Point-Based Global Illumination for Movie Production

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SIGGRAPH 2010 Course

PIXAR

Overview

- Point-based global illumination
  - generating direct illumination point cloud
  - rendering GI using point cloud
- Examples of use in movies
- Variations and extensions
- What's next?

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Related work

- Method is inspired by Bunnell's point-based GPU method
- Related to clustering radiosity and point-based subsurface scattering

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Point-based global illumination

- Fast, low memory, no noise
- Handles complex geometry (including dense polygon meshes, hair, leaves, displacement), many light sources, complex surface shaders, ...
- Movie-production friendly
- Part of Pixar's RenderMan renderer

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Point-based global illumination

- Three steps:
- Generate point cloud of directly illuminated surface colors (radiosity)
- Organize points into octree; larger points and spherical harmonics
- Render: compute diffuse/glossy global illumination at each shading point

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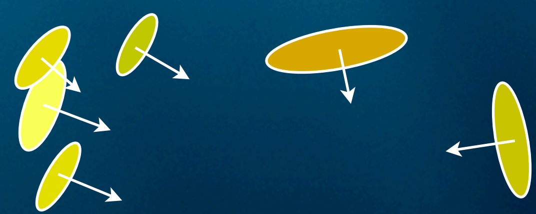
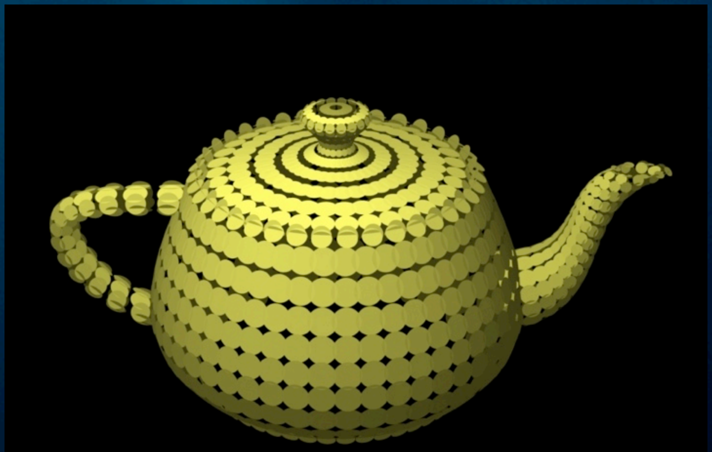
A point cloud

- Each point: position, normal, radius, color = a colored disk



point cloud



point cloud

- Terminology: “point” or “disk” or “surfel”?

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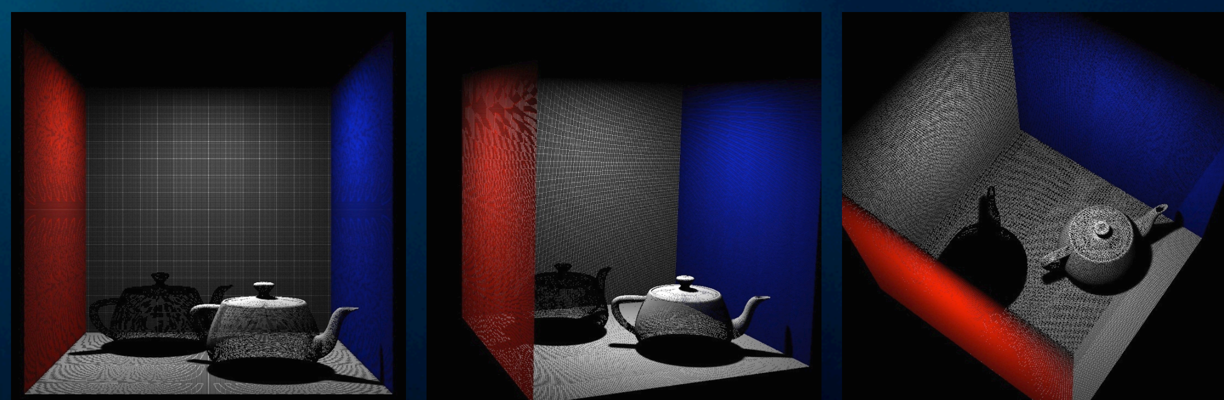
Generate point cloud

- Render direct illumination image
- Generate point cloud file at same time

rendered image



point cloud, 560K points (various views)

