Point-Based Color Bleeding

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Overview

- What is color bleeding?
- Other computation methods
- Point-based color bleeding
  - generating direct illumination point cloud
  - rendering using point cloud
- Examples of use in movies
- Variations and extensions

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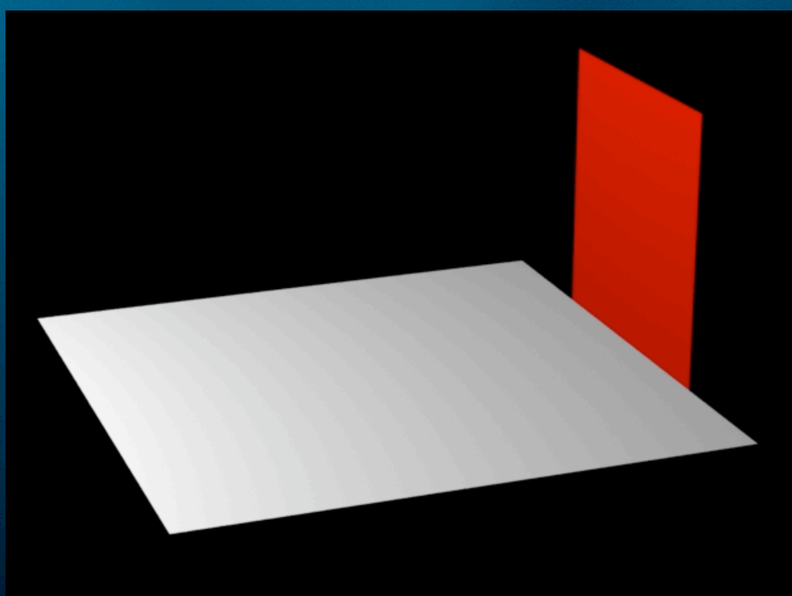
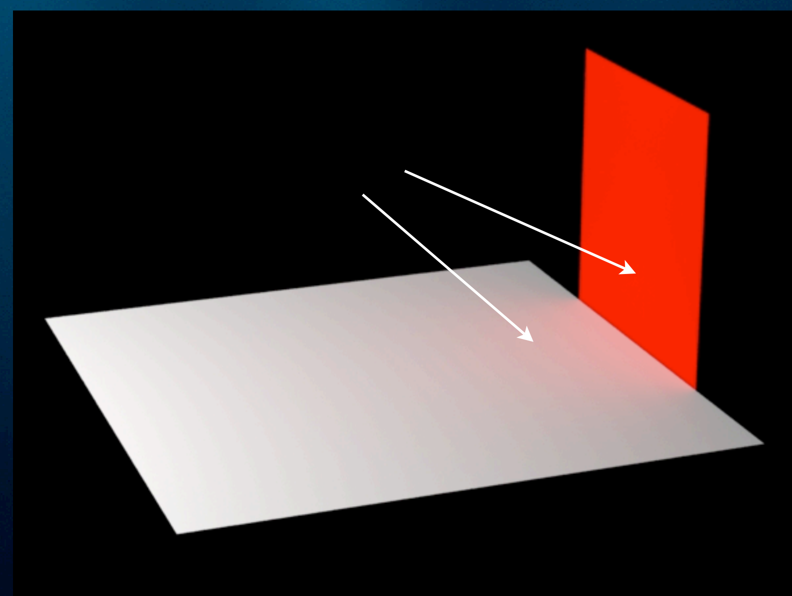
Color bleeding

- Soft indirect illumination between matte surfaces





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Computation methods

- Faking it: adding extra light sources
  - tedious; labor intensive
- Radiosity (finite elements)
  - requires entire scene geometry in memory
- Ray tracing
  - requires many rays + shader evaluations: slow
- Point-based
  - little memory, no shader evaluations

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Computation methods

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Point-based color bleeding

- Handles complex geometry (including dense polygon meshes, hair, leaves, displacement), many light sources, complex surface shaders, ...
- Very movie-production friendly
- Part of Pixar's RenderMan renderer

Point-based color bleeding

- Two steps:
- Generate point cloud of directly illuminated surface colors (radiosity)
- Render: compute color bleeding at each shading point

