside Method
- Parse calls TriangleMeshGroup

Pictures



Difference Intersection Union

CSG Plane



Some of Text File

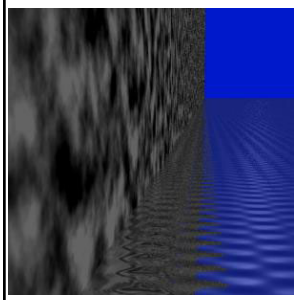
```
Group {
 numObjects 6

 Transform {
  Translate 0 0 1
  Group {
   numObjects 2
   Transform {
    Translate 3 3 0
    Scale 0.5 0.6 0.5
    Group {
     numObjects 4
     MaterialIndex 0
     Transform {
      Scale 2 2 2
      Group {
       numObjects 1
       Difference {
        TriangleMesh {
         obj_file cube.obj
        }
        Sphere {
                center 0 1 0
                radius 0.8
        }
       }
      }
     }
    }
```

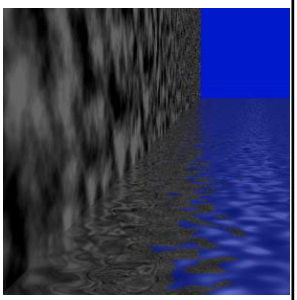
```
Transform {
  Translate 0 5 0
  Scale 1 5 1
  XRotate 180
  Group {
   numObjects 1
   Intersection {
   TriangleMesh {
    obj_file cube.obj
   }
   Sphere {
                center 0 1 0
                radius 1
   }
  }
 }
 Transform {
  Translate 0 -5 0
  Scale 1.5 4 1.5
  Group {
   numObjects 1
   Intersection {
   TriangleMesh {
    obj_file cube.obj
   }
   Sphere {
                center 0 1 0
                radius 1
   }
  }
 }
 Transform {
  Translate 0 2 0
  Scale 1.4 0.5 1.4
  XRotate 180
  Group {
   numObjects 1
   Intersection {
```

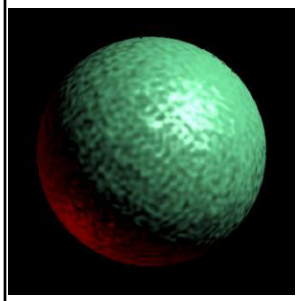
```
TriangleMesh {
 obj_file cube.obj
}
Sphere {
                center 0 1 0
                radius 1
}
}
}
}
MaterialIndex 1
Transform {
 Translate 3 3 4
 XRotate 90
 ZRotate 90
 YRotate -90
 Scale 1.5 0.5 3
 XRotate 90
 Group {
  numObjects 1
  Intersection {
  TriangleMesh {
   obj_file cube.obj
  }
  Sphere {
                center 0 1 0
                radius 1
  }
 }
}
}
MaterialIndex 3
Transform {
 Translate 5 -8 1
 Scale 0.5 0.5 0.5
```

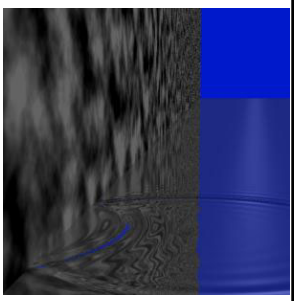
```
Group {
 numObjects 2
 Transform {
  Scale 1 5 1
  Group {
   numObjects 1
   Intersection {
   TriangleMesh {
    obj_file cube.obj
   }
   Sphere {
                center 0 1 0
                radius 1
   }
  }
 }
 Transform {
  Translate 0 11 0
  Scale 1 5 1
  XRotate 180
  Group {
   numObjects 1
   Intersection {
   TriangleMesh {
    obj_file cube.obj
   }
   Sphere {
                center 0 1 0
                radius 1
   }
  }
 }
}
MaterialIndex 1
Transform {
 Translate 5 -9 0
 Scale 1.2 1.5 1.2
 Group {
```

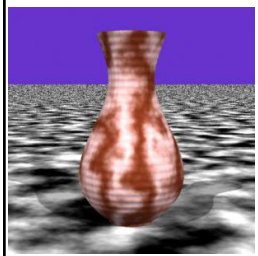
(2) Colin W.

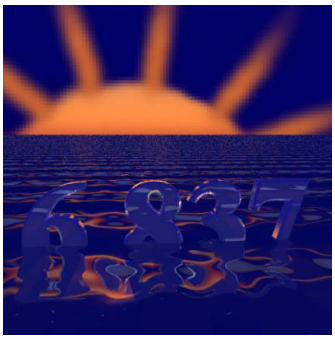












(3) Javier C.

Tensor Product of BSpline Curves

Javier Castro
MIT 6.837

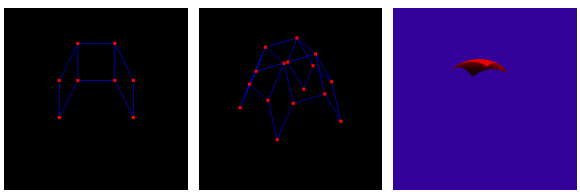
Definitions

- What is a Tensor Product?
- Definition of BSpline Patch
  - Can be of size M x N
  - Has two parameters: *s* and *t*

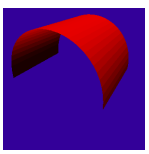
Problems

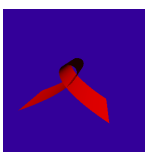
- BSpline Patch vs. Bicubic Bezier Patch
- 3D Point Editing via GUI

Example



Fun with BSpline Surfaces





(4) Evelyn E.

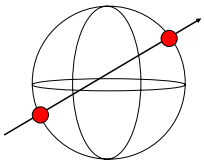
Ray Tracing Quartic Surfaces

Evelyn Eastmond

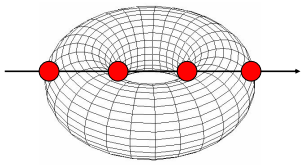
6.837 Assignment 10

Ray-Torus Intersection

- A Torus is a quartic surface



Quadratic surface - 2 roots



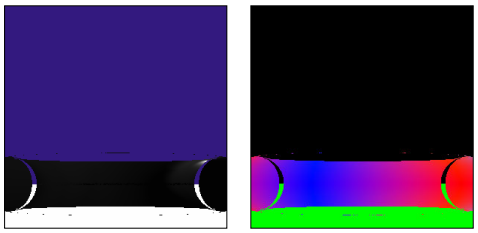
Quartic surface - 4 roots

Ray-Torus Intersection

- Torus equation:
  - $f(x,y,z) = (x^2 + y^2 + z^2 - r^2 - R^2)^2 + 4R^2(z^2 - r^2)$
  - $x = ro_x + rd_x$, $y = ro_y + rd_y$, $z = ro_z + rd_z$
- Steps
  - Find coefficients of quartic
    - By hand (1.5 hrs….)
    - Online
  - Solve using quartic solver
    - By hand?
    - Online!

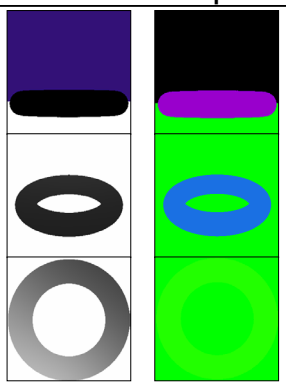
Ray-Torus: Failed Attempt 1

- Problem: inverted coefficients



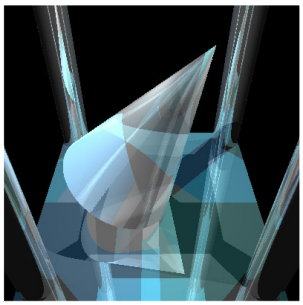
Ray-Torus: Failed Attempt 2

- Problem: false positive ‘t’ values



Lessons Learned

- Solve everything by hand
  - geometry?
- Use online sources for reference only
- Acknowledgements:
  - Ray torus equation:
    Max Wagner, http://emeyex.com/
  - Quartic solver:
    Geant 4 Group, http://geant4.web.cern.ch



(5) Andy A.

