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Frequency based Kernel Estimation for Progressive Photon Mapping

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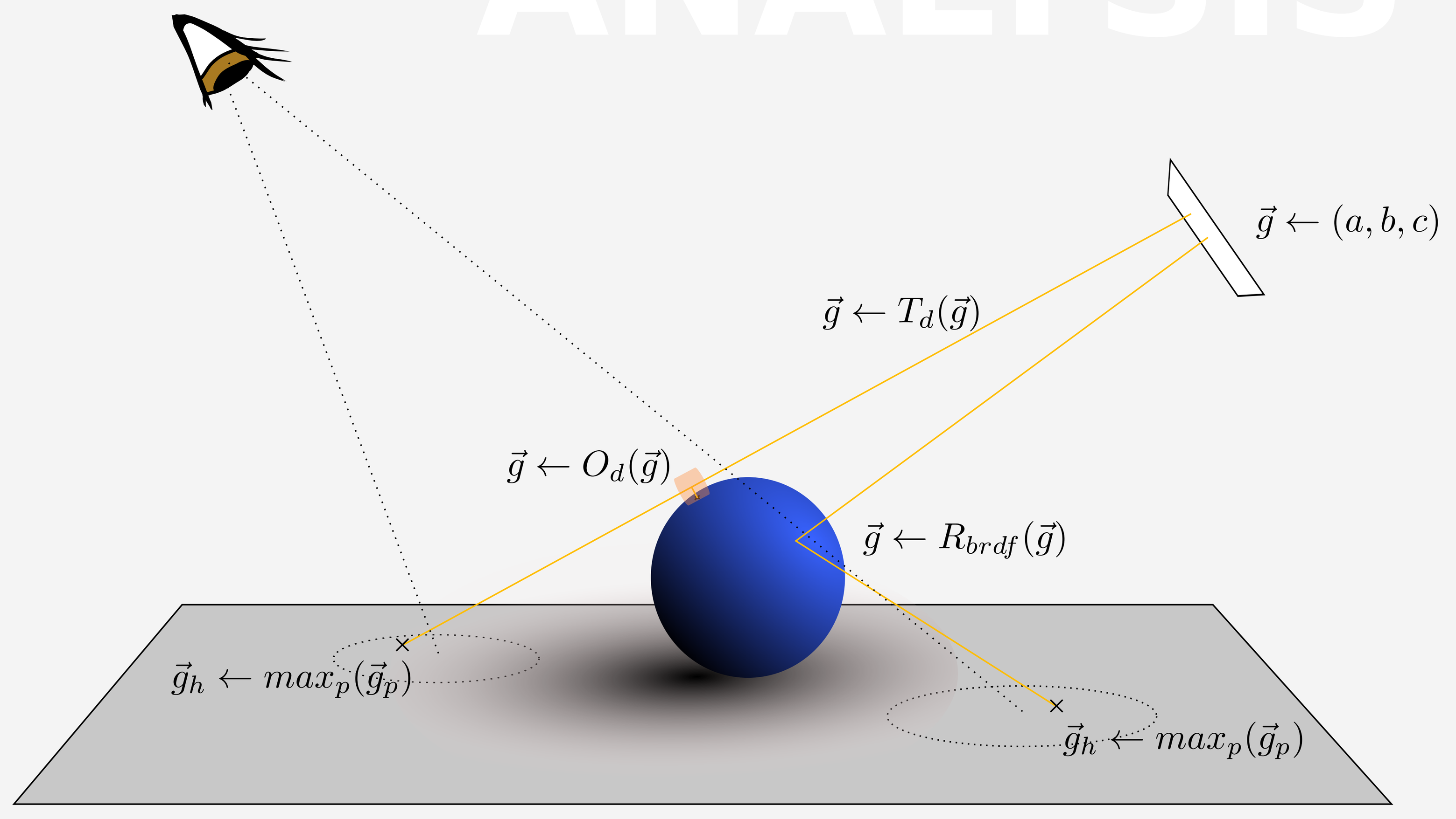
We present an extension to Hachisuka et al.'s Progressive Photon Mapping (or PPM) algorithm [Hachisuka et al. 2008] in which we estimate the radius of the density estimation kernels using frequency analysis of light transport [Durand et al. 2005]. We predict the local radiance frequency at the surface of objects, and use it to optimize the size of the density estimation kernels, in order to accelerate convergence. The key is to add frequency information to a small proportion of photons: frequency photons. In addition to contributing to the density estimation, they will provide frequency information.