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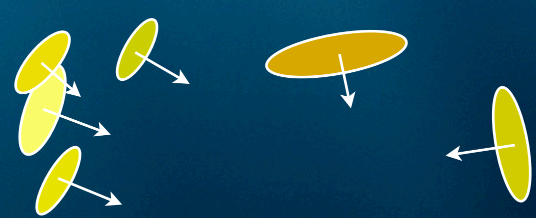
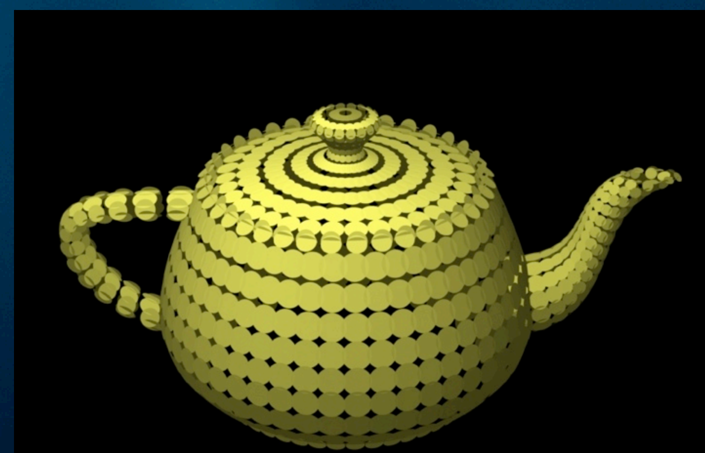
A point cloud

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



point cloud



point cloud

- Terminology: “point” or “disk”?

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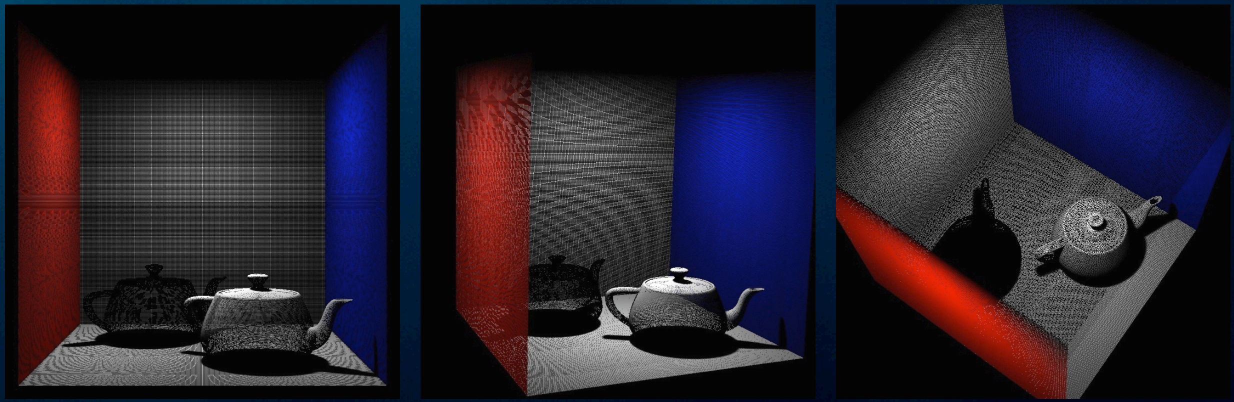
Generate point cloud

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

rendered image



point cloud, 560K points (various views)

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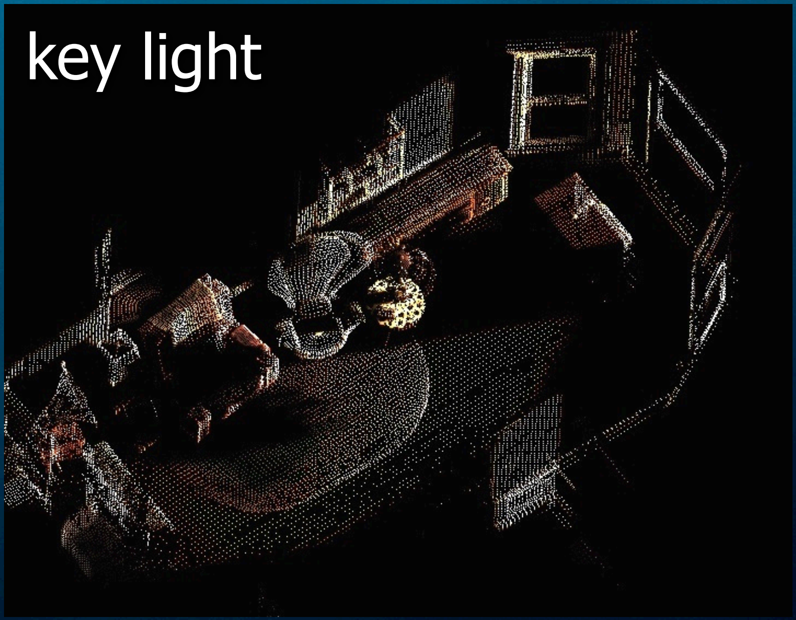
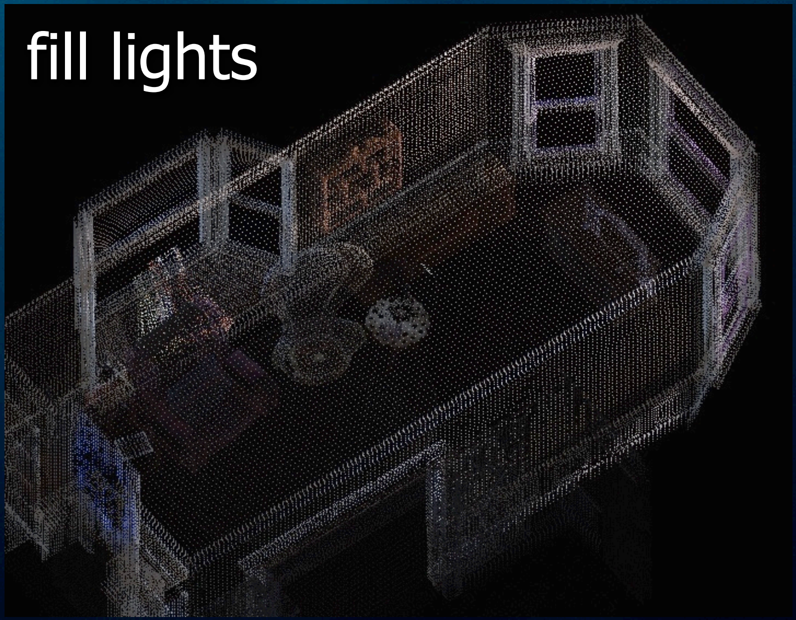
Generate point cloud

