Photon Mapping for Photorealistic and Non-Photorealistic Rendering

Parker Greene
pwgreene@mit.edu

I. Introduction

The rendering equation, introduced by Immel et. al. [1] and Kajiya [2], is much better estimated by photon mapping than simple ray tracing; however, unlike ray tracing, photon mapping relies on Monte Carlo sampling techniques, meaning the more photons mapped, the more realistic the rendered image appears. Thus, the method is much more computationally expensive than ray tracing, but with this increase in computation comes the power to render more complex effects, such as indirect illumination and caustics.

Though indirect illumination is one capability of photon mapping, I chose instead to focus on rendering caustics and more specifically, rendering lighting effects through transmitting surfaces. Another feature of photon mapping is that once the photons are mapped, the view camera can move and view the same scene, since the photons, though randomly distributed, do not move when the camera is moved. This view-independence feature was my primary motivation for exploring the possibility of view-independent non-photorealistic (NPR) rendering, since many methods of rendering artistic styles, stippling in particular, traditionally rely on generating random noise, which is difficult to keep consistent across multiple views.

A. Motivation

I was personally motivated to explore the non-photorealistic rendering of these artistic effects because of my background in drawing and painting. I was hoping to explore the more possibilities of imitating brush strokes with photon mapping, but this was a pretty unexplored area in computer graphics research, likely due to its difficulty. I instead spent much more time improving the rendering of realistic effects and pencil effects once I got a working implementation of the photon mapping algorithm.

II. Related Work

Photon Mapping was initially introduced by Jensen and Christensen [3] and my approach in this paper is primarily based on Jensen's algorithm. The photon mapping algorithm has seen a number of improvements, including adding a photon map for shadow photons [4], which I adapted to use as part of my implementation for rendering stippling effects.

Non-photorealistic rendering has been explored by a large number of computer graphics researchers. I am unaware of any research papers exploring the possibility of using photon mapping for stippling effects, though there has been plenty of research into rendering objects with this effect [5]–[7]. Li and Wang [8] utilized the photon mapping algorithm to develop a painterly rendering framework, using the the impressionist line integral convolution (ILIC) used by [9].

III. Approach

IV. Results

Since the photons are mapped independently of the camera, multiple views of a stippled scene can be generated without having to remap photons. This video shows a 360 degree view of the sphere from 4b. Frames are rendered in less than one second on the CPU.

REFERENCES

[1] Immel, David S.; Cohen, Michael F.; Greenberg, Donald P. "A radiosity method for non-diffuse environments" (PDF), Siggraph 1986

[2] Kajiya, James T. "The rendering equation" (PDF), Siggraph 1986

[3] Jensen, Henrik Wann and Niels Jrgen Christensen: "Photon maps in Bidirectional Monte Carlo Ray Tracing of Complex Objects". Computers and Graphics 19 (2), pp. 215-224, 1995.

[4] Jensen, Henrik Wann: "Global Illumination Using Photon Maps". Rendering Techniques '96 (Proceedings of the Seventh Eurographics Workshop on Rendering), pages 21?30, 1996.

[5] A. Lu et al., Nonphotorealistic volume rendering using stippling techniques. Proc. Visualization 2002, 81?89

[6] Lu et. al., 2003, "Illustrative Interactive Stipple Rendering". IEEE Transactions on Visualization and Computer Graphics, VOL. 9, NO. 2, APRIL-JUNE 2003.

[7] J. Kruger and R. Westermann. Efficient stipple rendering. In *Proceedings of IADIS Computer Graphics and Visualization*, 2007.

[8] M. T. Li and C. M. Wang. "A 3D Painterly Rendering Framework for Photon Mapping," Journal of Information Science and Engineering. 2010.

[9] C. M. Wang and J. S. Lee, "Using ILIC algorithm for an impressionist effect and stylized virtual environments," Journal of Visual Languages and Computing, Vol. 14, 2003, pp. 255-274.