Distribution Ray Tracing

Andy Arizpe
6.837
December 9, 2004

Soft Shadows

- Represent light source as area rather than point.
- For each shadow calculation, send multiple rays aimed at different points on the light.
- Points near the border of the shadow region will be partially lit.

Soft Shadows

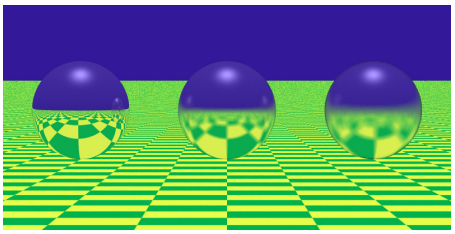
One ray per shadow calculation

Sixteen rays per shadow calculation

Glossy Reflection

- Used to model materials that are somewhere between perfect mirrors and diffuse.
- For each reflection, send several rays – each one offset from the perfect mirror direction by a random vector, calculated by sampling a square perpendicular to the perfect mirror direction.
- Size of square determines amount of blurriness.

Glossy Reflection

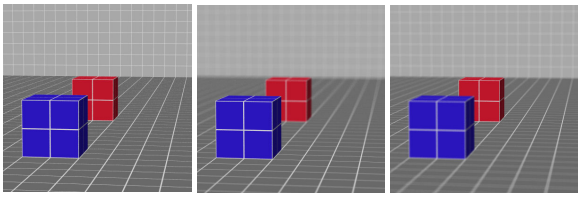


Three spheres with glossiness values of 0, 0.25, and 0.5 (from left to right).

Depth of Field

- Extend the perspective camera with notions of lens size and distance to focus plane.
- For each pixel, shoot multiple rays originating at different points on the "lens", but all going through the same point on the focus plane.
- With a larger lens size, objects get blurrier more quickly as you move away from focus plane.

Depth of Field

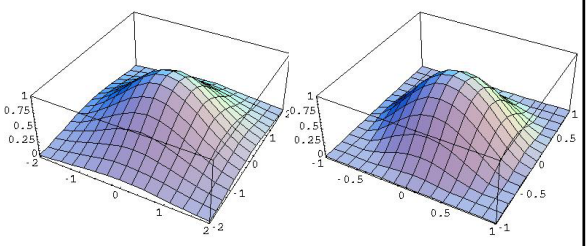


No focus – standard perspective camera

Focus on blue box

Focus on red box

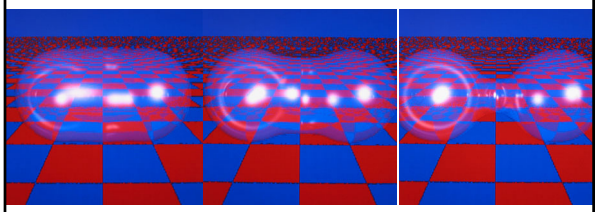
(6) Ilia M.



$f(r) = \exp(-r^2/2)$

$$f(r) = \begin{cases} r < 1: & (1-r^2)^2 \\ r \geq 1: & 0 \end{cases}$$

video…



PLAY VIDEO

(7) Bryan A.

EnvironmentObjects

- EnvSphere and EnvPlane
- Float getDistance(Vec3f pos)
- Vec3f getNormal(Vec3f pos)
- Void paint()

- Each system has an array of EnvironmentObjects, so you can have several in a scene

Basic Collision Detection

```
For each particle
   Update (using the Integrator)
   For each EnvironmentObject
        Calculate time of collision (-1 if no collision)
        if (collision_time >= 0)
              Collision response
```

Backtracking Collision Detection

```
For each particle
   curr_dt = dt
   While (curr_dt >= 0)
        Update (using Integrator) for curr_dt
        For each EnvironmentObject
           Calculate first collision (if any)
        If collision
           Revert to last state (last_pos and last_vel)
           Update system until collision (dt - max_time)
           Collision response
        curr_dt = max_time
```

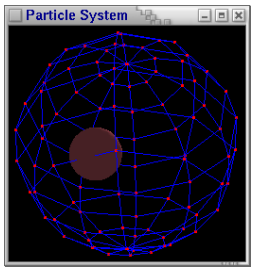
Particle Representation

- Normal particles, spheres, and cubes
- Float collisionTime(EnvObject* envObj)
  - Use envObj->getDistance(…) & ->getNormal(…), last_velocity and radius
- Void collisionResponse(EnvObject* envObj)
  - Mirror reflection
- Void paint()

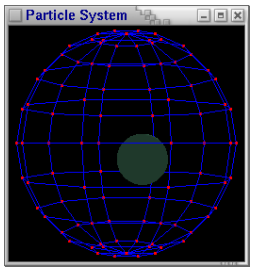
- Cubes consist of a group of six particles set around a center point (only the center point is sent to the Update function)

Backtracking vs. Normal Collision Response

Normal

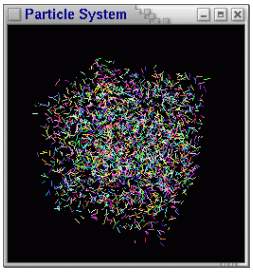


Backtracking

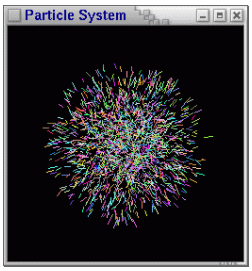


Setup Environments

Cube -> 6 EnvPlanes

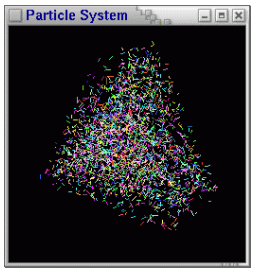


Sphere -> 1 EnvSphere

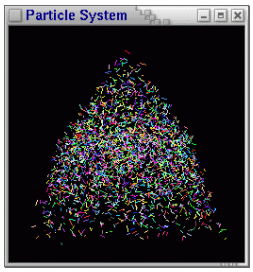


Setup Environments (cont.)

Triangular Bar -> 5 EnvPlanes

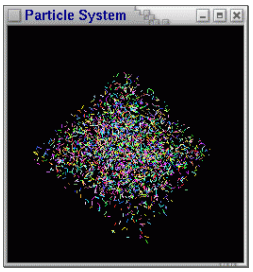


Square Pyramid -> 5 EnvPlanes



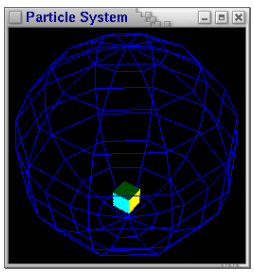
Setup Environments (cont.)