- Point cloud files from “Up”





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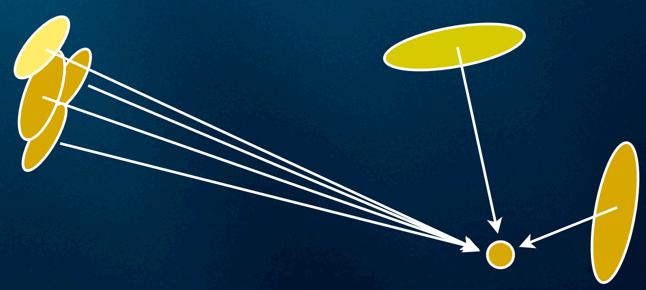
Compute color bleeding at a point

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



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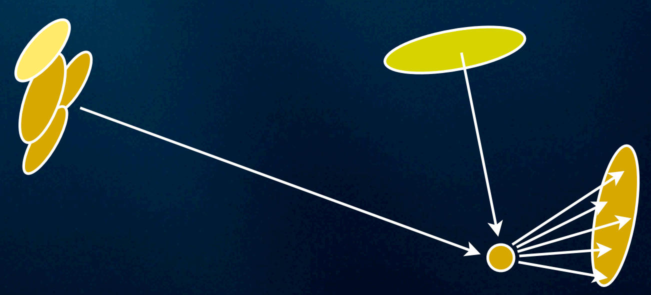
Compute color bleeding at a point

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



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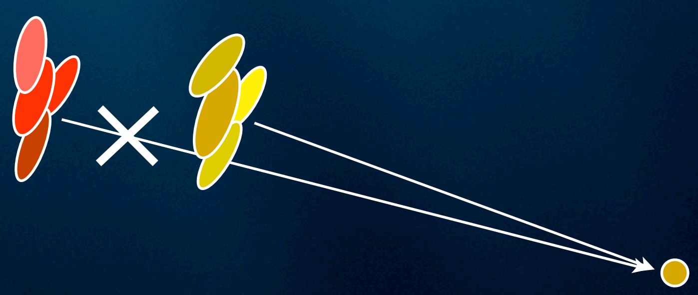
Compute color bleeding at a point

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



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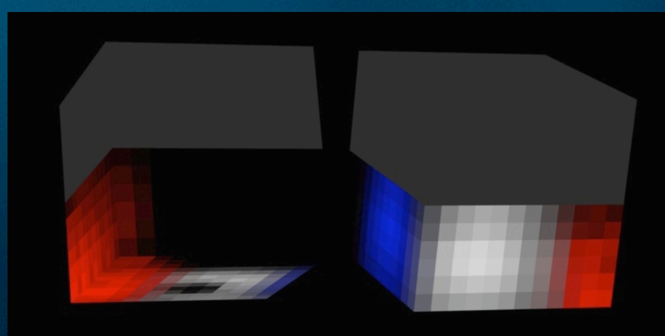
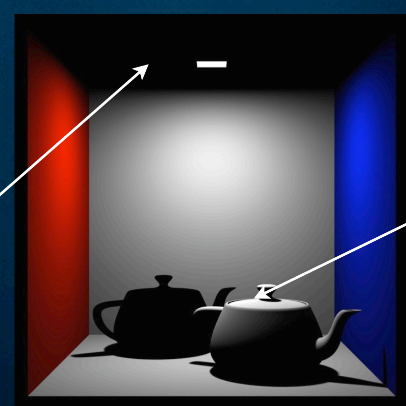
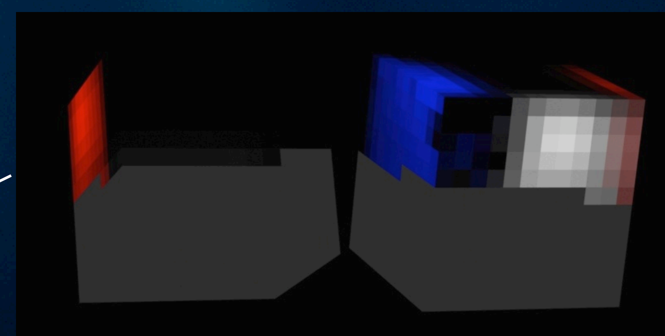
Compute color bleeding at a point

