Multi-sampled Photon Differentials

Incorporating the View Ray Differential in the Radiance Estimate

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Outline

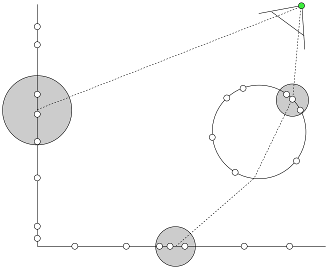
- What is photon mapping?
- What are photon differentials?
- Why consider the view ray differential?
- Introducing two different approaches:
  - Coplanar intersection-weighted photon differentials
  - Multi-sampled photon differentials
- Results

What is photon mapping?

- Global illumination algorithm by Henrik Wann Jensen
- Solves the rendering equation in discrete form:

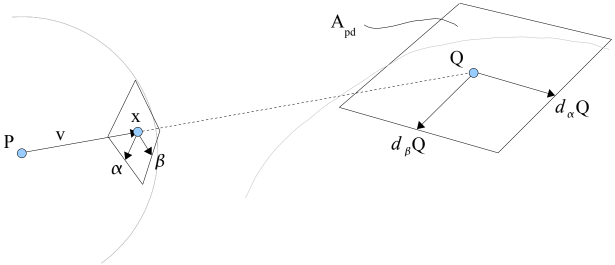
$$L_r(x,\omega) \approx \sum_{p=1}^{k} f_r(x,\omega_p,\omega)\frac{\Delta\Phi_p(x,\omega_p)}{\Delta A} K(\|x_p - x\|)$$

- Algorithm is divided into two stages:
  - Photon tracing
  - Rendering



What are photon differentials? (1/2)

- Extension of photon mapping proposed by Schjøth et al.
- Observation:
  - Finite number of emitted photons $\rightarrow$ each photon can be regarded as the center of a beam with size and shape
- Associates photons with *ray differentials* (dV, dP)
- Differential position vectors approximate footprint of beam on intersecting surfaces



What are photon differentials? (2/2)

- Can trace ray differentials alongside original ray by evaluating the differentials of the trace operations – example for transfer:

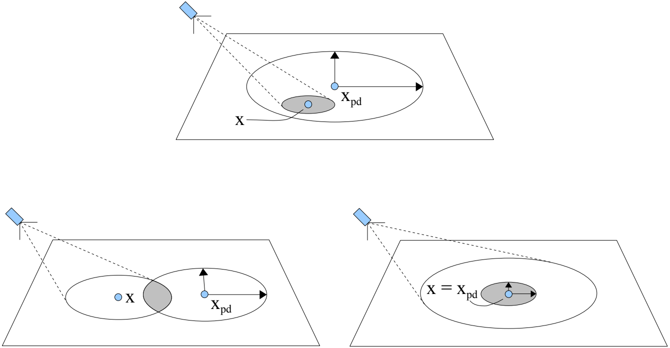
$$\begin{aligned} Q &= P + sV \\ dQ &= dP + (ds)V + sdV \end{aligned}$$

- Schjøth et al. use the extra information inherent in the footprints to rewrite the radiance estimate:

$$L_r(x,\omega) \approx \sum_{pd=1}^{k} f_r(x,\omega_{pd},\omega)\frac{\Phi_{pd}}{A_{pd}} K(\|M_{pd}(x - x_{pd})\|)$$

- M_{pd} takes relative sampling point $x - x_{pd}$ into filter space
- Filter space resembles an ellipsoid in world space
- Better at preserving features than regular photon mapping

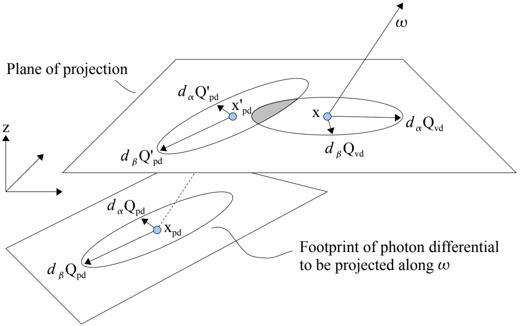
Why consider the view ray differential?



