Using Photon Maps and Irradiance Cache in Photorealistic Image Synthesis

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Abstract

Photorealistic image synthesis deals with simulation of the light energy transport in an artificial scene in order to generate realistic looking snapshot of the scene from a given position. From a physical point of view we need to compute the value of radiance L reflected to the camera at every visible point of the scene. This task is very difficult and time consuming, because of recursion in the computation process.
In our work, we chose a combination of two algorithms for realistic image synthesis: Photon Maps and Irradiance Cache. We further extended the algorithms in some aspects not addressed before.

1. Describing the Light Transport: The Rendering Equation

Rendering equation describes light transport in the space. Its simplified form is:

$$L_o \quad L_e \quad L_i \, f_r \cos \quad d$$

It tells that the reflected (or outgoing) radiance L_o at a given point and in a given direction is equal to the self emitted radiance L_e plus the radiance reflected from the surface from all the incoming directions.
It is a Fredholm's integral equation of second kind. It can be solved by stochastic Monte Carlo methods (ray tracing) or finite elements methods (radiosity).
The algorithms we used are the modification of stochastic Monte Carlo methods.

2. Light - Surface Interaction

There are more kinds of light-surface interaction. Depending on the type of surface (diffuse, specular, refractive) and the path of light quantum on its way from luminaire to the camera.
All the light-surface interaction types must be iterated as illustrated on Fig. 1 in order to compute an unbiased image. The light - surface interaction types are also denoted *components* of the image.
None of the common methods can take into account all the interactions. Thus some light effect can miss in the resulting image.