- 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 color bleeding at a point

- Multiply all raster pixel colors by reflectance function (BRDF); add
- Result is color bleeding at point

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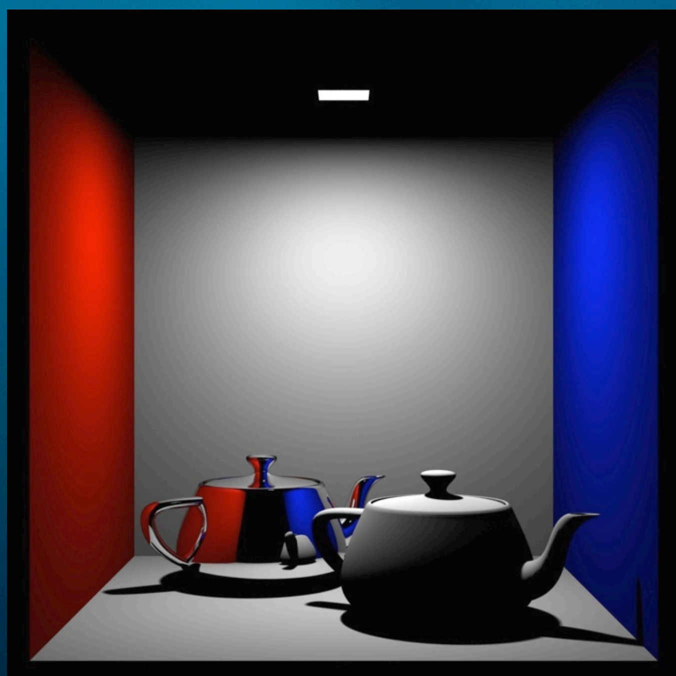
Color bleeding results



direct illum

direct illum + color bleeding

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Use in movies

- Pirates of the Carribean 2 & 3, Eragon, Surf's Up, Spiderman 3, Harry Potter 5 & 6, Chronicles of Narnia, Fred Claus, Beowulf, Spiderwick Chronicles, Ironman, Indiana Jones, 10,000 BC, Batman: Dark Knight, Quantum of Solace, Cloverfield, Doomsday, Hellboy 2, Inkheart, Wall-E, Star Trek, Terminator 4, The Boat that Rocked, Fast & Furious 4, Angels and Demons, Up, ...

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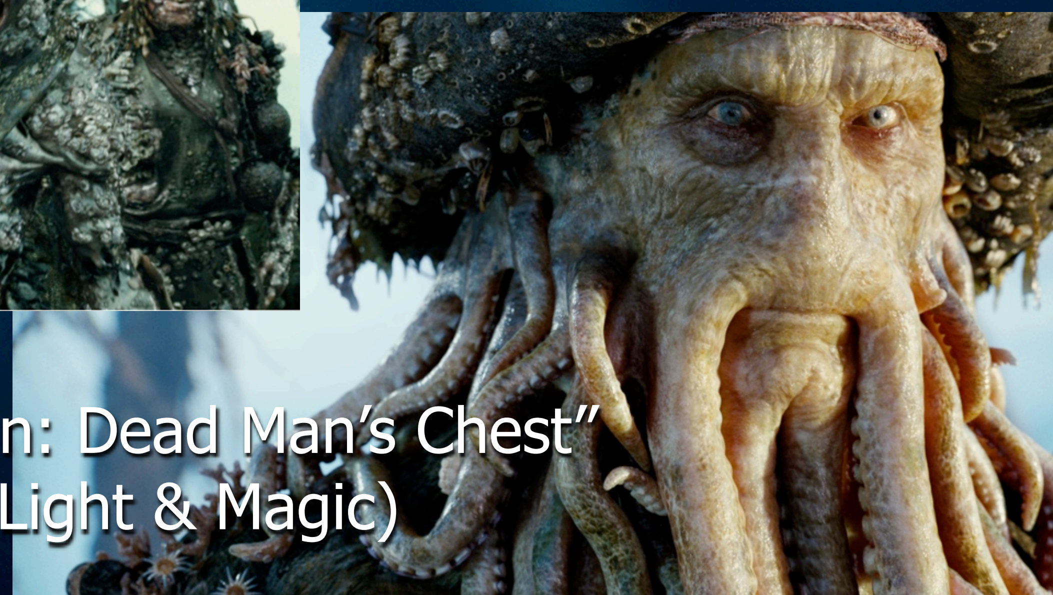
Davy Jones



