Sequential Monte Carlo for dynamic Image-based lighting

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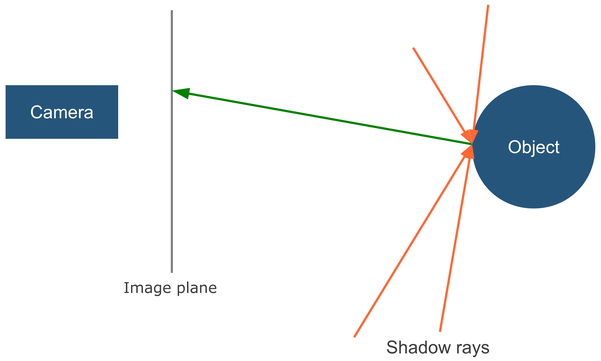
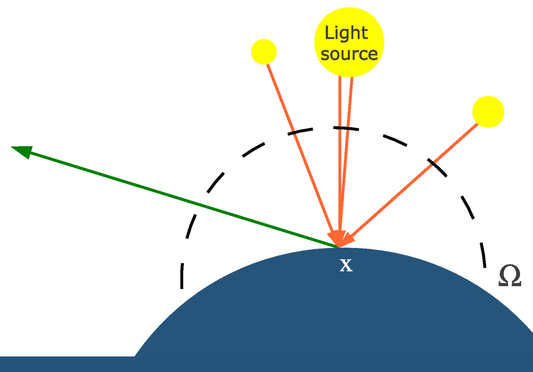
Summary

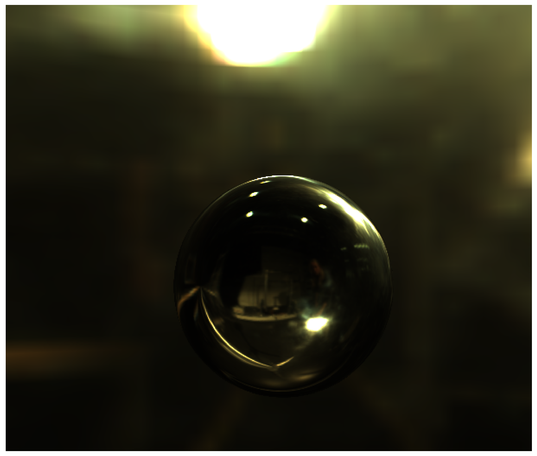
- Image-based lighting is a method in computer graphics to render objects in real-world scenes captured by special cameras.
- Traditionally, this has been done by importance sampling the light transport equation independently for each frame.
- Recent work has applied SMC methods (particle filters and smoothers) to solve this problem in a dynamical setting.

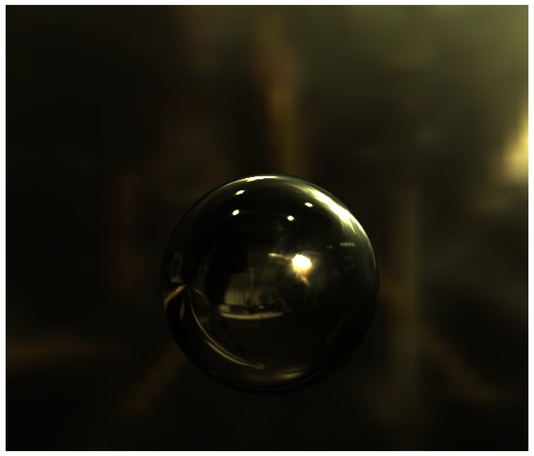
Image-based lighting



An important problem in computer graphics is to render **photorealistic images** using software. This includes calculating lighting on objects from different light sources found in the environment. Traditionally, these light sources were placed by artists. However, in this work this information was obtained using a state-of-the-art **high dynamic range (HDR) video camera** developed at C-research, Linköping University [1]. Visit `http://www.hdrv.org` for more information about HDR video applications.







In image-based lighting the luminance is calculated for each pixel using the **light transport equation**,

$$L_r(\omega_r) = \int_\Omega \overbrace{f_r(\omega_i \to \omega_r)}^{\text{BRDF}} \underbrace{L_i(\omega_i)}_{\text{EM}} \cos\theta_i V(\omega_i) d\omega_i.$$

Traditionally, this integral is solved using importance sampling, e.g. in the **bidirectional importance resampling** algorithm for **for each frame independently**.

Algorithm: Bidirectional importance resampling [2]

- Sample $M(\gg N)$ proposal directions (particles) uniformly from the CDF of the environment map or the BRDF.
- Calculate the weights of the proposal directions (particles) using the PDF of the BRDF or the environment map.
- Sample N directions (particles) from the proposal directions with replacement and weights as above.

Results using particle filters

By using particle filters, we can solve the light transport equation when **the environment map changes with time** by propagating the particles forward in time. This algorithm was implemented on a GPU using the OptiX SDK and the CUDA programming language from NVIDIA.

Algorithm: Basic PF for dynamic Image-based lighting [3]

- Sample initial particles using bidirectional importance resampling.
- For each time step, $t = 1, 2, \ldots, T$, do the following M times
  - Calculate the particle weights.
  - Resample if needed.
  - Mutate the particles using a random walk MH-sampler or sample independently from the environment map.
  - Estimate the light transport equation for **each color channel**.

Future work using particle smoothers

A new approach to this problem is using a **two-filter particle smoother**, where the information from the two passes are merged.

References

[1] Joel Kronander, Stefan Gustavson, and Jonas Unger. Real-time hdr video reconstruction for muliti-sensor sytems. In *ACM SIGGRAPH 2012 Posters*, 2012.

[2] D. Burke, A. Ghosh, and W. Heidrich. Bidirectional importance sampling for direct illumination. In *Rendering Techniques'05*, pages 147–156, 2005.

[3] A. Ghosh, A. Doucet, and W. Heidrich. Sequential sampling for dynamic environment map illumination. In *Rendering Techniques*, pages 115–126, 2006.