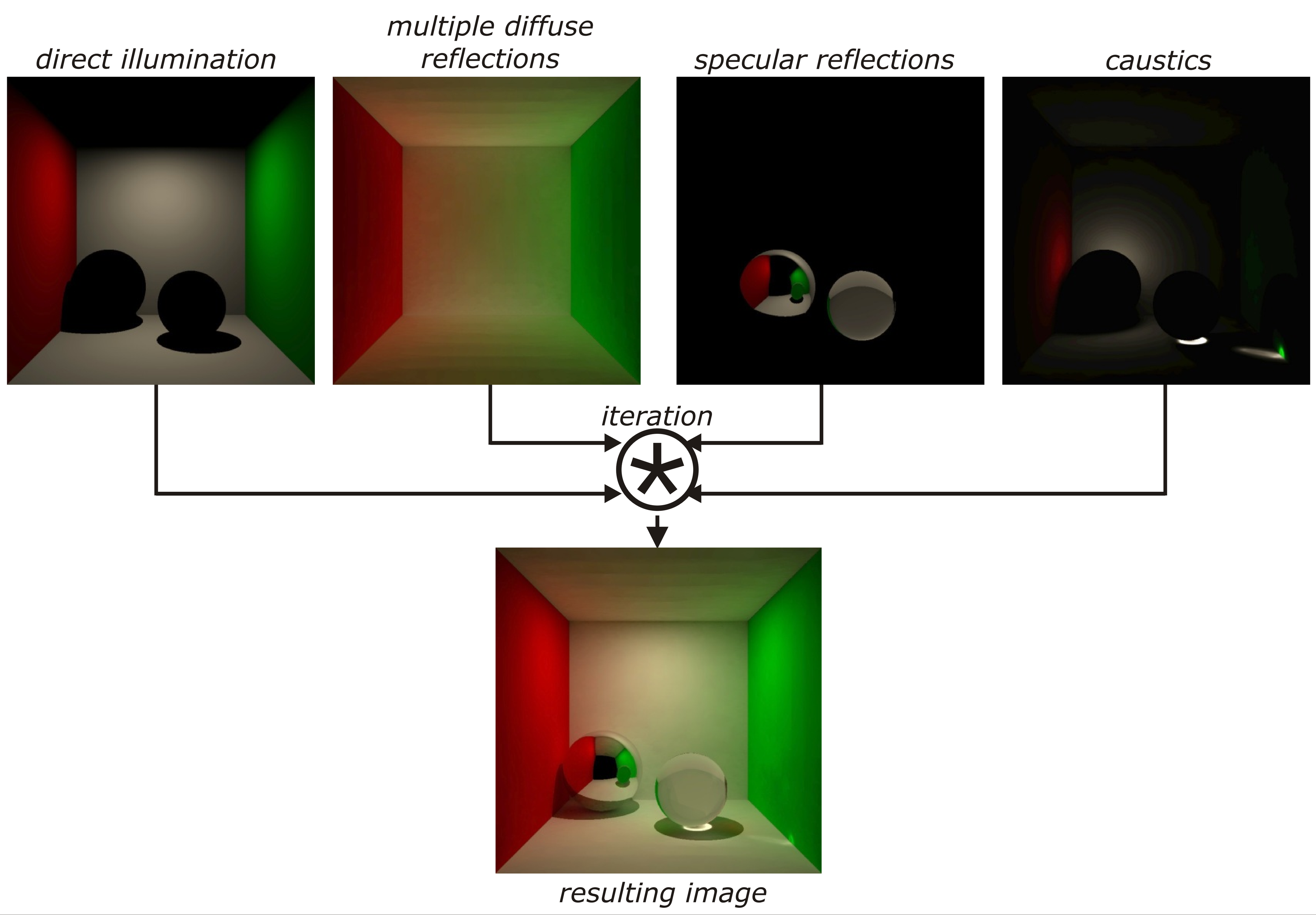

***Figure 1**. Components of the image. They must be iterated to create an unbiased resulting image.*

3. Photon Maps

Rendering with Photon Maps [1] is a two-pass stochastic algorithm. In the **first pass** photons are emitted from light sources and traced through the scene. All the photon-surface interactions are stored in a spatial data structure: a photon map. Two photon maps are created: the *global* and the *caustics* photon map.
In the **second pass** distribution ray-tracing is performed with additional queries to the photon map. Moreover, the indirect irradiance caching is used to speed up the computation by reusing already performed computations.

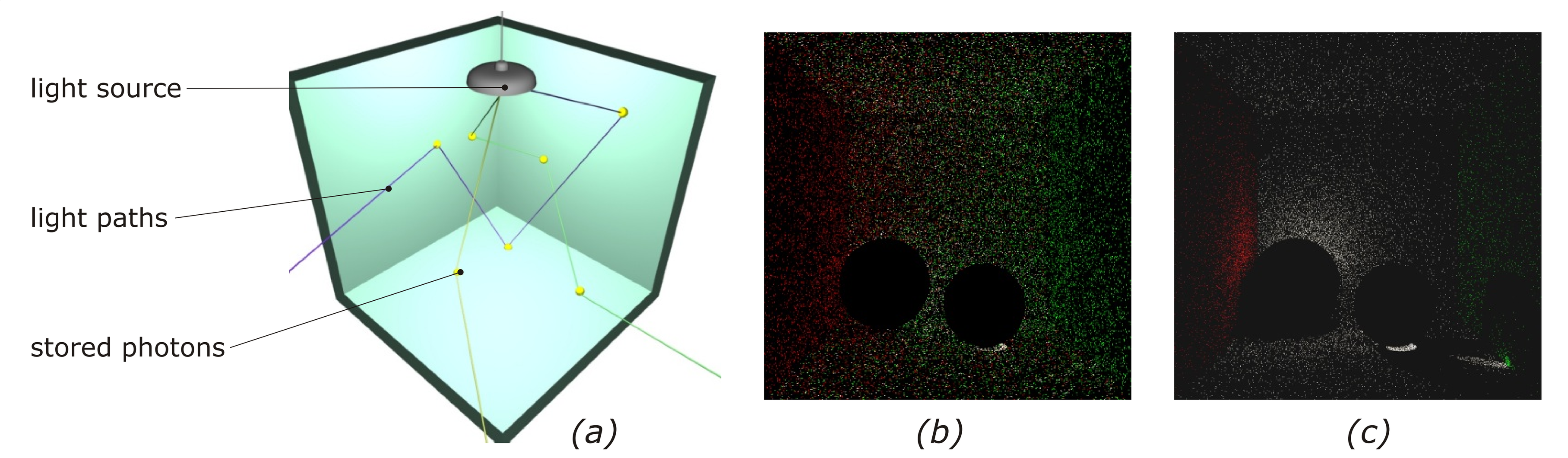

***Figure 2**. The Photon Map algorithm: first pass. (a) Illustration of the algorithm. (b) Resulting global photon map. (c) Resulting caustics photon map.*

