Review of Alexander Wilkie's habilitation thesis entitled "Predictive Rendering"

This thesis is the summary of Alexander Wilkie's recent results in an important branch of computer graphics, which can be called predictive rendering. The dissertation has an introduction and includes the most relevant papers published at the most prestigious forums of computer graphics. The habilitation dissertation has been submitted at the Charles University. The plagiarism audit has not shown any serious scientific misconduct regarding copying, which is not surprising since the dissertation is a collection of published scientific papers and each of the papers has gone through a serious check during the review of its respective journal.

I have to admit that I also acted as a reviewer of Dr. Wilkie's habilitation procedure at the Vienna University of Technology more than ten years ago, where the title of the dissertation was quite similar. However, the papers attached to this dissertation were all born after the previous habilitation procedure and show new research results. It means that predictive rendering has become an important field in computer graphics and Dr. Wilkie has remained very active in this field even after his first habilitation.

The first part of the thesis is the summary of the challenges in predictive rendering and a review of the candidate's work in this field comparing the state of the art ten years ago and now. I agree with the statement that we can observe a relevant progress, and increased realism can be obtained with the simulation of more physical phenomena. However, I still argue the point that predictive rendering requires 100 percent accuracy in geometric and optical models. In my view, models can never be perfectly accurate nor can the simulation process take into account all physical phenomena (physics itself is a just a model of reality), thus some error in rendering is inevitable. I think the goals and the pipeline of predictive rendering should also include the analysis and the quantification of the rendering error (e.g. an error value in each pixel) and the demonstration that this error is less than required by the given application, for example, less than the just noticeable error in movie rendering. This might be a research direction in the future. It would also be worth examining when we can use geometric optics and when physical optics is necessary, and establish practical criteria to answer this question.

The research results have been implemented in ART (started at the University of Vienna by the candidate and his supervisor) and also in the production renderer of Weta Digital.

The thesis includes 5 papers, two of them are published at ACM TOG, which is the highest ranking journal in computer graphics, and three of them in Computer Graphics Forum which is among to top three.

The first paper entitled "An Analytic Model for Full Spectral Sky-Dome Radiance" has been authored by Dr. Wilkie and his PhD student. The importance of the sky model in predictive rendering is that this is the typical illumination environment in practical cases, so its inaccuracy would fundamentally limit the rendering quality. The paper has generalized the Perez-Preetham sky model by executing path tracing simulations considering turbidity and Mie or Rayleigh scattering, and used the simulated data to fit the improved model. This paper has received 95 citations according to Google Scholar.

The second paper entitled “Hero Wavelength Spectral Sampling” is the result of the collaboration with Weta Digital. The paper has been presented at the Rendering Symposium and published in Computer Graphics Forum. The research goal here is to develop a sampling method for the wavelength providing unbiased and low variance estimates, but can easily be incorporated into existing single wavelength renderers. This paper got 34 citations.

The paper entitled “Scattering-aware Texture Reproduction for 3D Printing” and its follow up paper published last year take a fundamentally new direction and exploits predictive rendering to obtain better color reproduction in 3D painting. Unlike other papers discussed so far, this paper considers the full predictive rendering pipeline from material parameter measurement to printing the final result.

The paper “Handling Fluorescence in a Uni-directional Spectral Path Tracer” was also presented at the Eurographics Rendering Symposium, which is one of the highest ranking conferences in this field, and published in Computer Graphics Forum. The paper addresses the simulation of fluorescence, which has been in the focus of Dr. Wilkie’s research for a long time. Fluorescence is a challenge for most of the computer graphics algorithms since unlike higher energy photons applied e.g. in medical imaging, photons of visible light keep their energy and therefore frequency upon elastic scattering with electrons. Thus, wavelength can typically be simulated independently. In case of fluorescence, however, this simplifying assumption is not valid anymore, making many classical approaches inappropriate. The goal of the paper was to generalize the Hero wavelength approach for fluorescence, and thus to develop a practical extension of path tracing algorithms to handle this problem.

Finally, “Wide Gamut Spectral Upsampling with Fluorescence” also attacks the problem of fluorescence. This is a recent paper presented at the Rendering Symposium and published in the Computer Graphics Forum last year. The research attacks an inverse problem, from the tri-stimulus RGB values, the spectrum needs to be reconstructed. As this is an ill-posed problem because of metamers, the requirement of spectral smoothness is added. Again, this paper is an important contribution to fill the gaps of the development of practically applicable prediction rendering pipelines.

Concerning the Turnitin report that compared the introduction of the thesis and the papers accessible on the Internet, the total similarity is 15% and the maximum similarity with one particular paper is 3%. Turnitin was not able to find the strong correlation between the thesis introduction and the own publications of Alex Wilkie. I consider this as a positive fact since it means that Alex Wilkie really summarized the research objectives and results in a way that is appropriate for the short thesis summary and not just copy-pasted the abstracts of his own papers.

Summarizing, the attached papers demonstrate the continuous and high quality research work of Alexander Wilkie, who has become a renowned expert in predictive rendering. It should be emphasized that the research results have been published at the highest ranking forums and have found their application in practical industrial software. The research community also appreciated these achievements and Google Scholar shows more than 1200 citations on the papers of Alexander Wilkie.

Based on these facts, I, as an external reviewer, support Alexander Wilkie’s habilitation.

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