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Light Transport Simulation with Vertex Connection and Merging

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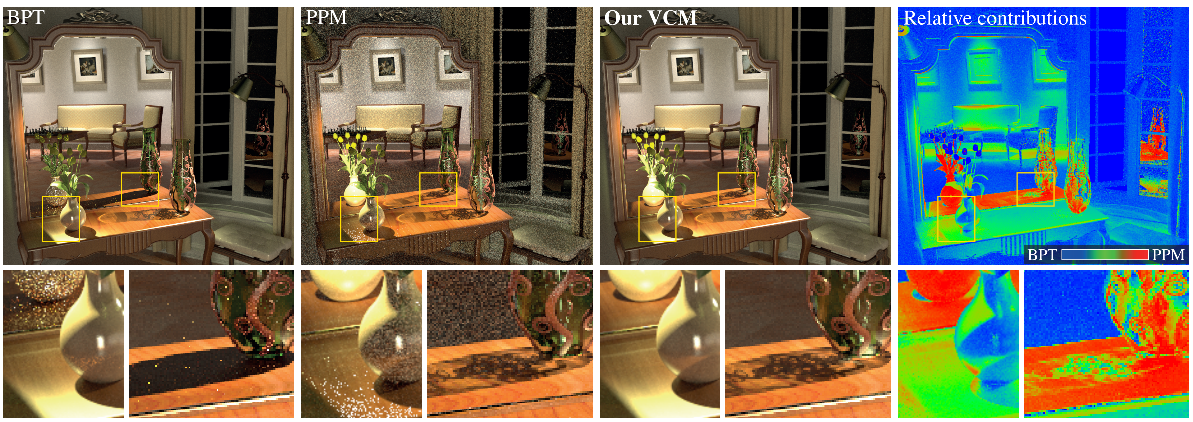

Figure 1: A comparison of our vertex connection and merging (VCM) algorithm against bidirectional path tracing (BPT) and stochastic progressive photon mapping (PPM).

Overview. Light transport simulation is an essential element in realistic image synthesis for computer-generated imagery. However, developing robust light transport simulation algorithms that are capable of dealing with arbitrary input scenes (scene geometry, surface reflectance, light sources) remains an elusive challenge. Although efficient light transport algorithms exist, an acceptable approximation error in a reasonable amount of time is usually only achieved for specific types of inputs. To address this problem, we present [1] a reformulation of the popular density estimator, known in computer graphics as "photon mapping" [2–4], as a bidirectional path sampling technique for Monte Carlo light transport simulation [6]. The benefit of our new formulation is twofold. First, it makes it possible to explain the relative efficiency of photon mapping and bidirectional path tracing [5, 7, 8] algorithms, which have so far been considered conceptually incompatible solutions. Perhaps more importantly, it allows for a seamless integration of the two methods into a more robust combined light transport simulation algorithm, dubbed *vertex connection and merging*, or VCM. A progressive version of this algorithm is consistent and efficiently handles a wide variety of lighting conditions, ranging from direct illumination and diffuse inter-reflections to specular-diffuse-specular light transport, which is notoriously difficult for bidirectional path tracing. Our theoretical analysis shows that VCM inherits the high asymptotic performance from bidirectional path tracing for most light transport path types, while benefiting from the efficiency of photon mapping for specular-diffuse-specular lighting effects.

Results. A comparison of our vertex connection and merging (VCM) algorithm against bidirectional path tracing (BPT) and progressive photon mapping (PPM) [2, 4] after 30 min of rendering is shown in Figure 1. BPT fails to reproduce the light focused by the vase and reflected in the mirror (specular-diffuse-specular transport paths), while PPM has difficulties handling the illumination coming from the room seen in the mirror. Our VCM algorithm automatically computes a good mixture of sampling techniques from BPT and PPM to robustly capture the entire illumination. The rightmost column shows, in false color, the relative contributions of the path sampling techniques from BPT and PPM, respectively, to the VCM image.

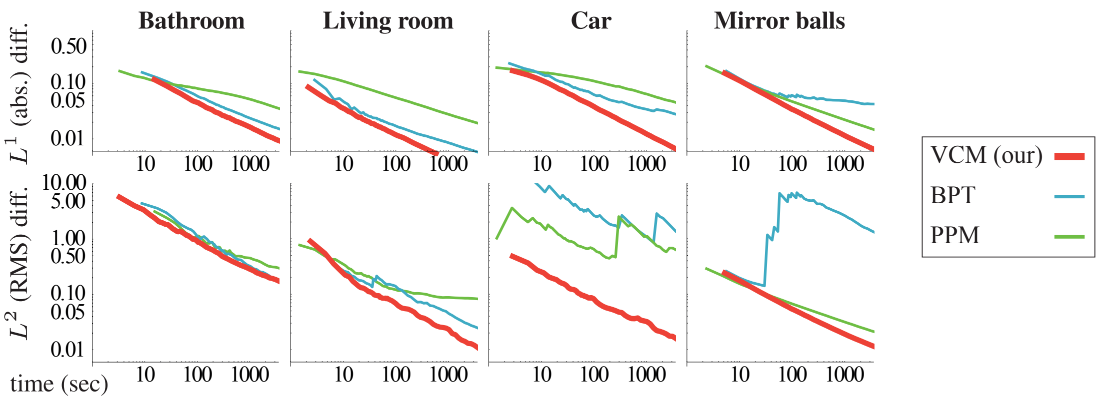

Figure 2: Convergence plots for our vertex connection and merging (VCM) algorithm, bidirectional path tracing (BPT) and progressive photon mapping (PPM).

Figure 2 shows the log-log plots of mean absolute (L^1) and root mean squared (L^2) error for the three algorithms in four different scenes. The plots provide an empirical evidence of our theoretical result that the new VCM algorithm converges at a higher rate than progressive photon mapping (PPM). The oscillations in the plots are due to the “fireflies” caused by low sampling probability of high contribution paths which increase the error of the produced image when found occasionally. For further details and results, please refer to [1] or the paper web site at http://cgg.mff.cuni.cz/˜jaroslav/papers/2012-vcm/.

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References

[1] I. Georgiev, J. Křivánek, T. Davidovič, and P. Slusallek. Light transport simulation with vertex connection and merging. *ACM Trans. Graph.*, 31(6):192:1–192:10, Nov. 2012.

[2] T. Hachisuka, S. Ogaki, and H. W. Jensen. Progressive photon mapping. *ACM Trans. Graph.*, 27(5), Dec. 2008.

[3] H. W. Jensen. Global illumination using photon maps. In *Eurographics Workshop on Rendering*, pages 21–30, 1996.

[4] C. Knaus and M. Zwicker. Progressive photon mapping: A probabilistic approach. *ACM Trans. Graph.*, 30, May 2011.

[5] E. Lafortune and Y. D. Willems. Bi-directional path tracing. In *Compugraphics '93*, pages 145–153, 1993.

[6] E. Veach. *Robust Monte Carlo Methods for Light Transport Simulation*. PhD thesis, Standford Univeristy, 1997.

[7] E. Veach and L. Guibas. Bidirectional estimators for light transport. In *Eurographics Workshop on Rendering*, 1994.

[8] E. Veach and L. Guibas. Optimally combining sampling techniques for Monte Carlo rendering. In *SIGGRAPH '95*, 1995.