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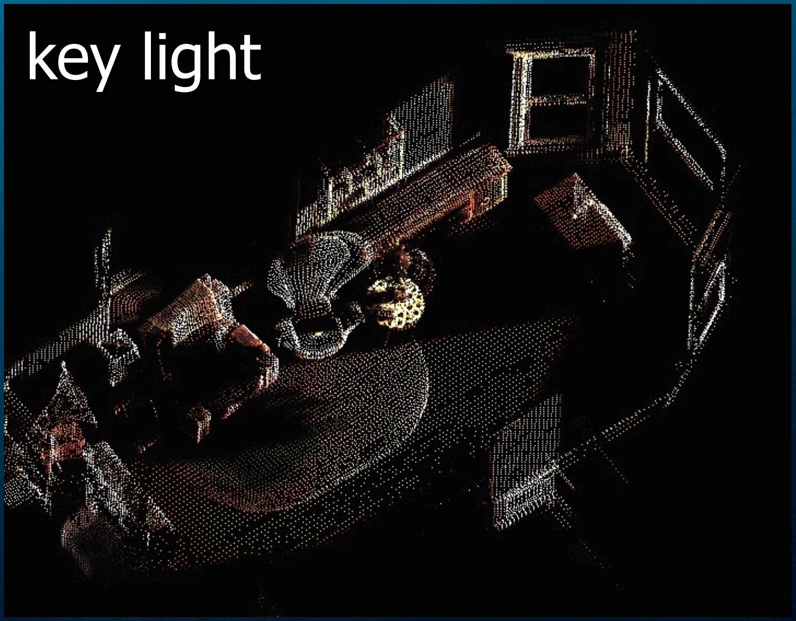
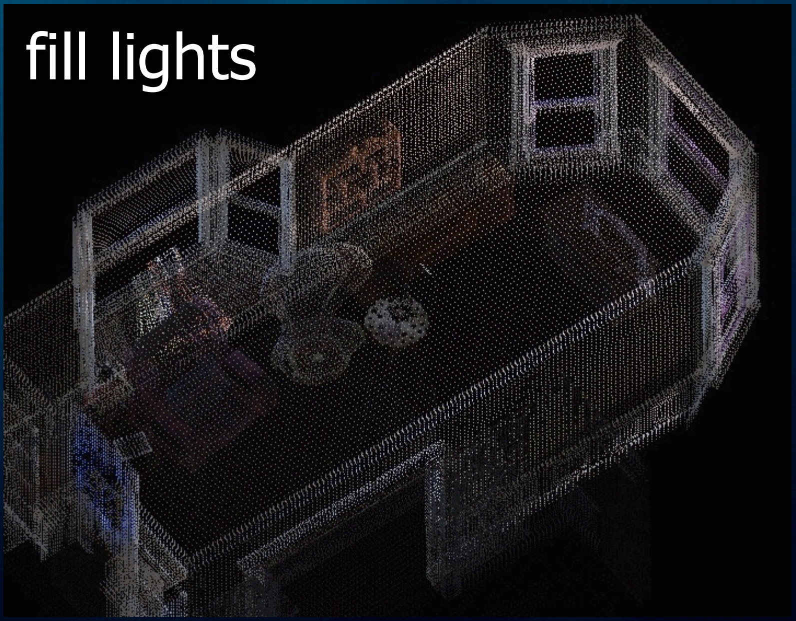
Generate point cloud

- Point cloud files from “Up”





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Organize points into octree

- Organize points into octree
- Each cluster of points is represented by a larger point or a spherical harmonic representation of directional light distribution

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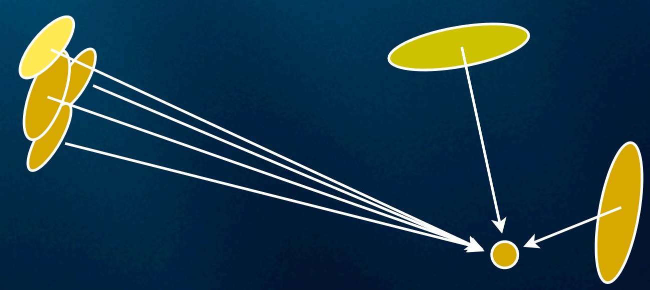
Compute global illum at a point

- Basic idea: add up color from all other points!



