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Report on the PhD thesis of Martin Šik

Martin Šik's thesis "Global exploration in Markov chain Monte Carlo methods for light transport" tackles the issue of global exploration, which is a long-standing and extremely challenging problem in the area of computer graphics.

Rendering algorithms generate photorealistic images by computing a high-dimensional integral over the space of light paths. This integral is typically riddled with discontinuities, singularities, and large areas that are entirely zero-valued. State-of-the-art integration techniques based on Markov Chains evaluate the integral using random sample generation and provide powerful strategies for local sample placement. This leads to good exploration of the integrand at a local level, but global exploration is often surprisingly poor, causing slow convergence and distracting artifacts. Martin Šik's thesis makes several important contributions that advance the state of the art of this challenging problem. In the following, I will briefly summarize the key contributions and describe my opinion regarding the originality and quality of the presented work.

Chapter 1 motivates the thesis and gives an initial overview of the problem of global exploration. Chapter 2 introduces prior "classic" rendering techniques that are not based on Markov Chains, and Chapter 3 introduces the fundamentals of MCMC.

Chapter 4 provides a comprehensive review of prior work on MCMC rendering techniques. I was impressed by this chapter and had not previously seen such an interesting and systematic discussion of prior work in this area. Martin Šik demonstrates a deep understanding of all presented methods and provides a detailed discussion of their properties and advantages or disadvantages relative to other approaches.

Chapter 5 introduces several new methods for realizing tempering and replica exchange-type mutations on a regularized form of the target distribution when rendering particularly challenging input. The contributions include techniques for sampling neighbor swaps and larger permutations between different temperatures, and improved scheme for equi-energy moves. The chapter concludes with an extremely systematic and insightful analysis of a large set of swapping strategies.

Chapter 6 discusses a technique that integrates vertex connection merging—at heart a density estimation technique—with Markov Chain transitions. An important take-away message from this work is the observation that an asymmetric design that combines both MC and MCMC sampling in a single algorithm can produce excellent results. In particular, using normal Monte Carlo integration for the camera sub-path ensures stratification and yields generally improved convergence. The method also applies replica exchange to make certain transitions only based on the binary visibility function. The final method is pleasantly simple to implement and achieves impressive results on a number of example scenes.

Finally, Chapter 7 concludes the thesis and presents future directions.

Martin Šik's thesis is of high quality. It presents a comprehensive and relevant body of work that advances the state of the art in the area of rendering. I found all material clearly and thoroughly presented and nicely illustrated. I recommend this thesis to be **accepted without reservation**.

Sincerely,
Wenzel Jakob

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