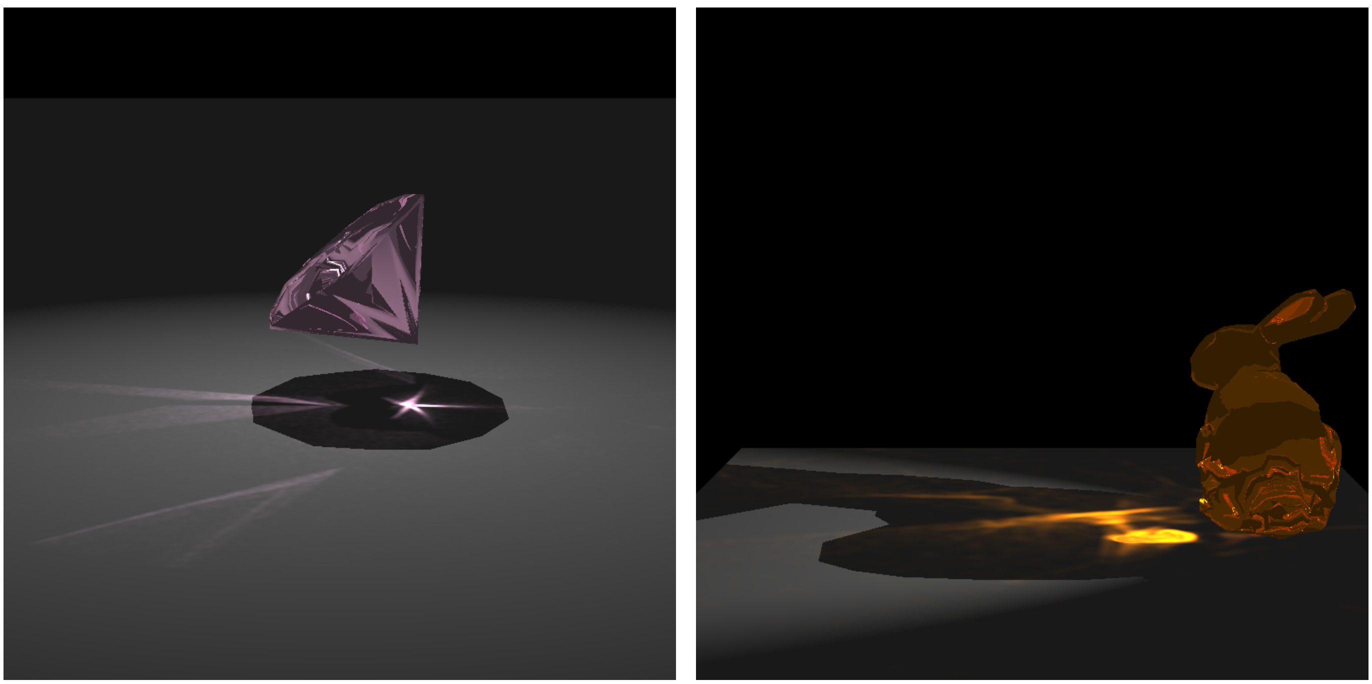

Fig. 1: The color of caustics can be estimated estimated very accurately.

Fig. 2: Layering of transparent surfaces shown by a wine glass and wine. Rendered using 100000 photons. The liquid gets darker with more depth, an animation for the pink diamond animation can be found at https://www.youtube.com/watch?v=NwYMuA0i4MA

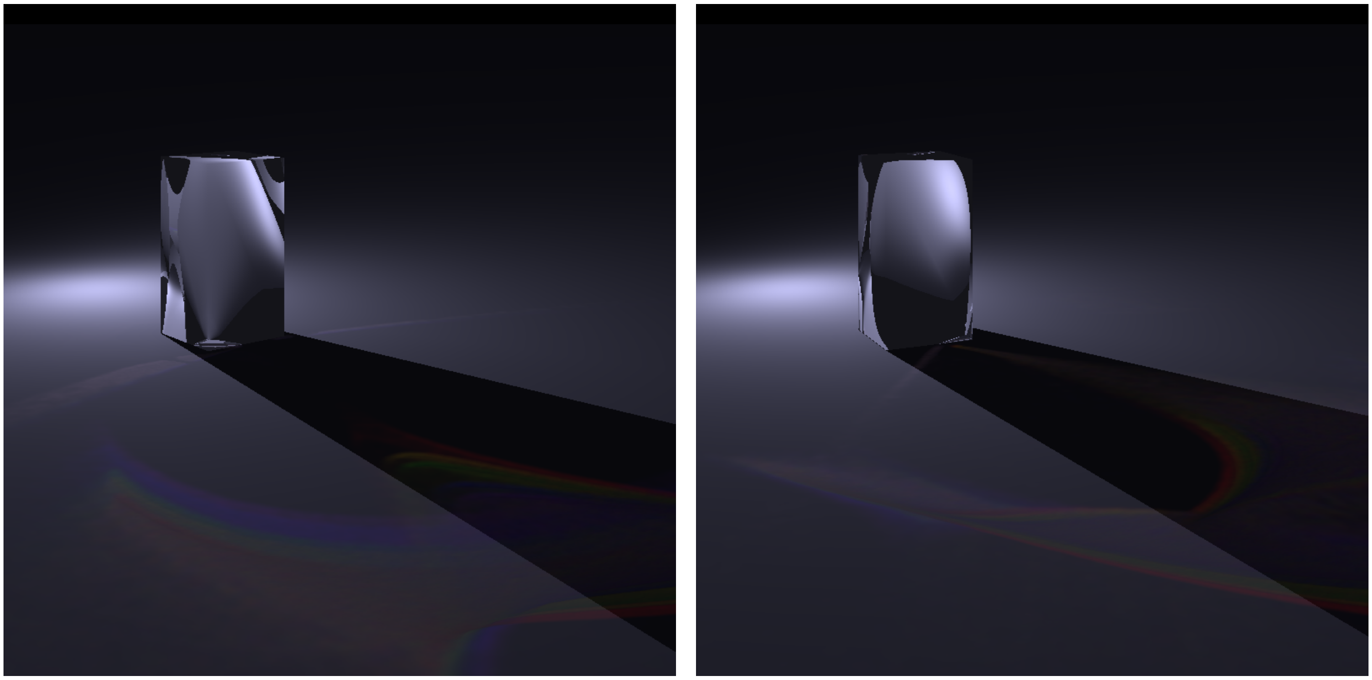

Fig. 3: Prism rendered at two different angles. The bands of light are more separated on the left, and they combine at the right. Rendered with 90000 photons. 5 wavelengths were sampled. A video with 90 degrees can be found at https://www.youtube.com/watch?v=A88_MirA29w

(a) Stippling effect on a sphere with a spotlight

(b) Stippling effect on a sphere with an area light

Fig. 4: The difference in the choice of lights to render the stippling effect

(a) Stanford dragon rendered with a spot light. 50000 photons were used

(b) Bunny rendered with an area light. 30000 photons were used. Notice that the shadowed side of the bunny has much more shape than the lit side

Fig. 5: more complex geometries are handled quite nicely by the stippling effect using photon mapping