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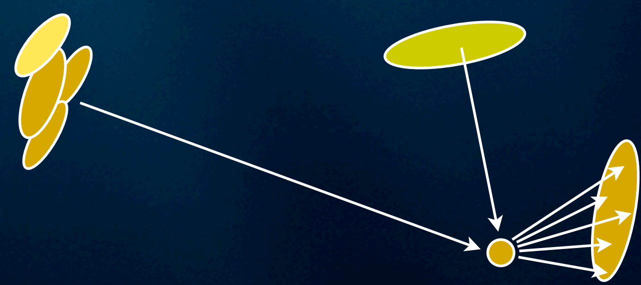
Compute global illum at a point

- For efficiency: use cluster of points for distant points
- For higher accuracy: ray trace close points



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Compute global illum at a point

- Problem: if all points are added up, even points "hidden" behind other points will contribute

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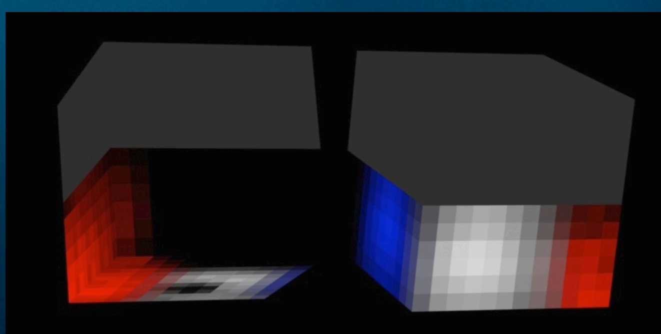
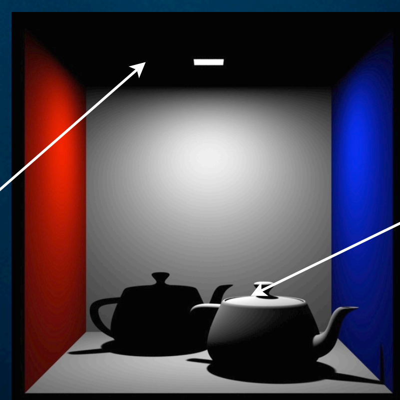
Compute global illum at a point

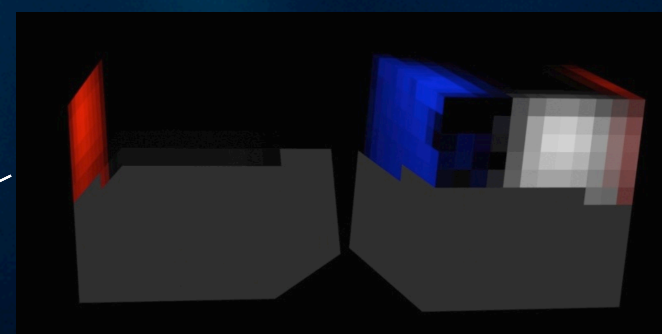
- Solution: rasterize colors contributing to a point -- world “as seen” by that point

- Raster cube examples:



point on ceiling





point on teapot lid

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Compute global illum at a point

- Multiply all raster pixel colors by reflectance function (BRDF); add
- Result is diffuse / glossy reflection at point

