University of California  *San Diego*

Henrik Wann Jensen
Computer Graphics Laboratory
Department of Computer Science and Engineering

henrik@graphics.ucsd.edu
9500 Gilman Drive
CA 92093-0404

Review of Jiri Vorba's thesis

This is a review of the thesis by Jiri Vorba titled "Adjoint-Driven Importance Sampling in Light Transport Simulation".

Let me start by saying that the thesis clearly proves the author is able to perform creative scientific work.

The thesis has two significant contributions that have also been published in papers in ACM Transactions on Graphics (the premier journal in computer graphics) as well as presented at the SIGGRAPH conference, which is the premier conference in computer graphics.

The first major research contribution is a method for progressively learning the lighting and importance distributions in a given scene. The proposed technique for learning using a Gaussian Mixture Model is able to represent lighting/importance with much greater accuracy than previous methods. The learned lighting/importance distributions can be used to improve importance sampling in a Monte Carlo ray tracing framework by sampling according to the predicted lighting distribution. Most methods in Monte Carlo ray tracing only consider the local reflectance properties (BRDF) of the surface for importance sampling. The proposed method combines both techniques using multiple importance sampling rather than using the product (which would be optimal). The results demonstrates that considering the incident lighting/importance in addition to the BRDF leads to much faster convergence in scenes with complex lighting. Compared to previous work the improved accuracy of the representation results in improved importance sampling which reduces noise. Interestingly, the improvement to basic techniques such as path tracing and photon tracing is much more significant than the improvement to more complex methods such as bidirectional path tracing and VCM/UPS. This potentially opens an avenue where a basic method such as path tracing can be used in more situations. This is advantageous since path tracing is easy to implement and understand, but more importantly also easy to control in scenes with complex changing materials as often seen in movie production. The learning method presented in the thesis is a promising new way of computing and representing lighting / importance distributions in 3d scenes. I believe it can be used as a promising tool in future global illumination algorithms.

The second major contribution in the thesis is an improvement to Russian Roulette, which is a technique for terminating a sample path. Normally, Russian Roulette use local sur-

face properties (such as reflectance) or path properties such as throughput to compute a probability for terminating a path. The thesis presents a new method that uses an estimate of the lighting contribution to compute a probability of terminating a path. This makes it possible to terminate paths in dark uninteresting parts of the scene with a higher probability than previous techniques were able to do. Furthermore, it is also possible to increase the number of paths using splitting, which generates multiple samples from a single path vertex. This allows a much finer exploration of the sample space in important regions of the scene. The resulting technique leads to a promising noise reduction for several scenes. When combined with the learning method presented earlier in the thesis the noise reduction is significant. The new termination / splitting criteria is a significant contribution that improves on state of the art, and it takes a widely used technique and improves it in a promising way.

My main critique of the thesis is the limited description of previous work in the field. There has been significant work in the area of Monte Carlo ray tracing and the presented work builds on previous work such as a paper I wrote in 1995 titled "Importance Driven Path Tracing using Photon Maps". The author does compare to the method in the description of the new learning technique, but I feel the introduction of the thesis should describe the previous techniques in more detail as well as outline in more detail the limitation of these techniques. While it is written along with the presentation of the method I believe it should be earlier in the thesis to properly frame the new research. Right now the claims are a bit broad – claiming that previous methods use the BRDF for importance sampling, while there are several papers that use lighting as well as the product of lighting and the BRDF. Related to this point, the paper from 1995 I mentioned above is importance sampling the product of the BRDF and the lighting, while the proposed method only is able to importance sample either the lighting or the BRDF (and then uses MIS to combine the methods). It is unclear from reading the thesis if the product of the lighting and BRDF is used when comparing with previous work. One fairly significant short coming of the thesis is the lack of a comprehensive bibliography. It seems clear that the thesis is based on the two published SIGGRAPH papers, where space is limited, but in a thesis I would expect a more detailed discussion and listing of previous work. There has been quite a few papers dealing with importance sampling the product of lighting and BRDF's. One example is:

Clarberg et al. "Wavelet Importance Sampling: Efficiently Evaluating Products of Complex Functions", SIGGRAPH 2005

While this paper is not dealing with indirect illumination it does deal with environment lighting and BRDF sampling, which the author does spend a bit of time discussing.

In addition, there has been previous papers dealing with learning lighting distributions and sampling them:

Bustillo, "A neuro-evolutionary unbiased global illumination algorithm", Rendering Tech-

niques ’97

It would be good if the thesis discussed and referenced this and other papers in order to more precisely describe the research contribution.

For the Russian roulette sampling and splitting I would also have liked to see a more comprehensive discussion of previous work to properly frame the contribution. One minor oversight of the author is that the technique by Dutre et al. 1995 also used the potential contribution to control the absorption of a path (rather than plain Russian Roulette). However, this paper did not explore the method further and it was only utilized in a light tracing framework.

The thesis refers to supplemental work for a number of comparison techniques. I find this quite unusual and it seems like a mistake caused by using SIGGRAPH papers as a template. I believe all comparisons should be in the thesis, so that the thesis is a complete work in itself.

A few minor details. Page 58, hight -¿ high

Why is the graph for RMSE for path tracing in figure 4.13 to similar (it seems the improvement is more significant)?

In conclusion, I believe the two presented techniques shows that Jiri Vorba is able to perform creative scientific work, and I do like the research results and proposed techniques.

Sincerely,

Henrik Wann Jensen
Professor of Computer Science
University of California, San Diego