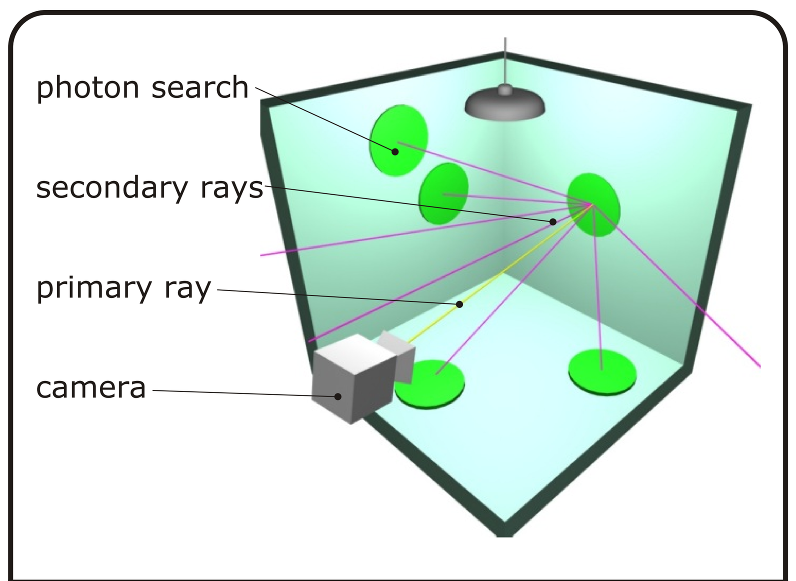

***Figure 3**. The Photon Map algorithm: second pass.*

4. Irradiance Cache

Irradiance cache [3] is a spatial data structure which allows to save computed values of indirect irradiance at diffuse surfaces and to retrieve them later very efficiently. Irradiance caching allows to decide whether it is necessary to compute indirect irradiance at a given point or it is possible to interpolate the irradiance from previously computed values. The irradiance is interpolated at large, flat surfaces where it changes very slowly.
This interpolation scheme greatly improves the speed of computation of multiple diffuse interreflections.

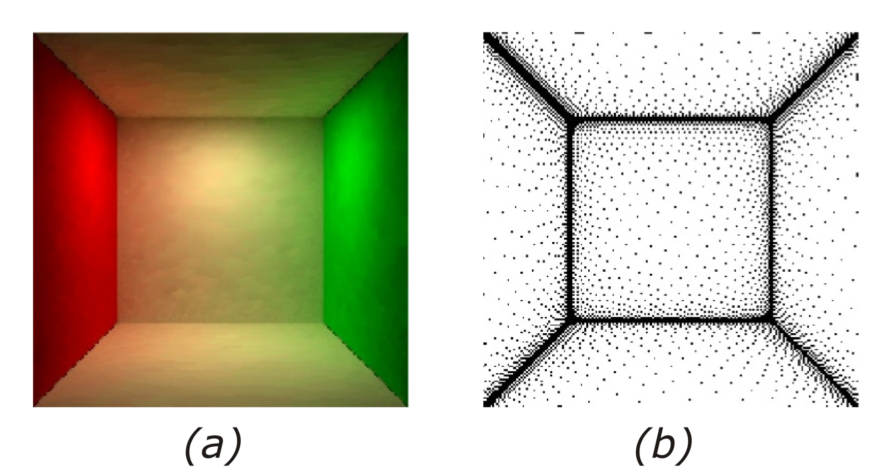

***Figure 4**. Irradiance cache. (a) Resulting image (b) Positions, where indirect irradiance was computed.*

5. Edge Detection in Photons Maps

Edge detection is a novel technique introduced in [2]. It allows to detect the edges of caustics and to sharpen them. Normally, the edges are blurry. This can be pleasant (for example the caustics cast by waves on the water) but it can also be very annoying (for example the caustics cast by a rectangular mirror).
The technique can also be seen as applying a radically non-symmetrical filter on the values of flux got from the photon map.