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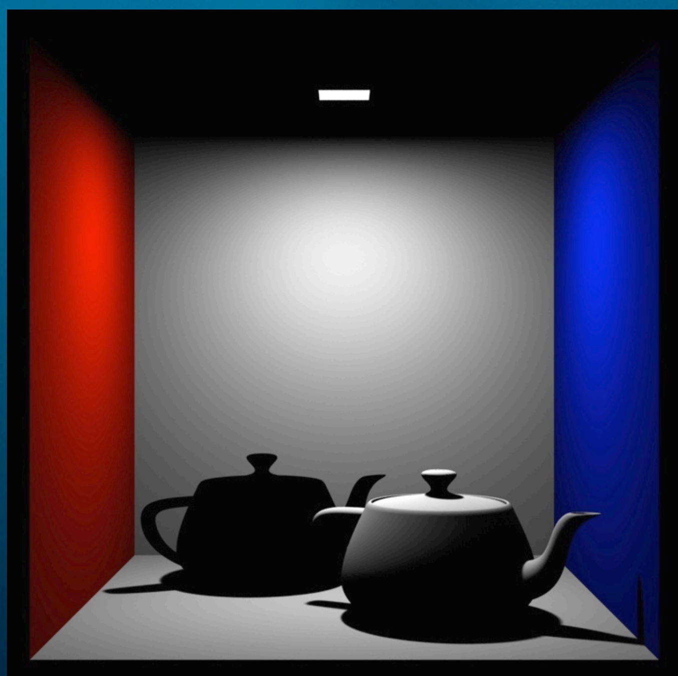
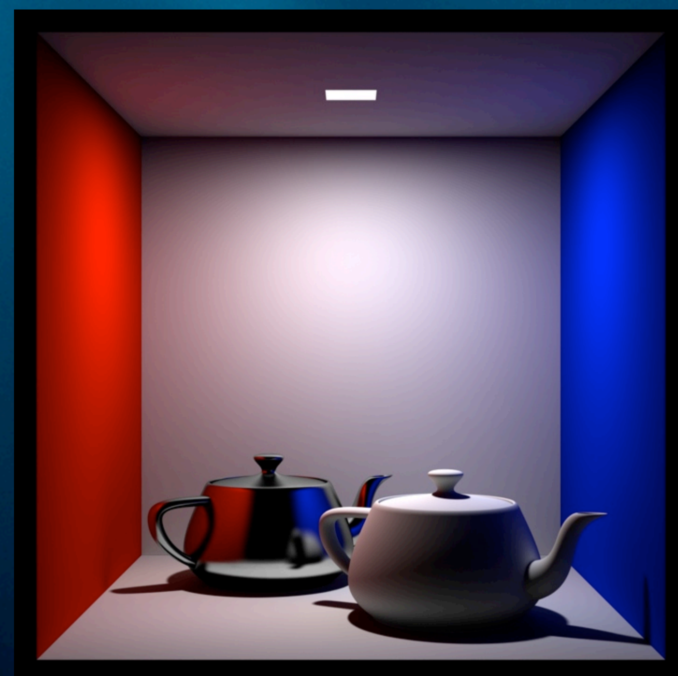
Global illumination result



direct illum (9 sec)



direct illum + diffuse GI + glossy GI (21 sec)

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Use in movies

- Implemented in Pixar's RenderMan
- Integrated into lighting pipeline at ILM, Pixar, Disney, DNeg, MPC, ...

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Use in movies

- Pirates of the Caribbean 2 & 3, Eragon, Surf's Up, Spiderman 3, Harry Potter 5 & 6, Chronicles of Narnia, Fred Claus, Beowulf, Spiderwick Chronicles, Ironman 1 & 2, Indiana Jones, 10,000 BC, Batman: Dark Knight, Quantum of Solace, Cloverfield, Doomsday, Hellboy 2, Inkheart, Wall-E, Bolt, Star Trek, Terminator 4, The Boat that Rocked, Fast & Furious 4, Angels and Demons, Night at the Museum, Up, Transformers 2, 2012, Sherlock Holmes, Percy Jackson, The Green Zone, Prince of Persia, Toy Story 3, ...

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Sony: "Surf's Up" ambient occlusion

"Surf's Up" test (Courtesy of Rene Limberger, Sony)

