Irradiance Caching
in Pixar’s RenderMan

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Overview

• Irradiance caching in Pixar’s RenderMan:
  – simpler than the general case
  – more intuitive error control

• Ambient occlusion caching

• Use in movies
Pixar’s RenderMan (PRMan)

- Used for a lot of movies:
  - all Pixar movies: Toy Story, ..., Wall-E, ...
  - special effects: Abyss, Terminator 2, ...
- Uses the REYES scan-line rendering algorithm

PRMan was also used for Star Wars episodes 1-3, Lord of the Rings 1-3, the Harry Potter movies, etc.
Every Visual Effects Oscar Winner of the past 15 years used PRMan.

A list of movies produced with PRMan can be found at https://renderman.pixar.com/products/whatsrenderman/movies.html
The REYES rendering algorithm

- Object surfaces are split into parametrically square pieces ("grids")
- The square pieces are divided into micropolygons:
- The micropolygons are shaded; projected onto screen
Irradiance caching and interpolation

- General case: cached data are from random points in space (may be from different surfaces)
- REYES: we know that a grid-full of shading points are all from the same surface
- Simpler!
Irradiance caching and interpolation

- Compute irradiance and gradients at the 4 corners of grid
- Interpolate the irradiance to 5 points on grid using the values at the 4 corners
We assume that the irradiance on the patch has a bilinear variation. If not, we split the patch.
Error control

• Instead of ‘a’ in Radiance
• Specify max error (deviation from correct value)
  – for example 1% or 2%
• More intuitive
How to deal with concave and displaced surfaces has already been covered by the previous speaker.
Ambient occlusion

- Fraction of hemisphere above a point that's covered
- Similar to shadows on overcast day
- Values between 0 and 1
Ambient occlusion: examples
Ambient occlusion: examples

Luigi from `Cars’

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... more cars
Use of ambient occlusion

- First used for movie production in ‘Pearl Harbor’ (ILM; mental ray)
- Used a lot in movie production
- Faster than global illumination: no need to evaluate the color at ray hit points
Ambient occlusion gradients

- Ambient occlusion can be interpolated just like irradiance!

- Gradients computed as for irradiance (1 color band): just treat ray hit like irradiance 1, miss as irradiance 0

- Interpolation as irradiance (either Ward’s formulas or ...)

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More ambient occlusion examples ...

This is 15 copies of Al’s car from Toy Story 2. The floor has ambient occlusion computed using irradiance gradients.
More ambient occlusion....
Global illumination in RenderMan

- Several methods:
  - photon mapping for full global illumination
  - baking direct illumination for single-bounce
    - ray tracing
    - point-based
- All (can) use irradiance caching and interpolation
The radiosity map method

- Standard photon mapping method: when final gather ray hits a point, look up nearest n photons to estimate irradiance
- More efficient: precompute irradiance at photon positions; lookup 1 photon
- Further optimization (if local color is stored with each photon): precompute radiosity at photon positions -- radiosity map

More information about the radiosity map method can be found in the SIGGRAPH 2007 Course Notes “High-quality rendering using ray tracing and photon mapping” (Henrik Wann Jensen and Per Christensen).
The radiosity map method

- Last step: distribution ray tracing using irradiance caching and interpolation
Example: box with teapots

- Direct illumination (400k points)
- Photon map (2.6M points)
- Radiosity map (2.6M points)
- Global illumination image

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‘Ratatouille’ kitchen radiosity map
Global illumination was actually not used on the Rat movie, but ambient occlusion was used a lot!
This is a global illumination example I rendered using the kitchen geometry and shaders from the Rat movie.
Notice the complex direct illumination and shading: ~200 light sources, ~150 surface shaders, ~1000 textures.
Summary

- Two special cases of irradiance caching:
  - REYES algorithm
  - ambient occlusion

- Irradiance and occlusion caching are ubiquitous in production rendering!
More information about PRMan

- “Advanced RenderMan” book (ARM)
- Several other books ...
- RenderMan application notes
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Thanks!
Questions?