Four-sided Pyramid -> 4 EnvPlanes

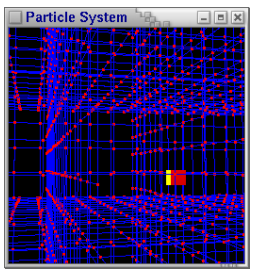


Cube Pics

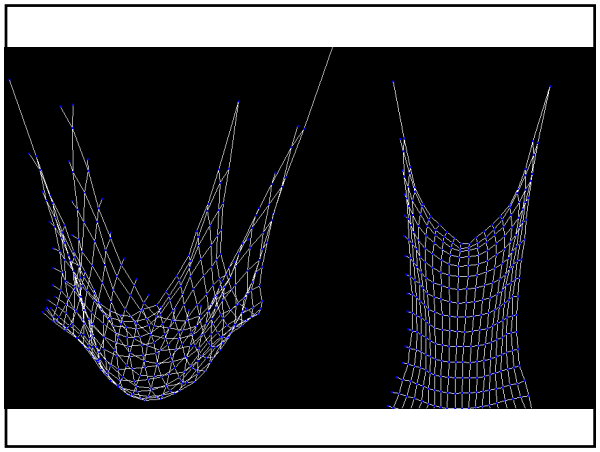
Cube Inside an EnvSphere

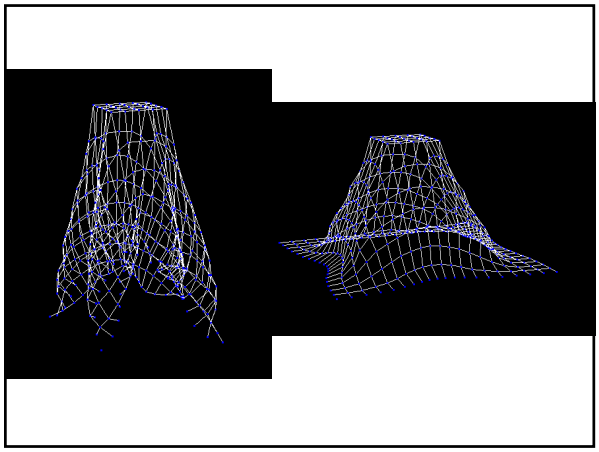


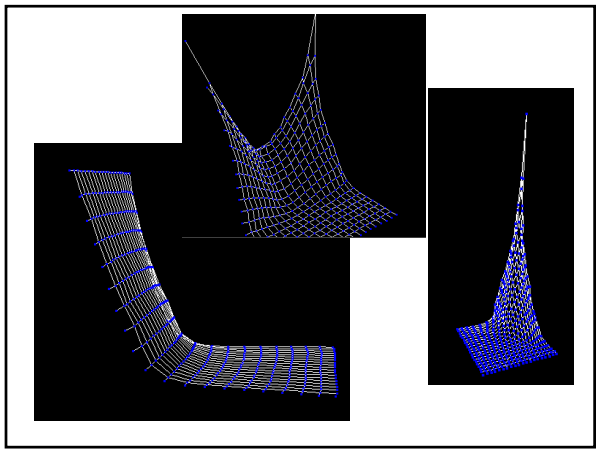
Cube Inside a Cube (6 EnvPlanes)

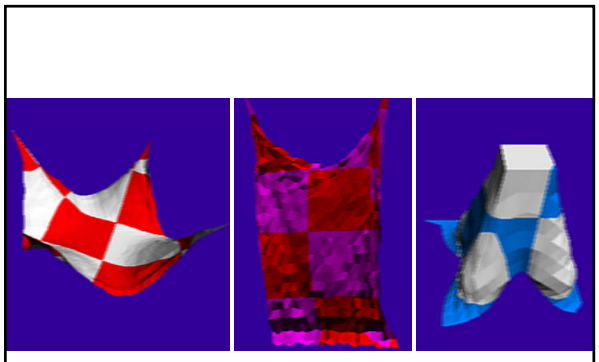


(8) Mariana B.

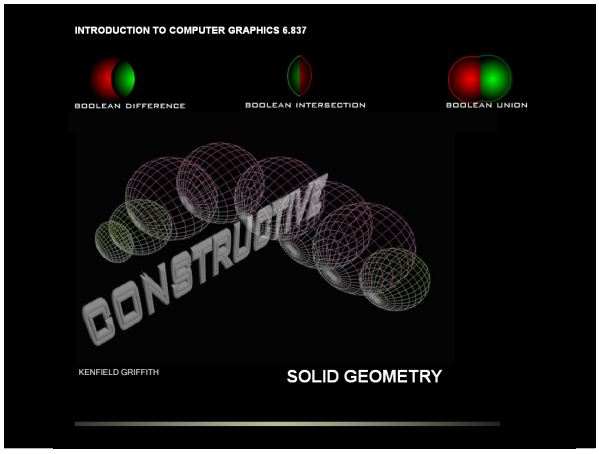


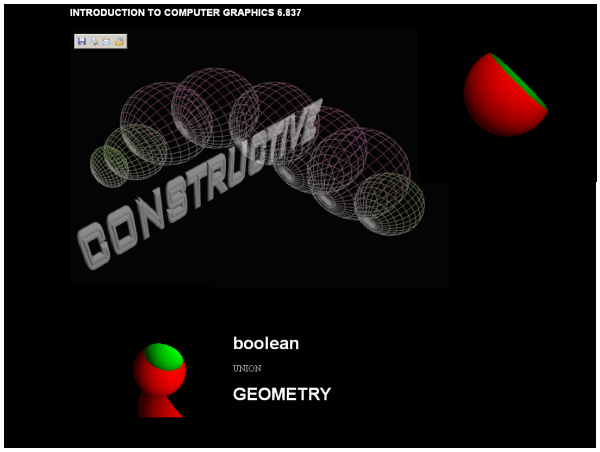


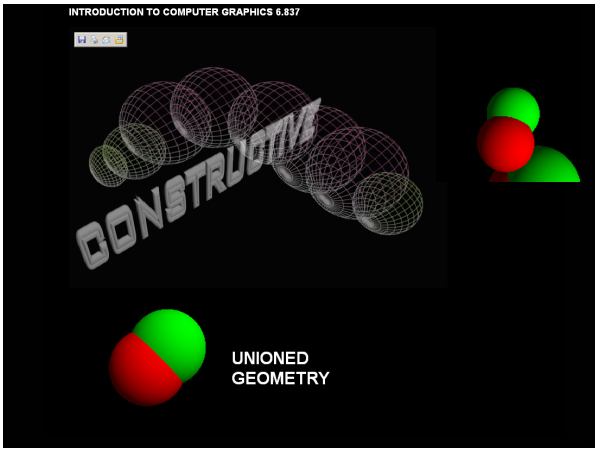


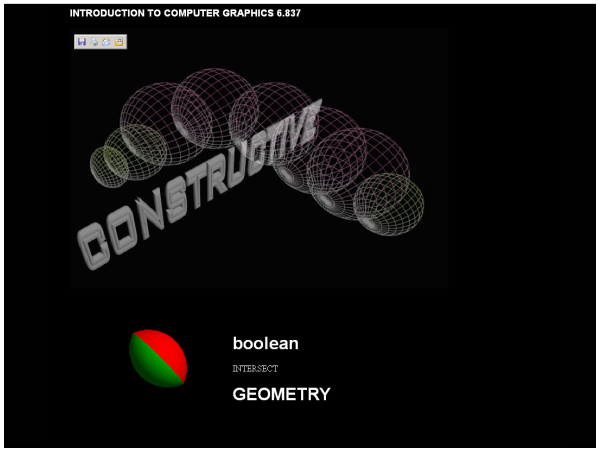


(9) Kenfield G.


INTRODUCTION TO COMPUTER GRAPHICS 6.837
BOOLEAN DIFFERENCE
BOOLEAN INTERSECTION
BOOLEAN UNION
CONSTRUCTIVE
KENFIELD GRIFFITH
SOLID GEOMETRY

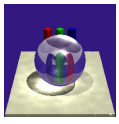
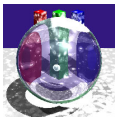




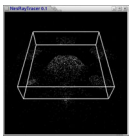
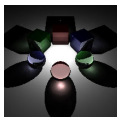


(10) Nestor H.

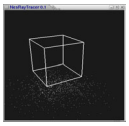
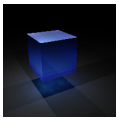
Nestor Hernandez: Photon Mapping

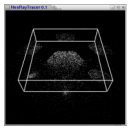
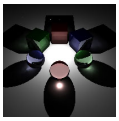
mishaps

10000 photons

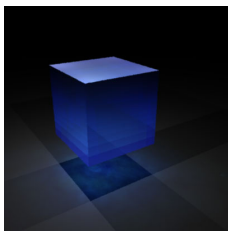
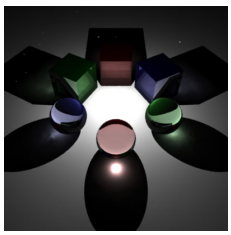



~2500 photons

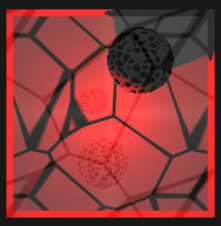
20000 photons

Nestor Hernandez: Photon Mapping

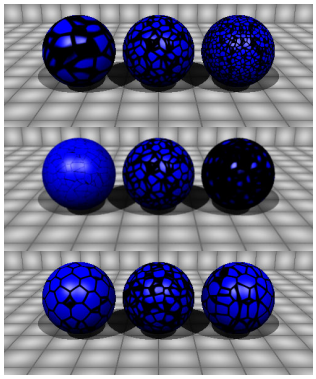
(11) Matthew W.