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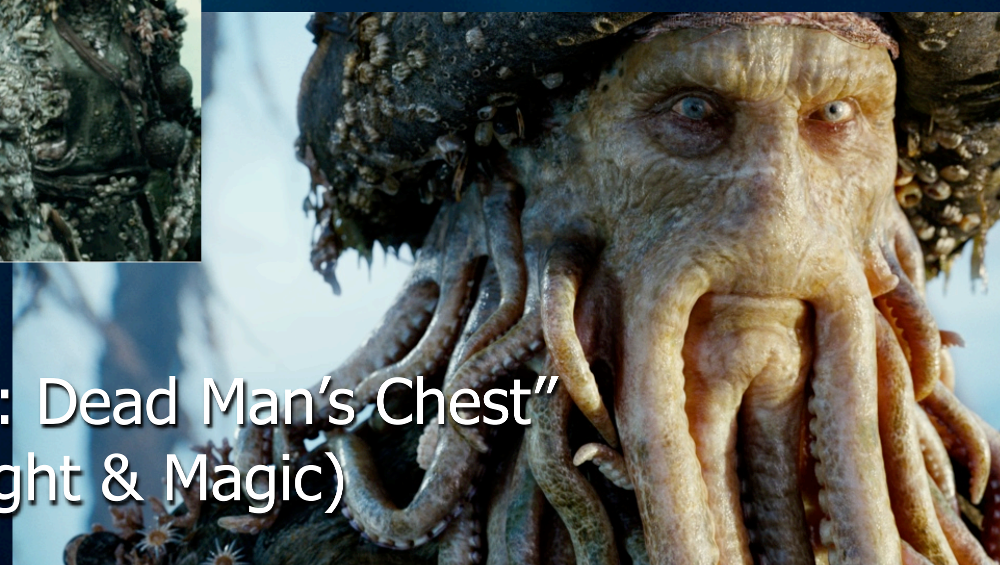
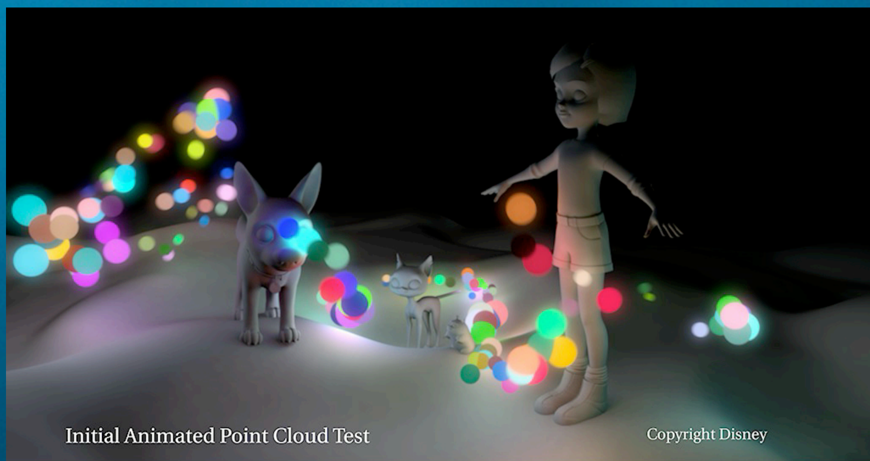
ILM: Davy Jones



"Pirates of the Caribbean: Dead Man's Chest"
(Courtesy of Industrial Light & Magic)

Disney: special effects on "Bolt"



(Courtesy of Dale Mayeda, Disney)

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“Up” example without global illum

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"Up" example with global illum

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"Up" example without global illum

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"Up" example with global illum

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“Toy Story 3” examples

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“Toy Story 3” examples

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"Toy Story 3" examples

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"Toy Story 3" examples

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"Toy Story 3" examples

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"Toy Story 3" examples

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Variations and extensions

- Area light sources
- Environment illumination
- Multiple light bounces
- Final gather for photon maps
- Ambient/directional/reflection occlusion
- Volumes

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Area light sources + soft shadows

- Treat area light sources the same as surfaces: generate point cloud with color data
- Light sources can have arbitrary shape and colors
- Also write (black) points for shadow-casting objects

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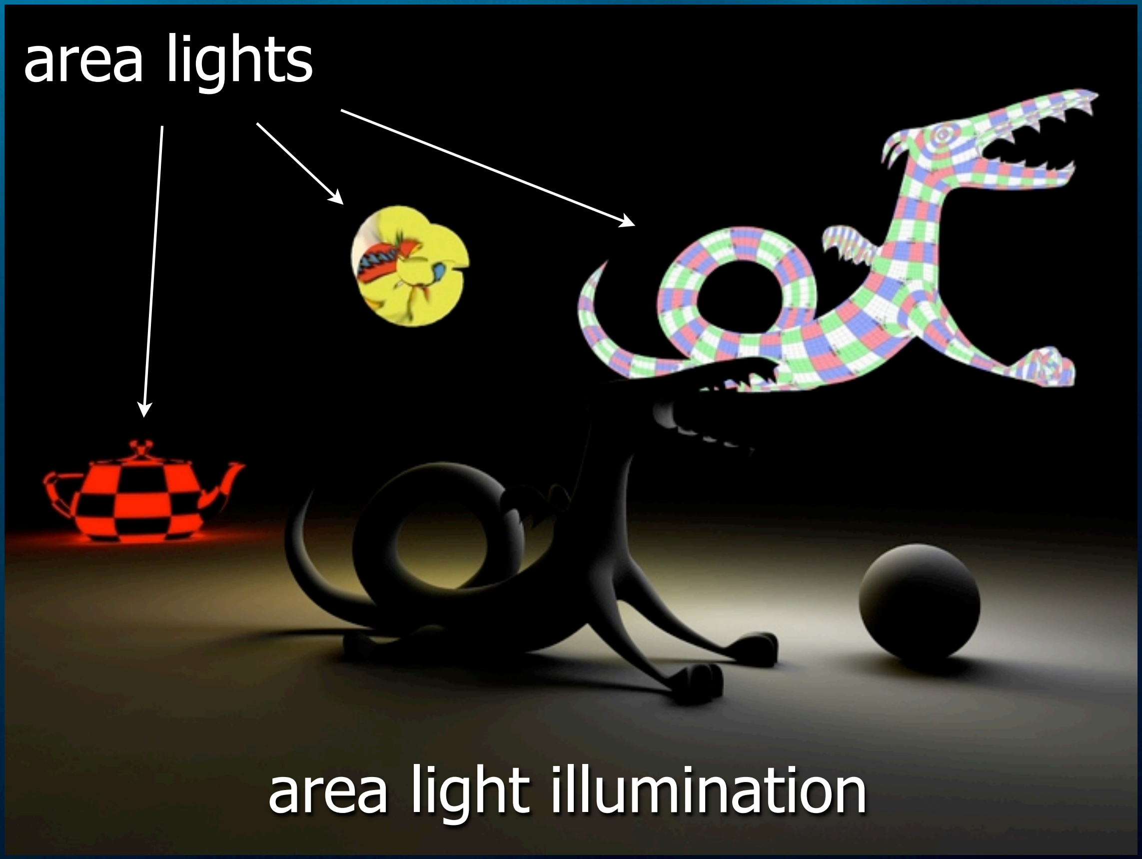
Area light sources + soft shadows