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

“Up” example without color bleeding

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"Up" example with color bleeding

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"Up" example without color bleeding

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"Up" example with color bleeding

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"Up" example without color bleeding

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"Up" example with color bleeding

Variations and extensions

- Glossy reflection
- Area light sources
- Environment illumination
- Multiple light bounces
- Ambient occlusion, reflection occlusion
- Volumes

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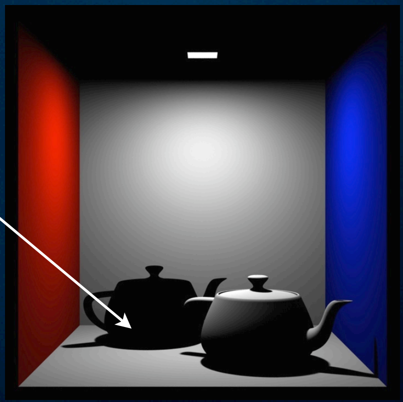
Glossy reflection

- Only collect illumination from within a small cone of directions
- Raster cube example:



- Multiply raster pixel colors by glossy reflectance function (BRDF)

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Glossy reflection

narrow glossy reflection

wide glossy reflection

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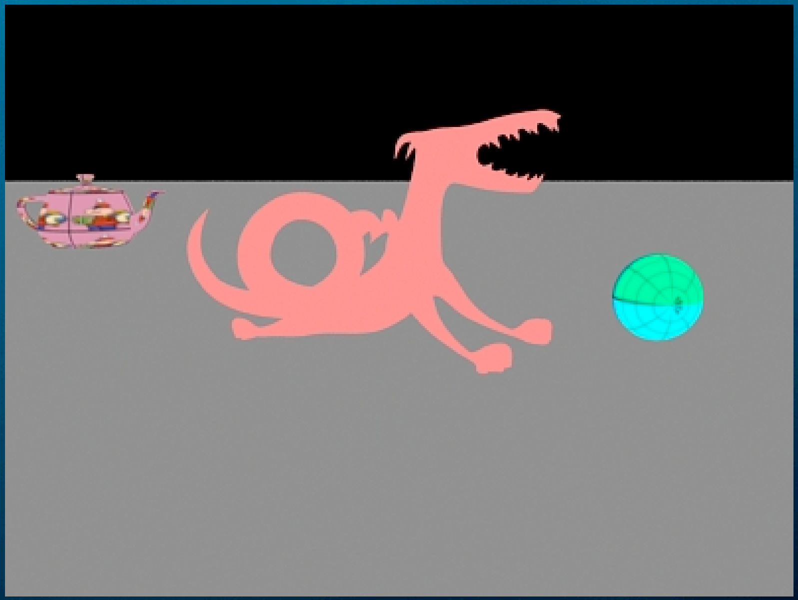
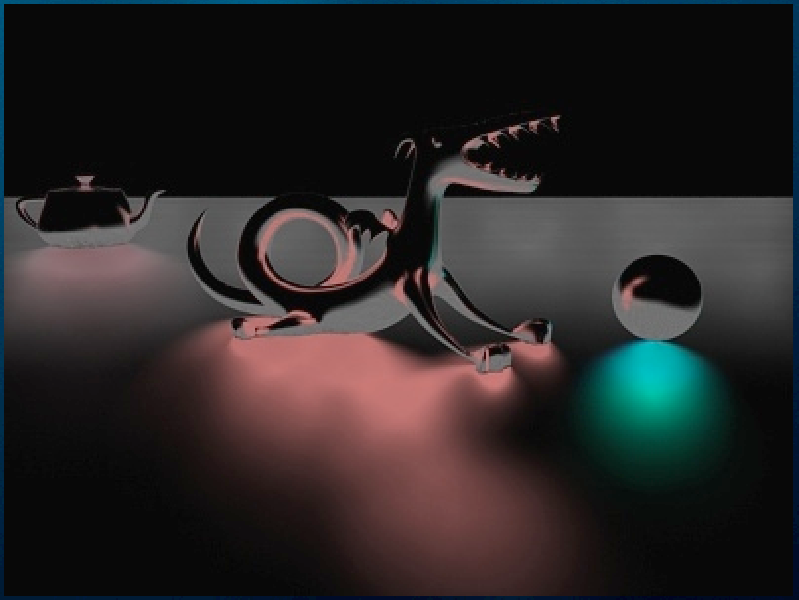
Glossy reflection



