Density Estimation Optimizations for Global Illumination

Rubén García, Carlos Ureña, Jorge Revelles, Miguel Lastra, Rosana Montes

Thursday, February 2, 2006

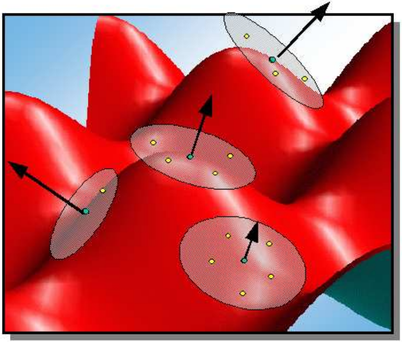
Grupo de Investigación en Informática Gráfica.
Lenguajes y Sistemas Informáticos.
University of Granada.

Method

Based on the density estimation technique of Photon Maps, however DETP

- Stores the trajectories of the photons.
- To calculate irradiance at a point, a disc of fixed radius centered at the point and tangent to the surface is created, and the contribution of the rays intersecting the disc are added.
- Finally, the result is divided by the area of the disc.

Diagram

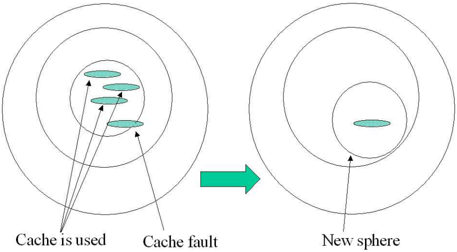


Density Estimation on the Tangent Plane

DETP Optimization: Sphere Caché

- A hierarchy of englobing spheres is created which allows for the rapid calculation of the rays intersecting a given disc.
- Inner spheres are recalculated when the disc leaves the sphere.
- This method is useful if the discs have spatial coherency: Point sorting.

Diagram

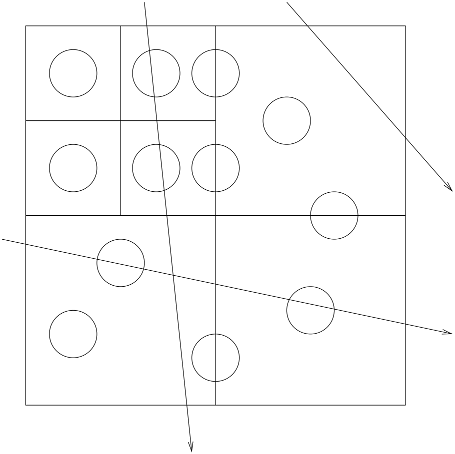


Sphere Caché

DETP Optimization: Disc Indexing

- A spatial indexing of the discs is created.
- For each ray, the structure is traversed from the origin of the ray until its intersection with the real scene.
- Each intersected disc increases its energy according to the energy of the ray.
- Independent of the spatial indexing method.

Disc Indexing



Disc Indexing

Experimental Results

Tree

72 500 triangles

Atrium

122 318 triangles

Disc Indexing obtains up to 50 % reduction in time with respect to Sphere Caché for small discs.

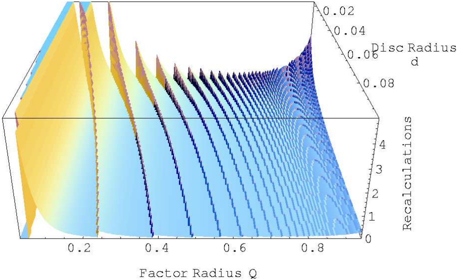
Theoretical results: Notation

- n_R: number of rays
- n_P: number of irradiance points.
- d: disc radius
- r_0: radius of the first sphere, which surrounds the scene.
- Q: Radius factor: $r_{i+1} = Q * r_i$; $0 < Q < 1$

Assumptions of the analysis

- Uniform distribution of rays.
- Uniform distribution of irradiance points.
- With this, the average fraction of rays in a convex set can be calculated:
- It is the ratio between the surface of the set and the surface of the bounding box of the scene.

Result: Estimation of the optimal value of Q



Intersections

- optimal Q if the radius of the last sphere equals the disc radius.
- Small Q implies less cost in cache misses.
- The global minimum is around 0.6-0.7. This is coherent with experiments.

Theoretical efficiency results

- Sphere Cache
  - $O(n_R n_P)$, hidden constant $\frac{d^2}{r_0^2}$
  - For $d \approx$ distance between samples: $O(n_R \sqrt[3]{n_P})$
- Disc Indexing, $d \approx$ distance between samples
  - Unbalanced trees: $O(n_R \sqrt[3]{n_P} \log n_P)$
  - Balanced trees: $O(n_R \sqrt[3]{n_P})$
- Disc Indexing, large discs $O(n_R n_P)$, hidden constant $\frac{d^2}{r_0^2} \log \frac{r_0}{d}$

Future Work

- The theoretical study allows us to use known characteristics of the scene to guide hybrid algorithms.
- Example: Quasi-static scenes (static scene, relatively small mobile objects)
    - Static Scene: Disc Indexing theoretically more efficient.
    - Dynamic Objects: Sphere Cache theoretically more efficient.
    - This allows for an efficient hybrid algorithm for these scenes.

Conclusion

- Disc Indexing has been described and implemented. This technique increases performance of Global Illumination calculations.
- A theoretical study of the time efficiency has been carried out.
- The usefulness of the theoretical study to guide the development of algorithms has been shown. (Quasi-static scenes)