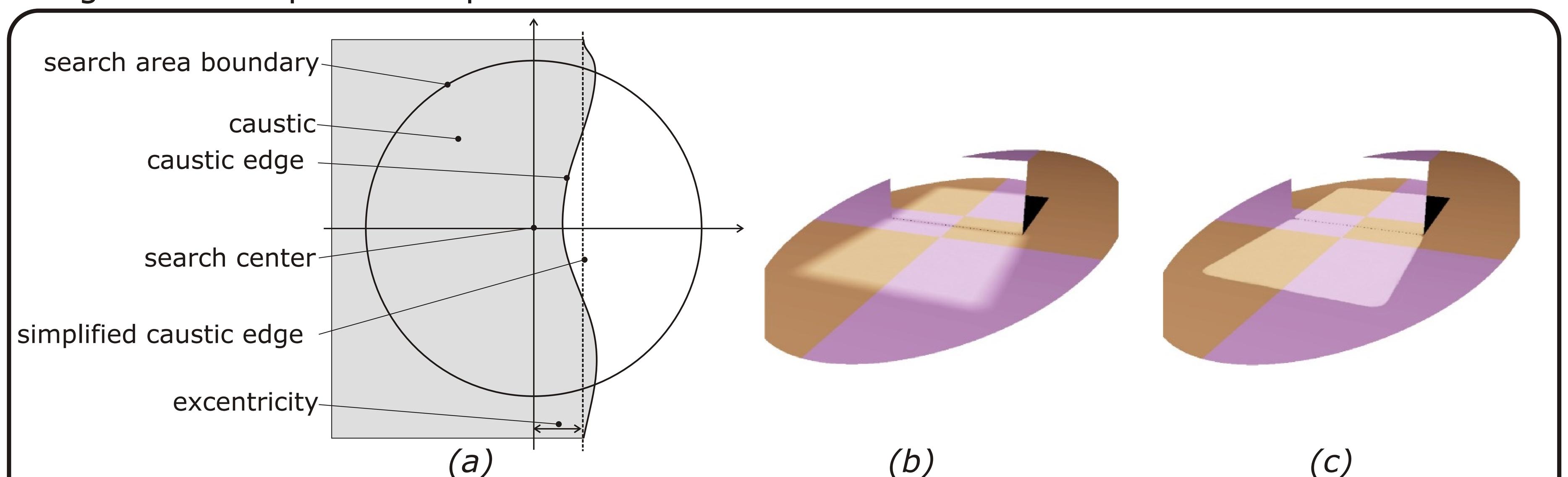

***Figure 5**. Edge detection. (a) Situation at the edge of the caustic. (b) Caustics cast by a rectengualr mirror onto a diffuse floor. No edge detection. (c) With edge detection.*

6. Conclusion

We implemented the Photon Map and the Irradiance Cache algorithms, we addressed the problem of blurry caustics edges and we solved it by the technique described in section 4.
In the future we would like to solve the problem of rounded caustics edges (see figure 5c). Our edge detection technique could be used to improve the shadow photon map to detect the edges of cast shadows.

7. References

[1] Jensen, H. W.: Global illumination using photon maps. In Rendering Techniques '96 (Proceedings of the Seventh Eurographics Workshop on Rendering), pages 21-30. Springer Verlag, 1996.
[2] Křivánek J.: Modern algorithms for image synthesis. Master's thesis, Czech Technical University, Prague, February 2001.
[3] Ward G. J., Rubinstein F. M., Clear R. D.: A ray tracing solution for diffuse interreflection. Computer Graphics, 22(4):85-92, 1988.

***Figure 6**. Caustics cast by a metal ring on a table.*