FREQUENCY ANALYSIS

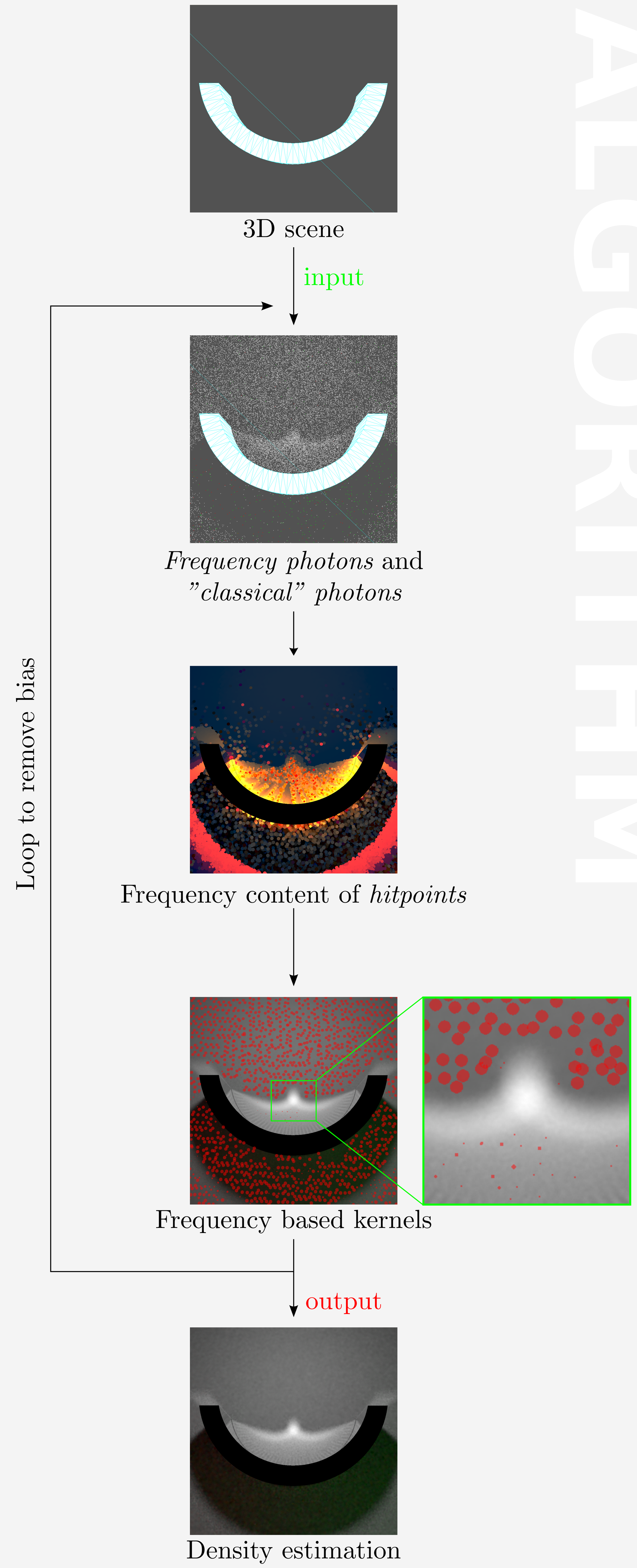


Durand et al. [2005] presents a Fourier analysis of the light transport in 4D. For efficiency reasons, we assume the radiance function to be isotropic in space and isotropic in angle, reducing the dimensionality of the spectrum of the radiance function to 2. We further approximate the spectrum by a gaussian:

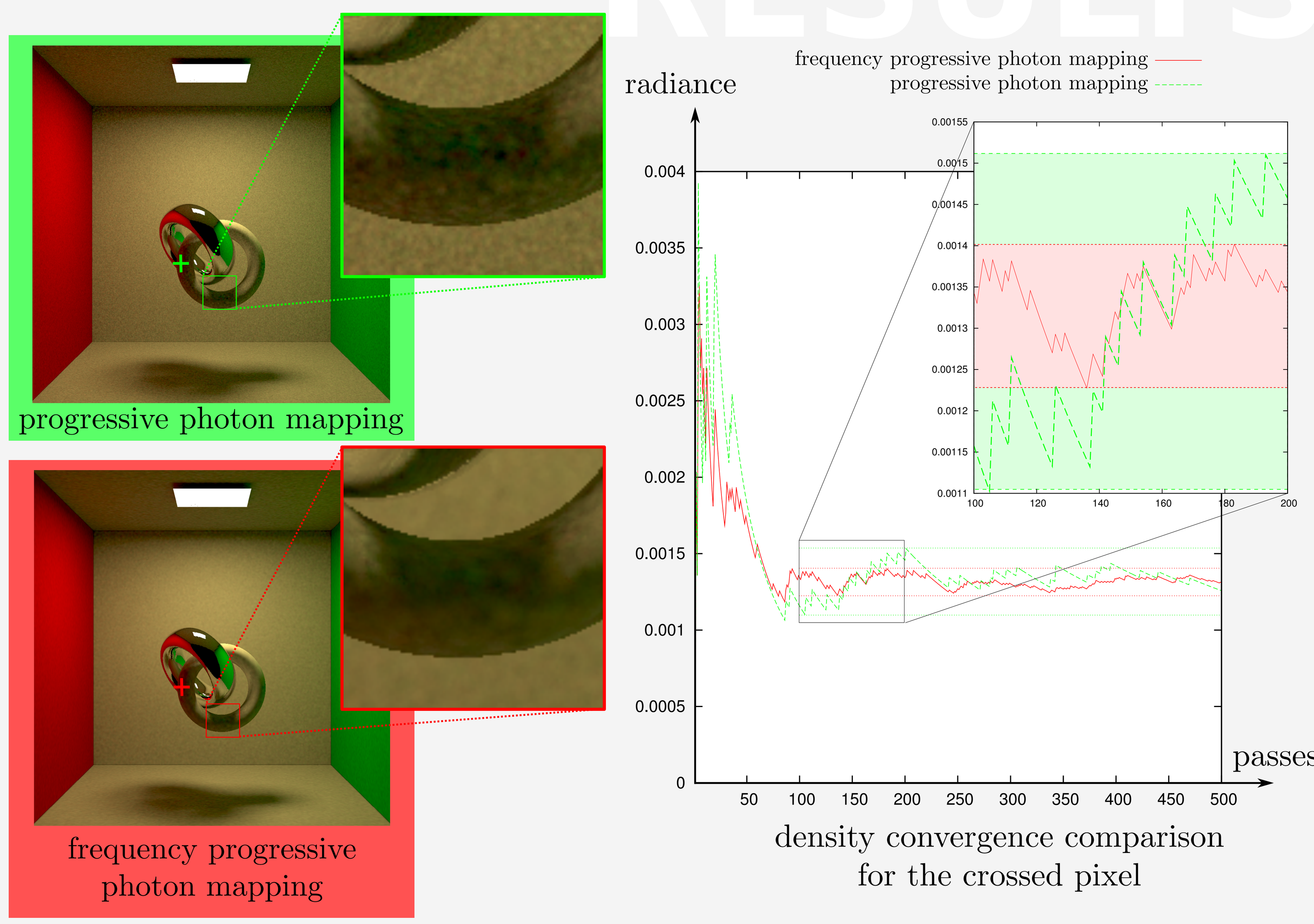
$$\hat{l} = Ee^{-(a\Omega_x^2 + c\Omega_x\Omega_\theta + b\Omega_\theta^2)}$$

At light sources, frequency photons are initialized with (a, b, c) values corresponding to the local radiance spectrum of the light source. When a photon is traced in the scene, we update these coefficients for each light transport atomic operation (travel in free space T, partial occlusion O, and reflection R). Indeed, each of these atomic operation translates into asimple arithmetic operator on (a, b, c). Please refer to our supplementary materials for derivations.

ALGORITHM



RESULTS



We update PPM by adding a frequency analysis step where the collected frequency photons' parameters will drive the radius reduction. We make the hitpoint's radius converge to a minimum radius defined as "bias free" (up to a user defined percentage) predicted by our frequency analysis. This allows to gather more photons per hitpoint when the minimum radius is reached and thus to reduce the variance of the estimate while avoid bias.

We demonstrate the effectiveness of our algorithm on various complex cases such as caustics, indirect illumination. The little overhead of the frequency analysis is compensated by the faster convergence of our method.

REFERENCES

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