Cellular Textures

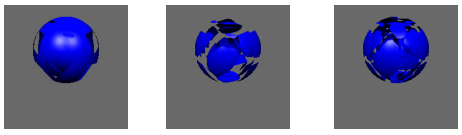


Matthew Webber

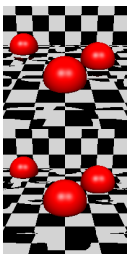
- Scale Transform
- Crack Width
- # of foci

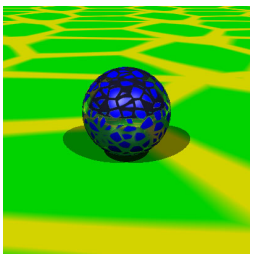


Transparency

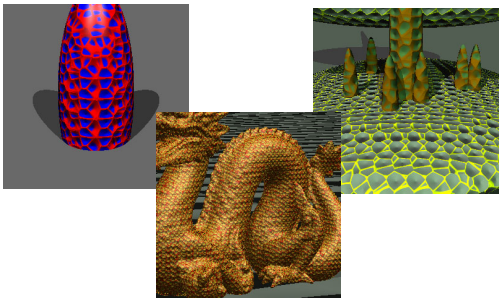


Reflection/Refraction

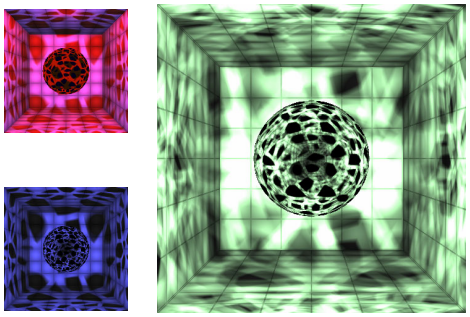




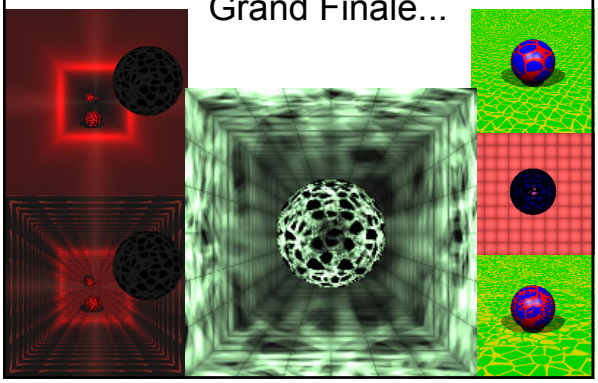
Bump Mapping

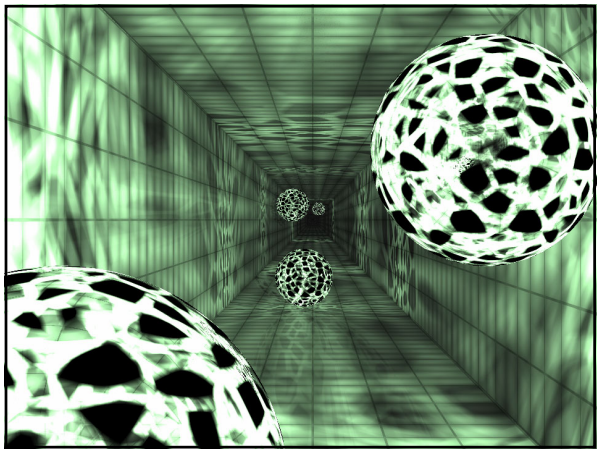


Projective Shadows



Grand Finale...

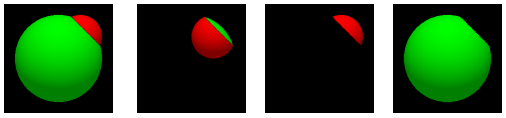




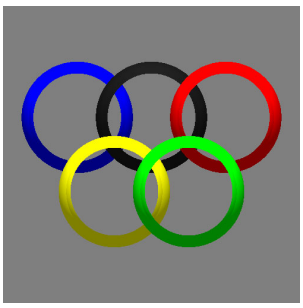
(12) Lawrie G.

Constructive Solid Geometry

- Three operations:
  - Union – all points in object A and all points in object B
  - Intersection – all points in objects A and B
  - Difference – all points in object A but not in object B

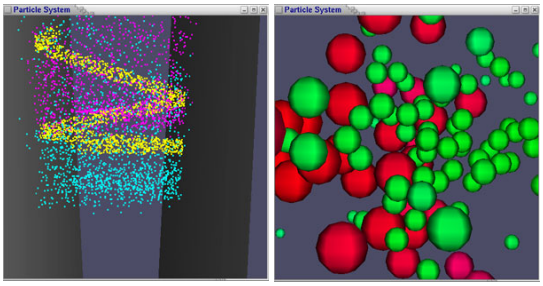


Constructive Solid Geometry



(13) Kevin D.

demo…



(14) Yan(James) P.

Collision Detection

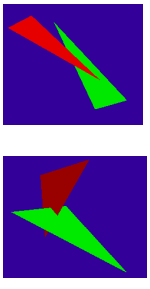
6.837 Final Assignment
By Yan(James) Pang

Introduction

- Importance for physical simulation, e.g. Virtual reality, Augmented reality, etc.
- Most of objects in VR application are defined by triangle meshes
- The important collision problem is to solve the collision between two triangles

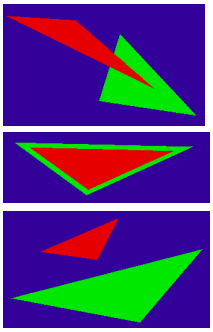
Two Scenarios of Triangle Collision

- Coplanar
- Non-coplanar



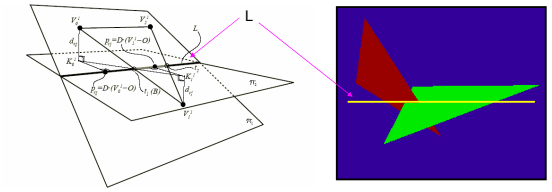
Coplanar Triangles

- Intersection
  - Edge-Edge Collision
    - AB = A + r(B-A)
    - CD = C + s(D-C)
    - Compute r, s A + r(B-A) = C + s(D-C)
    - ? r, s in [0, 1]
- Inside
  - Vertex inside Triangle?
  - Optimal algorithm: reduce dimension (3D to 2D)
- No Collision



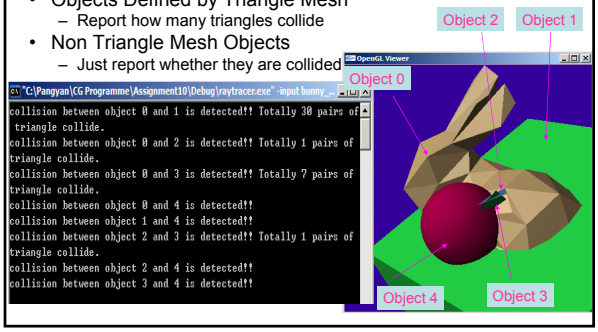
Non-Coplanar Triangles

- Non-coplanar triangles Collision
  - Intersection Line (L)
  - Project the vertex on the Intersection Line
  - Compare the Projected Intervals of vertex



