Photon Mapping in Pixar’s RenderMan

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State of the Art in Photon Density Estimation
Background

- PRMan has had photon maps implemented for ~10 years
- Currently undergoing a renewed development effort to make more programmable and implement new features
- Photons not for everything; use where advantageous
Overview

• PRMan uses photons several ways
  – for caustics
  – for irradiance estimate for global illum
  – for guiding diffuse rays -- NEW
  – for volume rendering -- NEW
Outline of talk

• Photon emission
• Photon scattering
• Rendering:
  – photon guiding
  – motion blur
  – mostly volumes
Photon emission: light sources

• General and programmable light sources are a pain:
  – barn doors, “cookies”, non-physical falloff, ...

• How can we match photon emission to direct illumination?
Photon emission: 3 methods

- Evaluate light source and emit accordingly
  - point/spot/directional, falloff; eval at hit point

- Generate direct illum point cloud; emit from points

- generatePhoton() shader method: org, dir, power
Photon scattering: 3 methods

- Built-in simple materials
  - matte, glass, chrome, dielectric, ...
  - isotropic, rayleigh, hazy mie, ...

- Read brdf scattering coeffs from point cloud

- Shader method (work in progress)
Photon map examples

photons (2.6M)
radiance estimates
Rendering

- Photon-guided diffuse rays
- Motion-blurred photons
- Photon beams for volumes
Photon-guided indirect diffuse rays

- Helps when direct illum is very uneven
  - e.g. spotlights or sunspot on floor of room

- When sampling hemisphere above a point for indirect illum: “blind” sampling or use nearest photons to guide
Photon-guided indirect diffuse rays

without guiding

photon map

with guiding
Motion-blurred photons

- Emit photons with random times $t$
- Lookups [Cammarano02]:
  - reject photons with $t$ outside shutter segment
  - divide radiance estimate by segment length
Photon beams for volumes

- Treat each photon in map as a beam instead of point [Jarosz08]

- Make better use of the information in the photon map
Photon beams for volumes

- Lookups: find nearest beams passing by shading point
- radiance = sum of (power * phasefunc) / area  (“2D estimate”)
Rendering: volume examples

- Homogeneous volume, photon map for indirect illum

- RT direct illum (3 min)
- Pmap indirect (1M photons, 3 min)
- RT direct + pmap indir (7 min)
Rendering: volume examples

- Inhomogeneous volume (sine func), photon map for indirect illum

RT direct illum (3 min) + pmap indirect (1M photons, 3 min) = RT direct + pmap indir (7 min)
Rendering: volume examples

- Inhomogeneous volume (sine func), pmap direct+indirect illum, soft shadow

Ref: RT direct illum (7 min)

pmap direct illum (8 min)

pmap direct + indir (9 min)
Rendering: volume examples

- Inhomogeneous volume (turbulence), anisotropic scattering, pmap direct+indir

- isotropic
- hazy Mie
- H-G 0.5
- H-G 0.8
Rendering: volume + motion blur

- Inhomogeneous volume (turbulence), pmap direct+indir illum
Rendering: volume caustic

photon beams (1k)

volume caustic (100k)
Other new photon stuff

- Parallel photon tracing
- “Transient” photon maps: single-pass, in-memory instead of two-pass, file on disk
Conclusion

- Photon mapping in PRMan can be used for
  - caustics
  - global illumination
  - photon-guided indirect diffuse rays
  - volumes: direct, indirect, caustics
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