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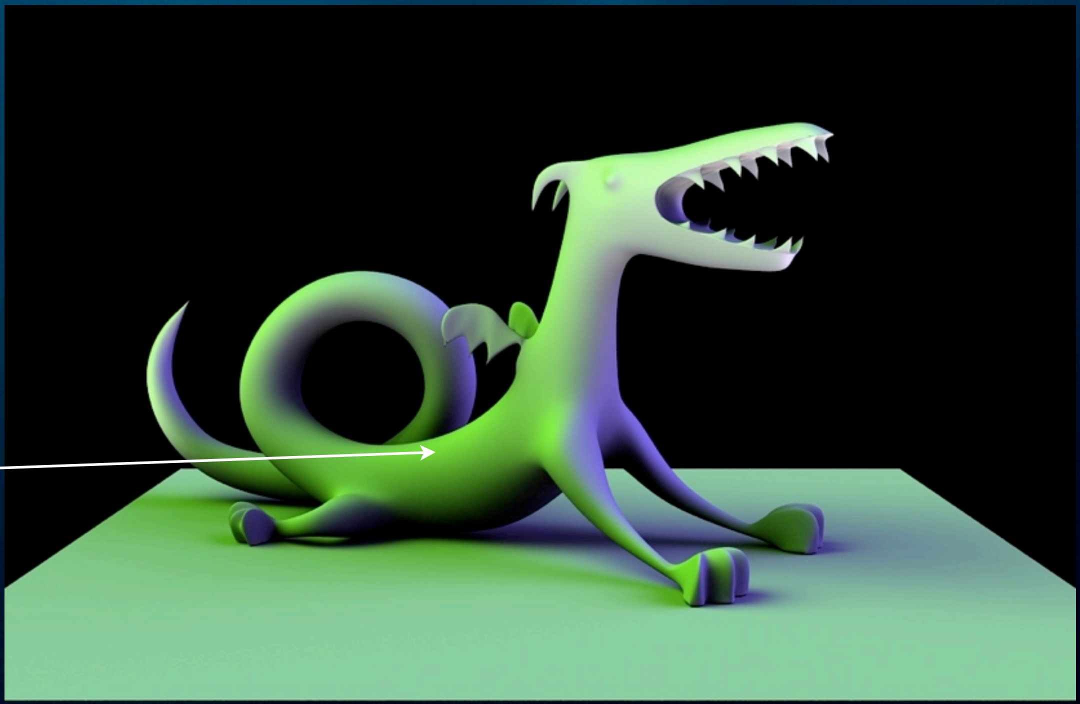
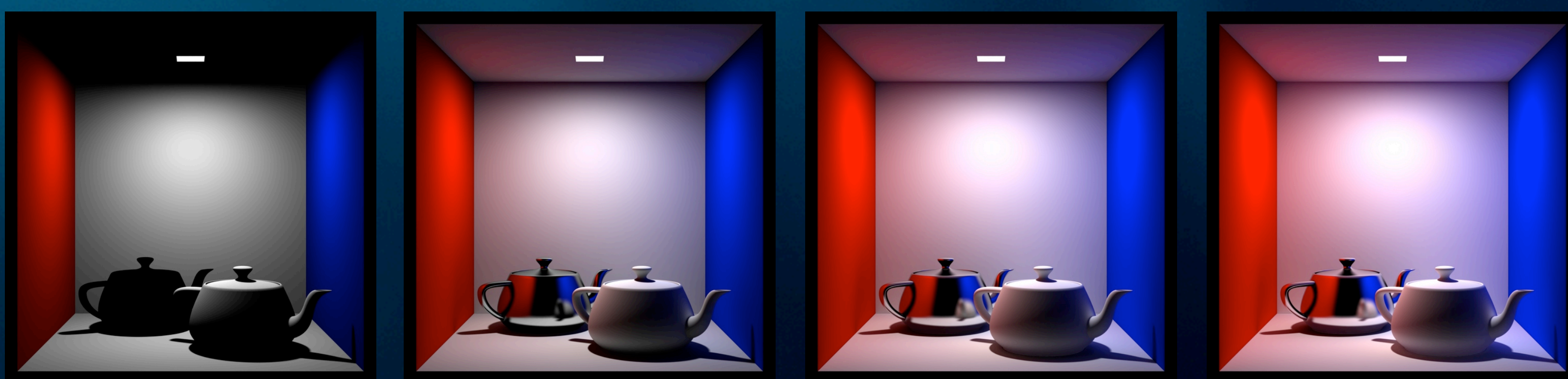
Environment illumination -- IBL

