Error Analysis for Modern Shadow and Lighting Algorithms

Doctoral Thesis Topic

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Recent years have seen an extraordinary evolution of Graphics Programming Units (GPUs) which allows efficient implementation of arbitrary algorithms in a massively parallel scheme. This major evolution has led to the development of a large number of very effective algorithms, in all aspects of computer graphics and in particular high-quality realistic rendering (e.g., soft shadows (Guennebaud et al 2007) or global illumination (Dachsbacher et al. 2007) etc.). As a consequence, unprecedented levels of realism and detail are now achievable on consumer level machines.

Nonetheless, the development of these algorithms is often very closely related to the hardware, leading to the adoption in many cases of arbitrary heuristics designed to take advantage of the specific hardware configuration. While the results are often very visually compelling, and can in some cases provide reasonable approximations, a true error analysis of the implied trade-offs is seldom performed.

Left: Example image from Antiradiance (Dacshbacher et al 2007). Middle and right, images from (Ritschel et al 2008). While compelling, the sources of error of these images has not been carefully analyzed.

In this thesis, our first concern will be to provide principled error analysis of various approximate but effective real-time algorithms. This error analysis will provide the basis for the development of better algorithms, which will be built on much more solid foundations.

Our goal is to develop a solid theoretical foundation for the analysis of the sampling and reconstruction error in such shadow and lighting algorithms. The first task will be the definition of the appropriate theoretical framework (potentially based on approaches akin to (Durand et al. 2005, Rammamoorthi et al. 2007)); other potential avenues of research include recent sparse coding methodologies which appear promising. In parallel we will concentrate on a few concrete examples which are relatively simple to analyse (e.g., the soft shadow approaches Guennebaud et al 2007 or Schwarz and Stamminger 2007), which will allow us to detemine the efficiency and applicability of our theoretical choices. We then hope to move on to more involved algorithms such as Antiradiance (Dachsbacher et al. 2007) or the more recent imperfect shadow maps (Ritschel et al. 2008). The error analysis approaches developed will also incorporate perceptual aspects of illumination (e.g., how much error humans can tolerate without perceiving a difference from a reference). Overall our research will hopefully lead to the development of improved algorithms with guaranteed convergence properties.

In addition we will investigate the relationship between GPU-based finite-element methods such as those mentioned above, and GPU-based ray-tracing approaches, in particular in light of the developments of solutions such as Optix from NVIDIA http://www.nvidia.com/object/optix.html.

Requirements

The successful candidate should have a Masters degree in Computer Science, and have preferably taken courses in computer graphics and have experience in computer graphics programming, with knowledge of OpenGL or DirectX, and some experience with shading languages such as GLSL/HLSL/Cg. Knowledge of signal processing, linear and non-linear optimization techniques is desirable.

References

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