Results

- Objects Defined by Triangle Mesh
  - Report how many triangles collide
- Non Triangle Mesh Objects
  - Just report whether they are collided

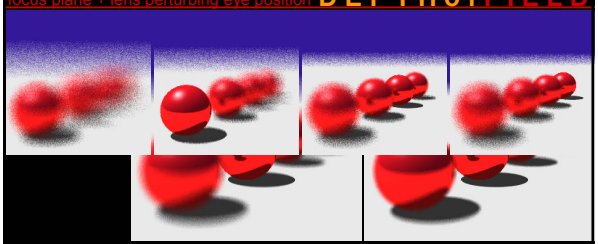


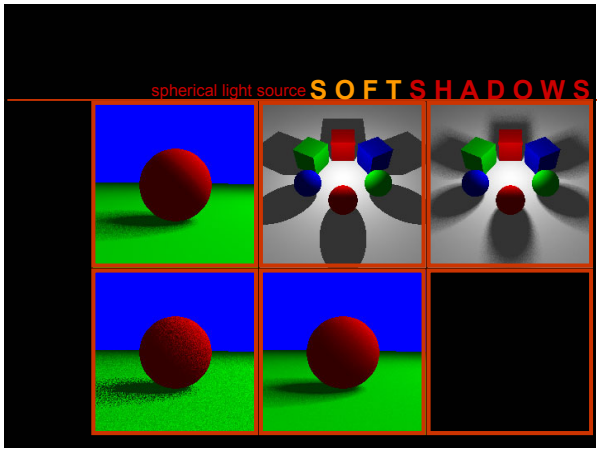
(15) Emily W.

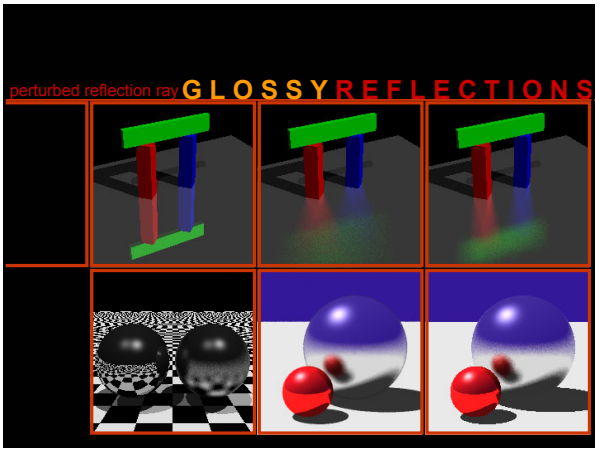
DISTRIBUTION RAYTRACING

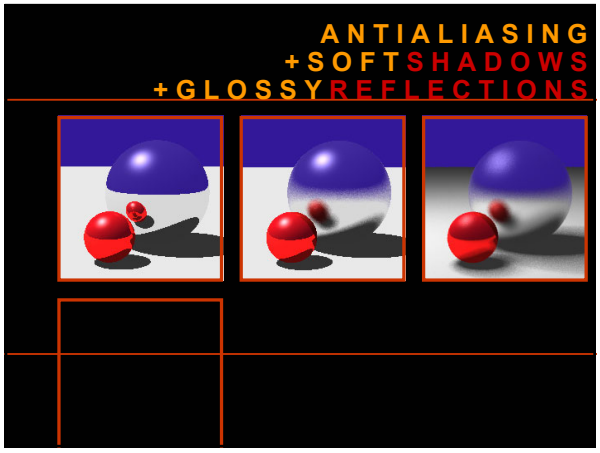
6.837
EMILY WHITING

focus plane + lens perturbing eye position DEPTH of FIELD









(16) Dumitru D.

Ray tracing implicit surfaces

6.837 Lab 10

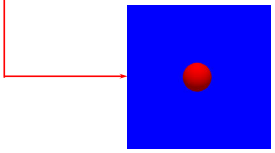
Dumitru Daniliuc

dum_dani@mit.edu

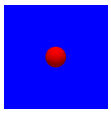
How do we define a surface?

- defined by a polynomial `P(x, y, z) = 0`
- input file:

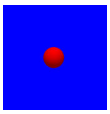
```
surface3d {
    polynomial x^2+y^2+z^2-1
}
```



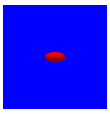
Some images



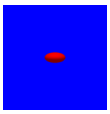
`Sphere` object



`Surface3D` object: `x^2+y^2+z^2-1`



Transformation of a `Sphere` object



`Surface3D` object: `x^2+4*y^2+z^2-1`

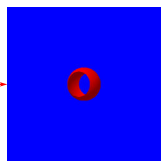
Add “cutting planes”

- Separates the space into two half-spaces
- Exactly one half-space is visible
- The normal determines which half-space is visible

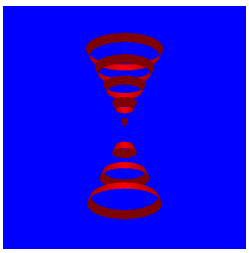
More input file extensions

- Defining a surface with “cutting planes”:

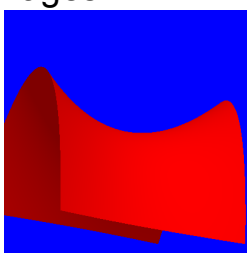
```
surface3d {
    polynomial x^2+y^2+z^2-1
    num_cutting_planes 2
    cutting_plane {
        normal 0 0 -1
        offset -0.7
    }
    cutting_plane {
        normal 0 0 1
        offset -0.7
    }
    planes_conditions 1&2
}
```



More images



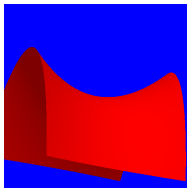
- double cone: `16*x^2+z^2-4*y^2`
- 16 cutting planes
- `planes_conditions`:
  `(1&2) | (3&4) | (5&6) | (7&8) | (9&10) | (11&12) | (13&14) | (15&16)`



- hyperbolic paraboloid: `x^2-z^2-8*y` (with 2 rotations)
- 3 cutting planes
- `planes_conditions`: `1&2&3`

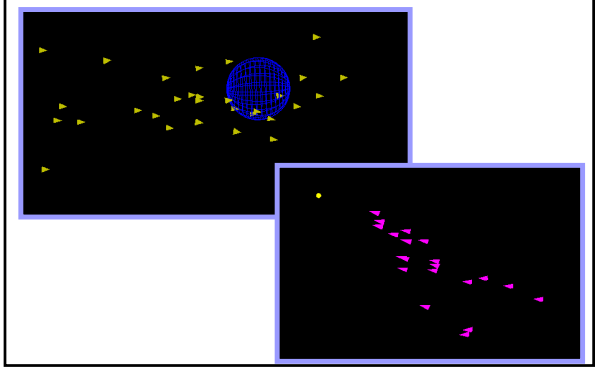
What about solid objects?

- How do you cover the “holes”?
- Adding intersections with the “cutting planes” does not work
- Other easy methods don’t seem to work either
- Find the surface intersection with every “cutting plane”?



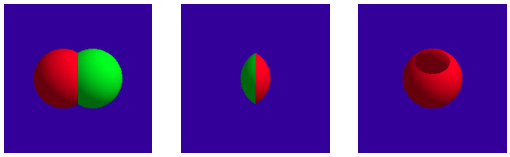
(17) Andrew W.

demo…



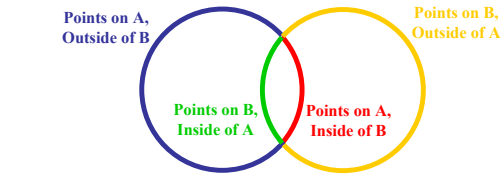
(18) Diane Y.