point cloud



glossy reflection

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Area light sources

- 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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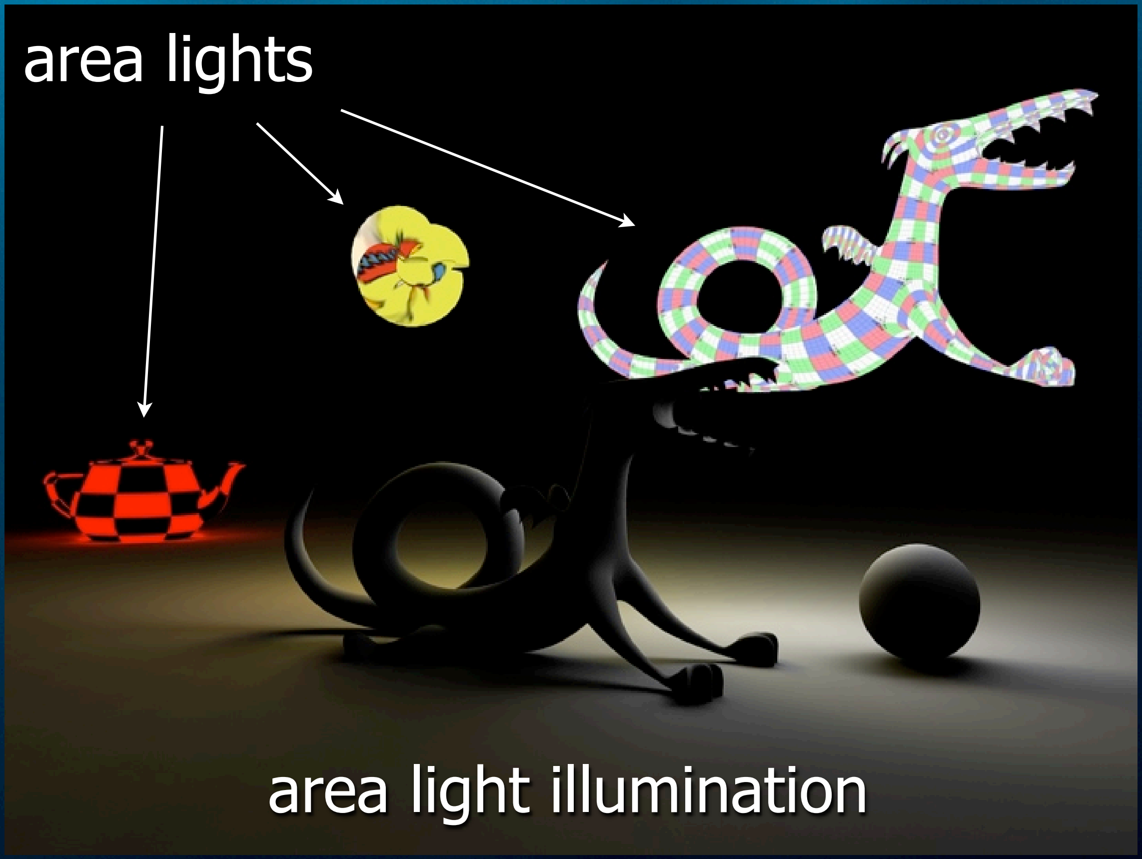
Area light sources



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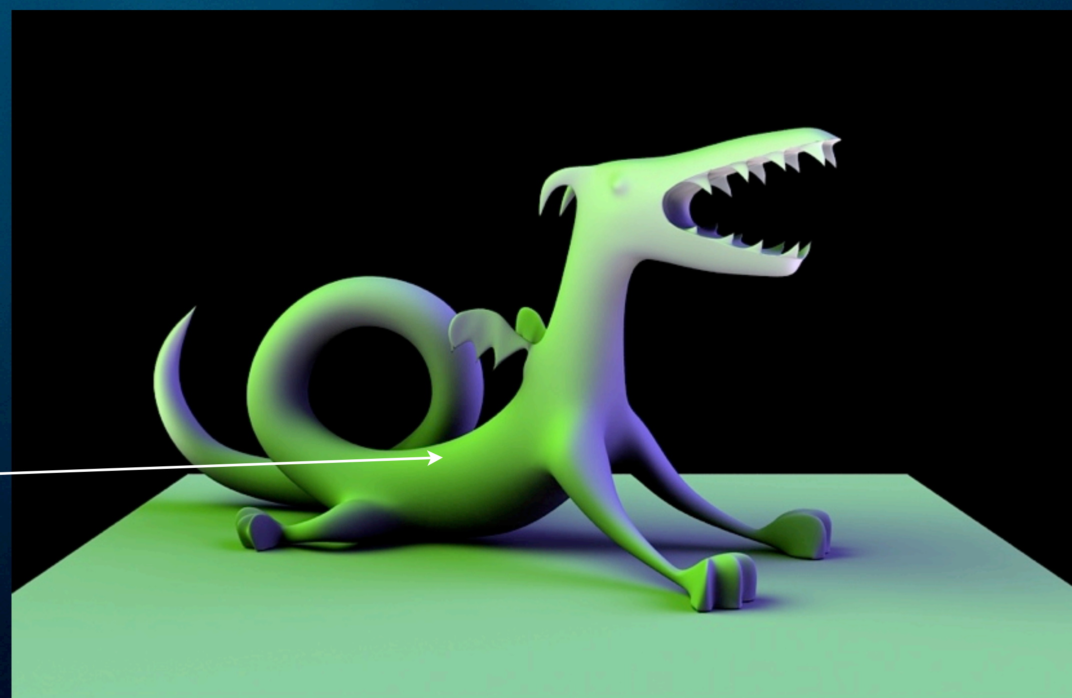
Environment illumination