- Use environment color for raster pixels not covered by points



Multiple light bounces

- Run the algorithm n times
- (For efficiency: first n-1 times can be computed at fewer points)



$n = 0$ $n = 1$ $n = 2$ $n = 3$

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Final gather for photon mapping

- Final gather step is usually done with ray tracing; slowest part of photon mapping
- Use point-based method instead

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Final gather for photon mapping

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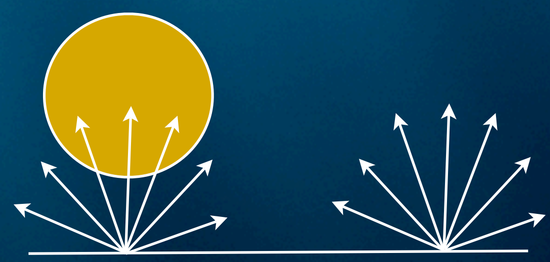
Special case: Ambient occlusion

- Fraction of hemisphere above a point that's covered



- Similar to shadows on overcast day
- Values between 0 and 1

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Ambient occlusion

- Generate point cloud with only position, normal, radius (no colors)

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Ambient occlusion

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Ambient occlusion (and reflections)

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NEW: Image-based relighting

- In addition to ambient occlusion, also compute directional visibility: spherical harmonic coeffs. at each point
- Compute SH coeffs for environment map
- (Re-)rendering is just multiplying SH coefficients -- 9 or 25 mults/point. Fast!

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NEW: Image-based relighting

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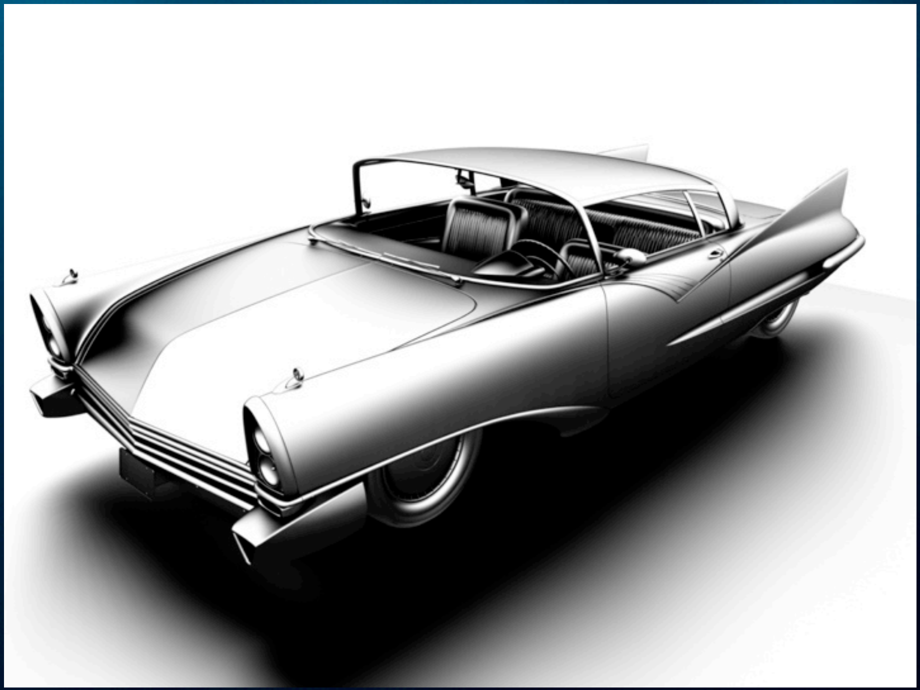
Special case: reflection occlusion