Constructive Solid Geometry (CSG)

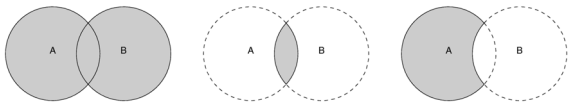


union intersection subtraction

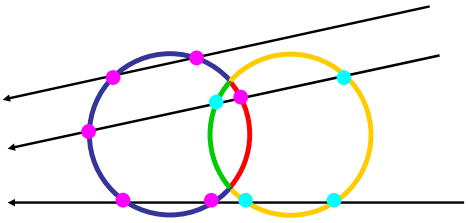
How can we implement CSG?



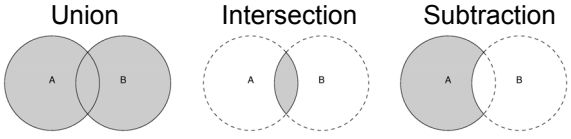
Union Intersection Subtraction



Collect all the intersections

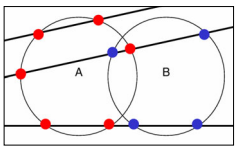


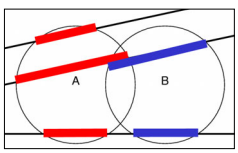
Union Intersection Subtraction



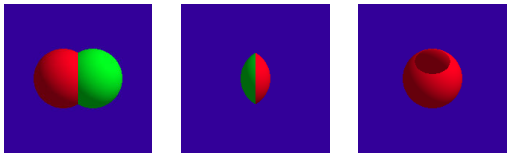
Implementing CSG

1. Test "inside" intersections:
   - Find intersections with A, test if they are inside/outside B
   - Find intersections with B, test if they are inside/outside A
2. Overlapping intervals:
   - Find the intervals of "inside" along the ray for A and B
   - Compute union/intersection/subtraction of the intervals





CSG with spheres

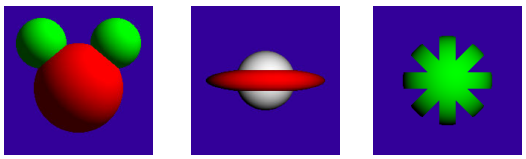


union | intersection | subtraction

CSG with triangles/planes

original | intersection w/ triangles | intersection w/ plane

Nested CSG's



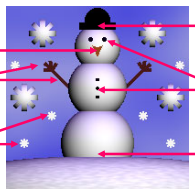
Mickey
Union of 3 spheres

Saturn
Union of sphere and transform

Snowflake ball
Union of 4 transforms, intersection with sphere

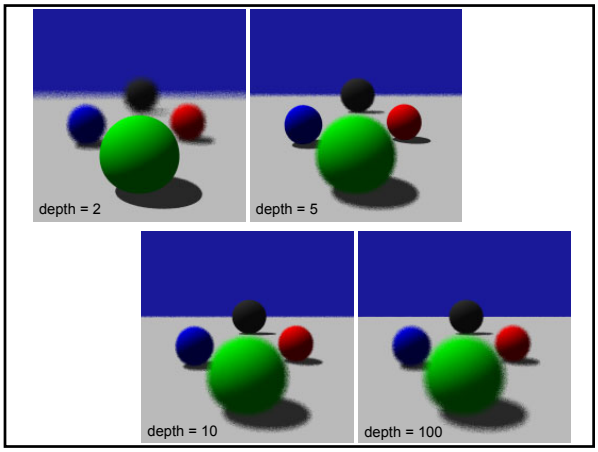
A snowman

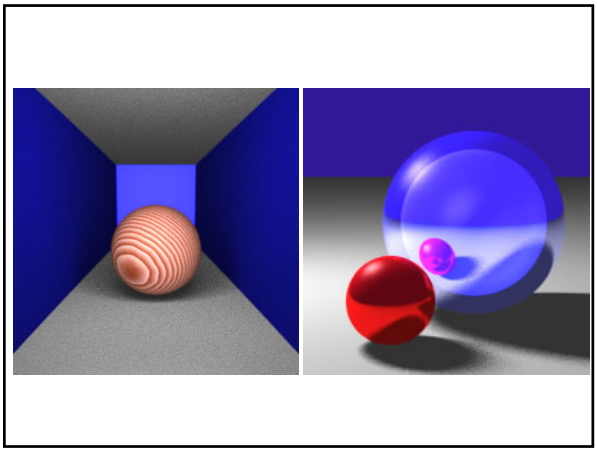
A snowman

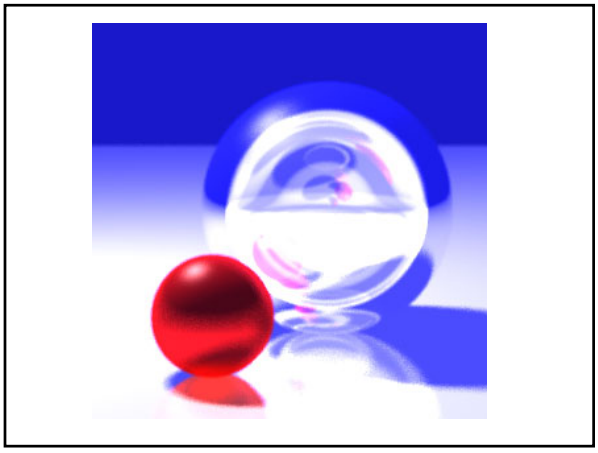


(with noise for the sky and ground)

(19) Abraham E.







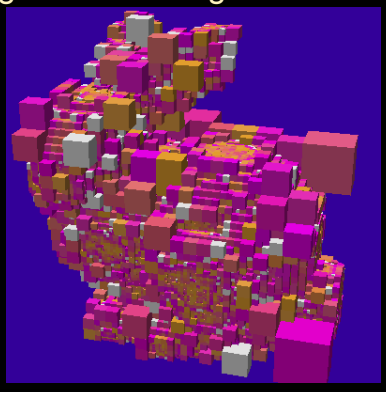
(20) Daniel W.

SUBGRIDS

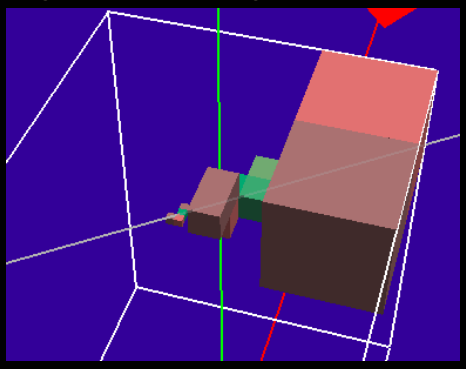
Daniel Wendel

-subgrid edge minD threshold maxD

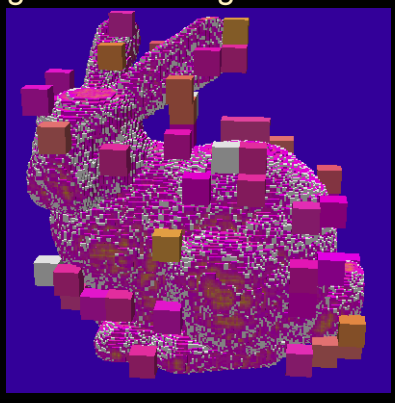
-grid 2 2 2 -subgrid 2 0 16 10



-grid 2 2 2 -subgrid 2 0 16 10

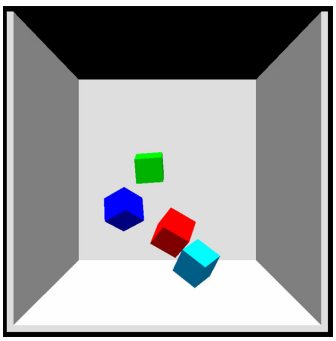


-grid 3 3 3 -subgrid 7 0 18 6



(21) Ioannis T.

demo…



(22) Emily Y.