- Use environment color for raster pixels not covered by points



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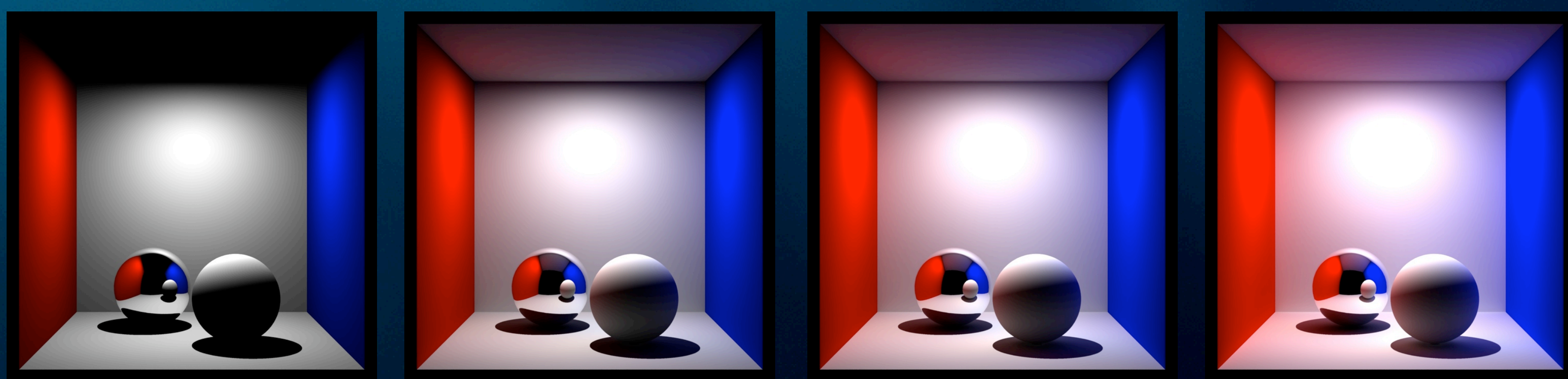
Multiple light bounces

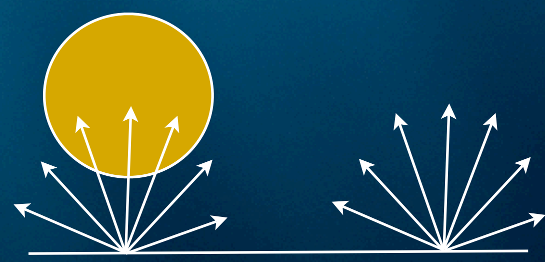
- Run the algorithm n times
- (For efficiency: first n-1 times can be computed at fewer points)