- As ambient occlusion, but narrow cone of directions (around reflection direction)



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Global illumination in volumes

- Points don’t have normals: spheres, not disks
- Illumination from all directions: entire raster cube
- surface ↔ volume
- volume ↔ volume

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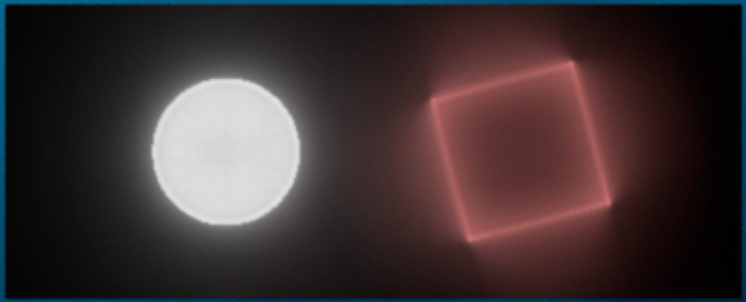
Global illumination in volumes



surface to volume

volume to volume

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Optimization: interpolation

- If the color bleeding varies only a little in an area (<2%), we simply interpolate it
- Technique known from ray tracing ("irradiance cache")

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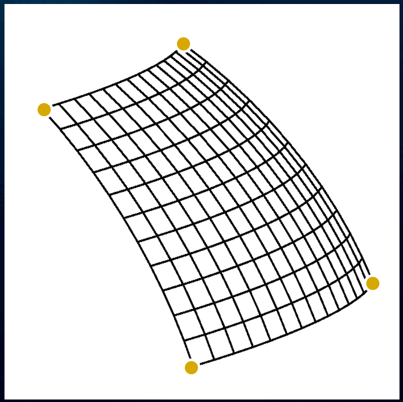
Optimization: interpolation

- Compute color bleeding at the 4 corners of surface patch
- Is the difference between 4 values small?
  - yes: interpolate on patch
  - no: split patch in 2; recurse



surface patch

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Parallel computation

- Global illumination at each point is independent
- Ideal for parallel execution
- Observed speedups:
  - 4 cores: ~3.6
  - 8 cores: ~6.6

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More information

- M. Bunnell, “Dynamic ambient occlusion and indirect lighting”, GPU Gems 2
- P. Christensen, “Point-based approximate color bleeding”, Pixar tech memo #08-01
- T. Ritschel et al, “Micro-rendering for scalable, parallel final gathering”, SIGGRAPH Asia 2009

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Summary

- Point-based diffuse and glossy global illumination is fast and can handle complex production scenes
- Also works for area lights, env. map illumination, multiple bounces, ambient occlusion, reflection occlusion, volumes
- In Pixar's RenderMan
- Widely used in production

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What's next?

- "Up" and "Toy Story 3": 1-bounce PBGI was used in addition to all the traditional lights
- Next:
  - reduce number of traditional lights?
  - multiple bounces?

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What's next?

- Implementation improvements:
  - improved accuracy in rasterization?
  - baking micropolygon grids?
  - GPU implementation?

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Acknowledgments

- RenderMan team: Dana Batali, ...
- Mike Bunnell, Rene Limberger, Christophe Hery
- Pixar: Max P, P Sumo, JC, Stefan, Guido, ...
- Dale Mayeda (Disney), Philippe Leprince (DNeg), Anders Langlands (MPC), ...

Thanks!

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Questions?

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