NPR Post-Processing of Images:

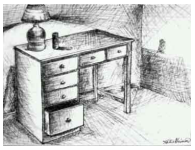
Giving pictures a more personal touch

Emily Yan

December 9, 2004

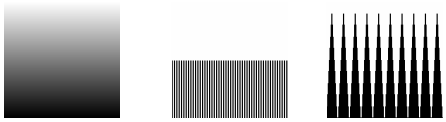
What is NPR?

- NPR = Non-Photorealistic Rendering
- Millions of different effects (AKA PhotoShop filters)
- Original goal: cross-hatch
- Use a sawtooth pattern to compare original grayscale image



Sawtooth Function

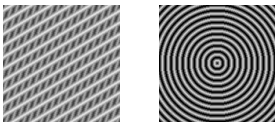
- Linear interpolation of grays
- Careful balance of repeat rate
  - Too high: bands are too wide, unable to catch a great deal of detail
  - Too low: not enough shades of gray, causes it to be difficult to capture differences in color



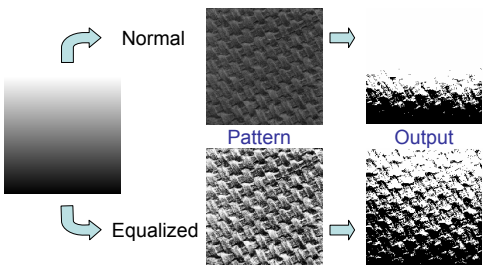
Original | Rep rate: 4 | Rep rate: 20

Options

- Horizontal/Vertical Bars
  - Slope
  - Scale
  - Offset
- Mesh
- Rings
- Stipple



Equalization Required

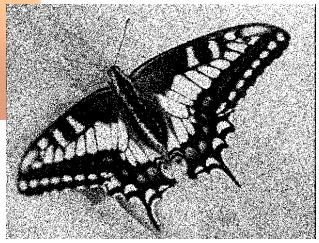


Sometime your pattern is just too dark…

Eye Candy

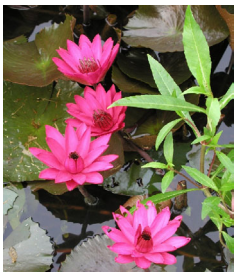
Uses mesh, equalize

Eye Candy



Stipple effect

Eye Candy



Uses rings

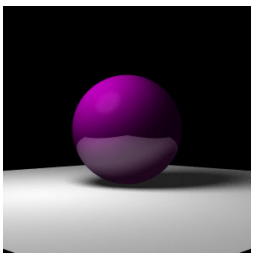
(23) Tom H.

Distribution Ray Tracing Effects

Tom Hoover
6.837

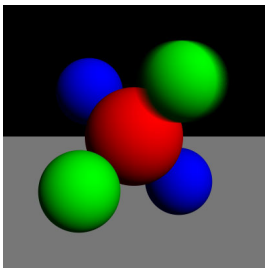
Soft Shadow

- Finite sized lights
- For each intersection sample over light
- Sampling over cone, not uniform distribution



Motion Blur

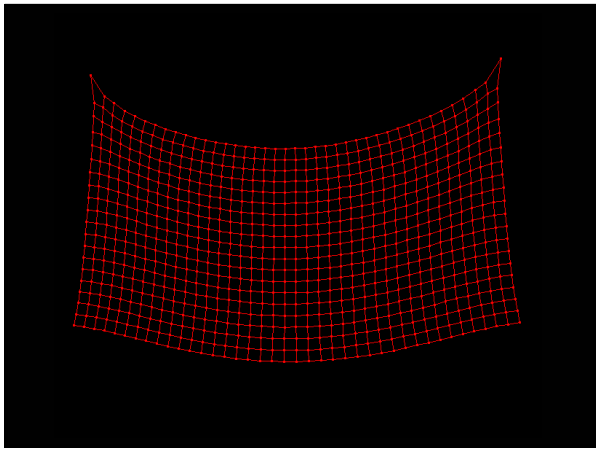
- Give ability for objects to have a start and an end point
- Keep track of time during the entire ray casting process
- For each pixel, sample over random time

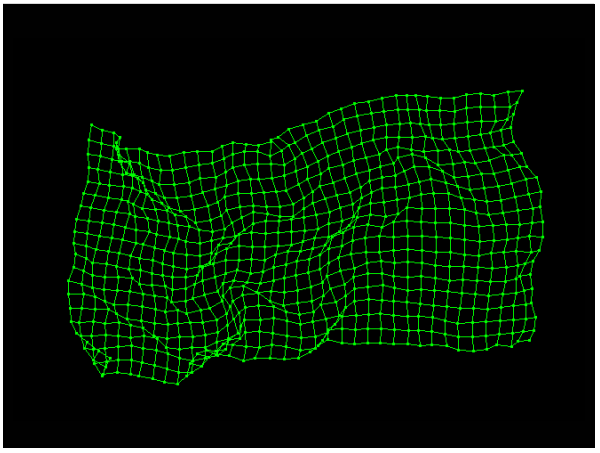


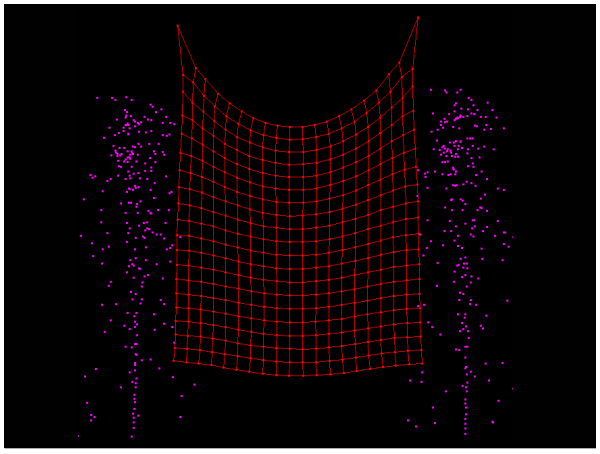
Glossy Materials

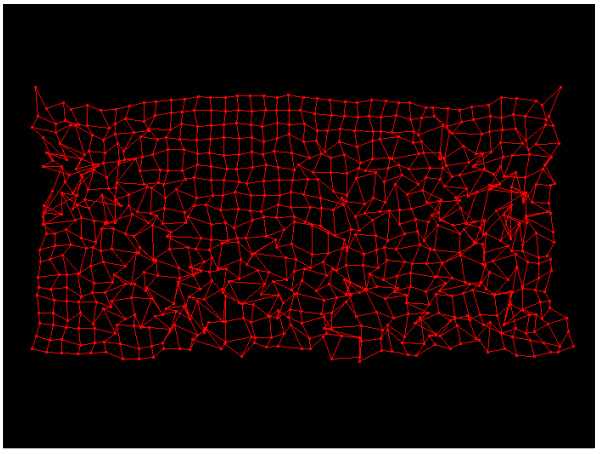
- Simulate the imperfections in surfaces
- Perturb reflected rays and continue to trace
- Sample using uniform distribution (over normal plane to reflected ray)

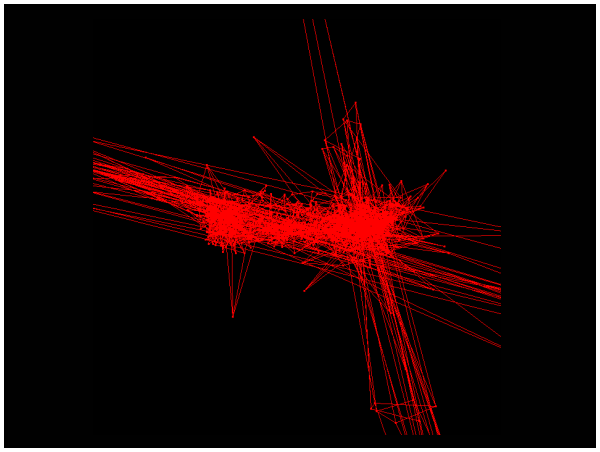
(24) Eric L.