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

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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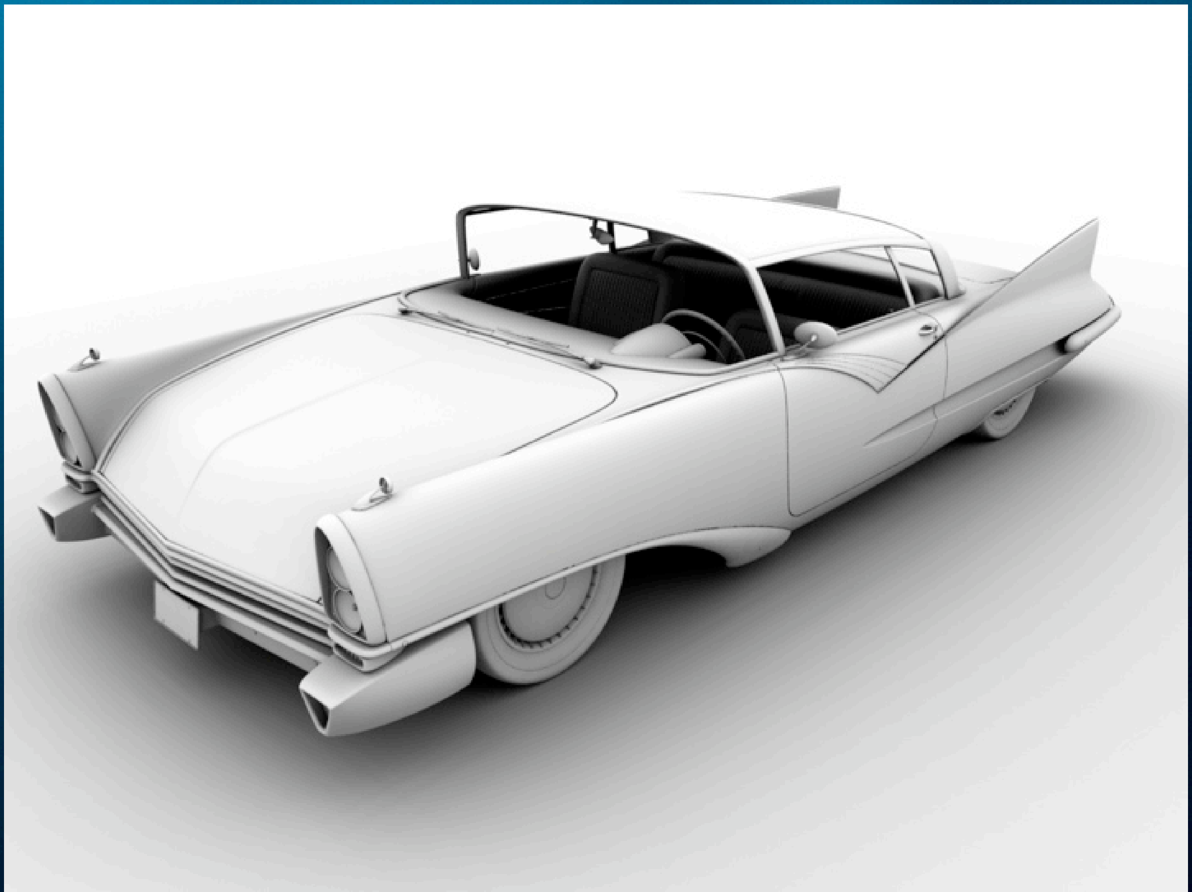
Ambient occlusion



Ambient occlusion (and reflections)

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Ambient occlusion

"Surf's Up" test (Courtesy of Sony Imageworks)

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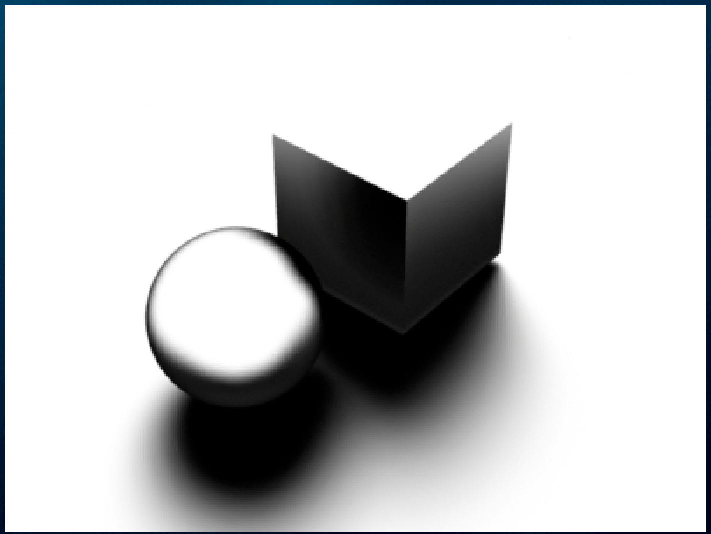
Special case: reflection occlusion

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

narrow reflection



wider reflection

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Other result types

- Given the raster cube it is also fast to compute:
  - average unoccluded direction (“bent normal”)
  - average illumination direction

Color bleeding in volumes

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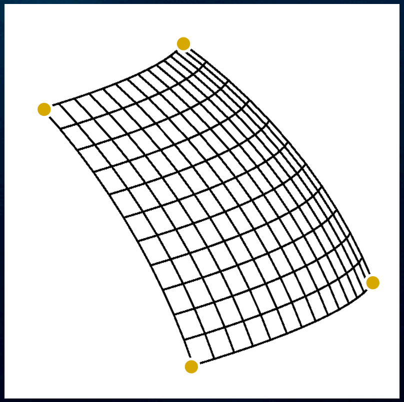
Optimization: interpolation

- 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

- Color bleeding at each point is independent
- Ideal for parallel execution
- Observed speedups:
  - 4 cores: 3.6
  - 8 cores: 6.6

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Summary

- Point-based color bleeding is fast and can handle complex production scenes
- Also works for glossy reflection, area lights, env. map illumination, multiple bounces, ambient occlusion, reflection occlusion, volumes
- In Pixar's RenderMan
- Is gaining widespread use in production

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More information

- "Point-Based Graphics" book by Gross & Pfister
- Pixar technical report #08-01: "Point-based approximate color bleeding"
- Talk this afternoon: Making of "Partly Cloudy" and "Up"

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Acknowledgments

- RenderMan team, Jean-Claude Kalache
- Rene Broca, Cedric Guiard, Marine Lamblin
- You for listening

Thanks!

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Questions?

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