- Should be possible to increase accuracy without tracing more view rays or increasing resolution of photon map

Coplanar intersection-weighted photon differentials (1/2)

- Idea:
  - Compute intersection explicitly
  - Problem depends on how the footprints are interpreted
- Approximate by intersection of coplanar convex geometry:
  - Project footprints into common plane, rotate into 2D
  - Reconstruct as convex polygons to compute 2D intersection



Coplanar intersection-weighted photon differentials (2/2)

- Intersection polygon $C_{vd\cap pd}$ yields:
  - $w_{vd\cap pd}$ – coverage of intersection along current view ray
  - $x_{vd\cap pd}$ – approximate centroid of intersection (unprojected)
- These can be incorporated in the radiance estimate as follows:

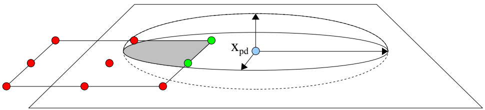
$$L_r(x,\omega) \approx \sum_{pd=1}^{k} f_r(x,\omega_{pd},\omega)\frac{\Phi_{pd}}{A_{pd}} K(\|M_{pd}(x_{vd\cap pd} - x_{pd})\|) w_{vd\cap pd}$$

- Potential contribution of photon differential is scaled by coverage
- K is evaluated in filter space transformation of $x_{vd\cap pd}$, not x
- Successfully incorporates the view ray differential, but performance is lacking → prompts alternative approach

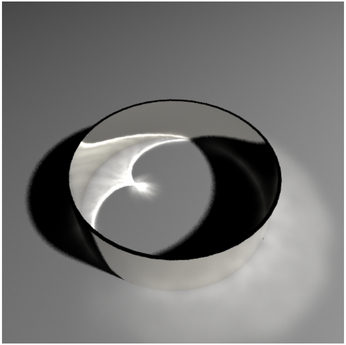
Multi-sampled photon differentials

- Idea:
  - Do not compute the intersection explicitly, but sample the photon differential in multiple places, averaging the results
  - Use the view ray differential to define the sample distribution
- Letting X denote the set of $N \times N$ sampling points, the radiance estimate can be written:

$$L_r(x, \omega) \approx \sum_{pd=1}^{k} f_r(x, \omega_{pd}, \omega) \frac{\Phi_{pd}}{A_{pd}} \left(\frac{1}{N^2} \sum_{i=1}^{N^2} K(\|M_{pd}(X_i - x_{pd})\|) \right)$$

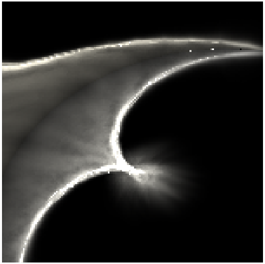


Results (1/3)

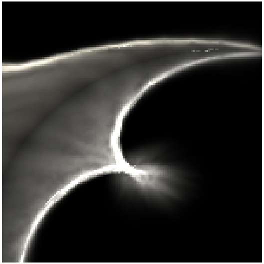


- Simple test case; the clearly defined contour of the caustic should provoke undersampling artefacts
- 120000 photon differentials, of which 20000 are caustic
- $k = 50$

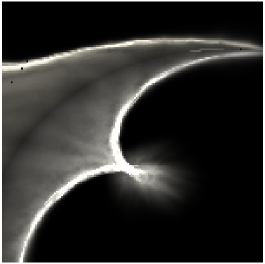
Results (2/3)



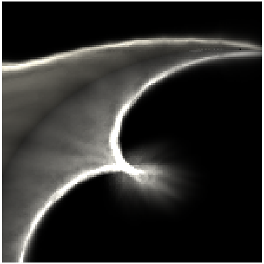
(a) Regular, 1×1 rays/pixel



(b) Regular, 3×3 rays/pixel



(c) Coplanar intersection-w.



(d) Multi-sampled, 8×8

Results (3/3)

Method	Rendering time in seconds
Regular, 1×1 view rays/pixel	20.637
Regular, 3×3 view rays/pixel	183.255
Coplanar intersection-weighted	380.045
Multi-sampled, 8×8 sampling points	63.671

- Increasing number of view rays/pixel results in linear increase in rendering time $\rightarrow$ expected
- Coplanar intersection-weighted photon differentials does not perform well enough to be worth it over tracing more view rays per pixel
- Multi-sampled photon differentials performs well; three times faster than tracing more view rays per pixel, and the results are practically free of visible artefacts

That's it

Questions?