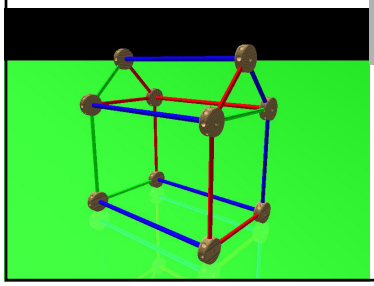






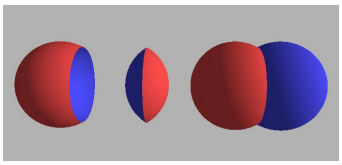
(25) Rohit R.

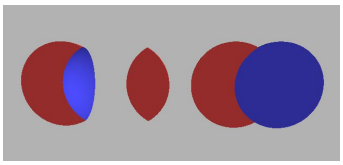
CSG



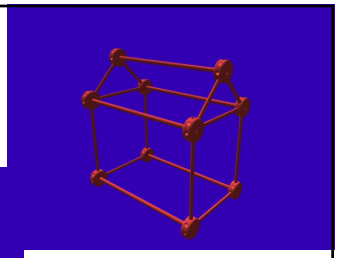
Rohit Rao
6.837
12/9/04

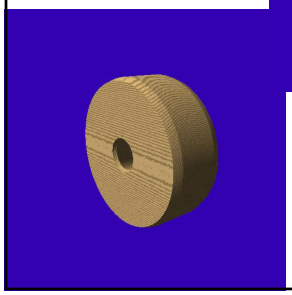
CSG Operations





Tinkertoys



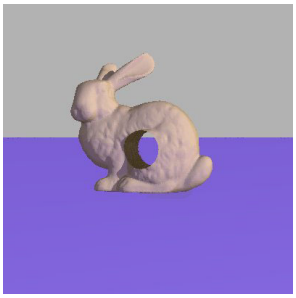


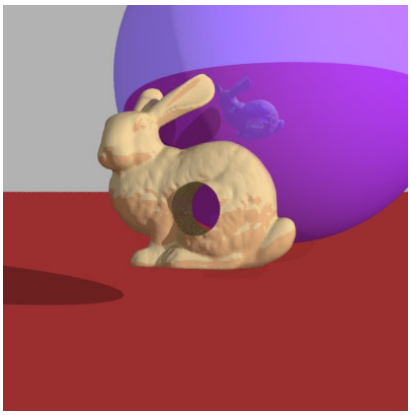
Why my CSG sucks

- Scenes get very complex, very fast
  - Tinkertoy house was ~2000 lines
- Can't really use grid acceleration
  - Difference(40k bunny, cylinder)

Grid Acceleration

- Solution: put the Grid inside the CSG object





(26) Annie D.

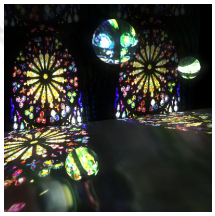
Lighting Stained Glass

Texture Mapping
Transparent Shadows
Volumetric Raytracing

Annie Ding
December, 2004

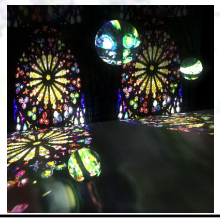
Texture Mapping

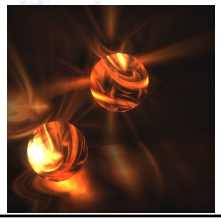
- Map coordinates from bitmap image onto primitives



Transparent Shadows

- Extension of assignment 4
- Accumulate transparent color as shadow ray passes through objects

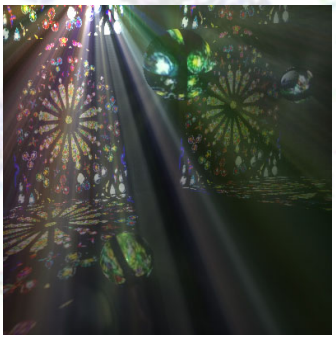


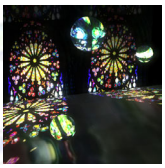


Volumetric Raytracing

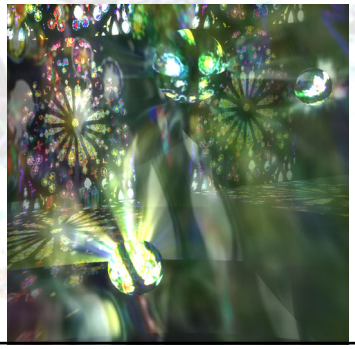
- Dust/smoky effect - to show light rays
- Incrementally step along the rays cast, shooting additional rays towards the light sources
  - Accumulate color over the ray by using exponential function: e^Density*step_length

Eye Candy





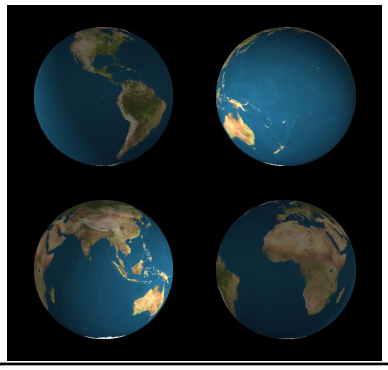
Eye Candy



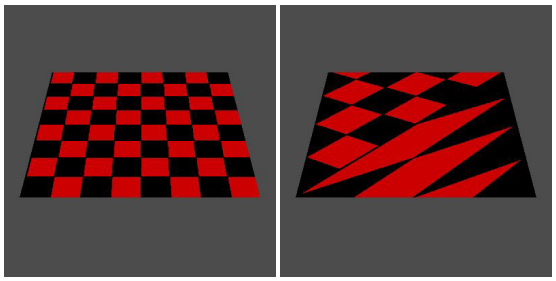
Eye Candy

(27) Jim G.

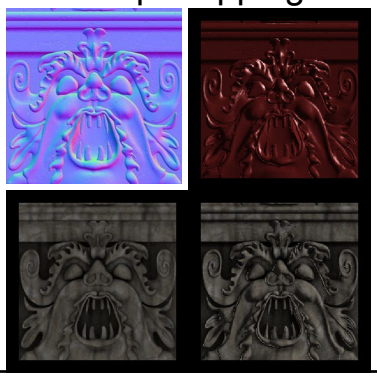
Sphere Texture Mapping



Triangle Texture Mapping



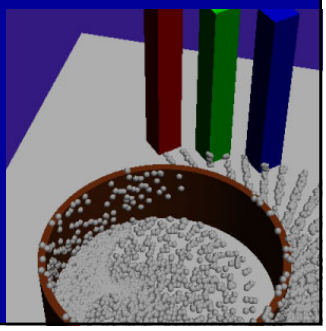
Bump Mapping



(28) Mike M.

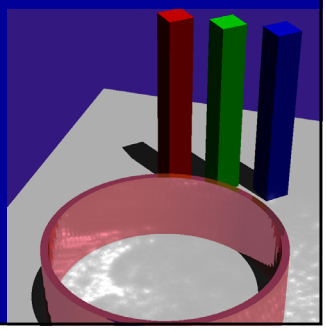
Pass 1: Photon Tracing

- Create photons from PhotonSources
- Trace photons through the scene using tracePhoton()
- When a photon hits a diffuse surface, store it in PhotonMap



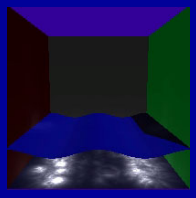
Pass 2: Rendering

- Render image using the standard ray tracing algorithm, but now add photon contributions
- radianceEstimate() calculates color contribution at each hit point using data in PhotonMap



Animated Water Demo

- Animate.exe creates a sequence of frames simulating water waves
- 1000 photons / 10 samples per pixel
- 24 frames
- 20 minutes on 6 Xeon 2.0ghz workstations



Index of Refraction Demo

- Animate.exe varies index of refraction (0.8-2.8) and rotation angle
- 5000 photons / 15 samples per pixel
- 96 frames
- 17 minutes on 6 Xeon 2.0ghz workstations

The End

Great Job Everyone!