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Objet : report for the dissertation of Asen Atanasov.

Efficient and Expressive Microfacet Models

The scientific work presented in the dissertation of Asen Atanasov takes place in the context of material appearance representation in realistic image synthesis. The study is focused on microfacet models which are a physically based representation of how light interacts with matter (through geometrical optic assumptions). Due to their ease of use and the wide range of materials that can be simulated, microfacet models are a key element in many of professional rendering tools. They have been the focus of much attention for over three decades where many of previous studies address optimization problem in rendering software or try to extend range of modeled materials (transparency, layered, glints, etc.) The scientific work of Asen Atanosov is part this continuity.

In addition to the introduction and conclusion, the core of the manuscript is splitted in four parts. Parts 2 and 3 highlight the essential concepts and the state of the art related to the research topic. Parts 4 and 5 are focused on the two major contributions of the thesis. Each of them has been published in an international renowned computer graphics journal.

Introduction
After a short summary of the historical attempts to represent how objects reflect the light, the introduction mainly treats microfacet models through a bibliography with selected pertinent references related to the dissertation topic. This allows to quickly position the motivations of the thesis work : the representation of anisotropic and glinty appearances. The introduction ends with a summary of the two major contributions presented later in the manuscript and finally indicates the publications produced by Asen Atansov during his thesis : two papers in journals also presented in recognized conferences (Eurographics and EGSR) as well as 3 talks presented at SIGGRAPH (major conference in the field).

Part 2 : Measuring reflection
This part focuses on the needed backgrounds about BRDF models. Indeed, it starts with a short reminder about fundamental radiometric notions and then clearly exposes equations related to BRDFs, their properties (energy conservation, reciprocity, etc.) and constraints on their integration in rendering engine (fast evaluation and importance sampling for instance). Lambertian and Fresnel models for purely diffuse and specular BRDF are also presented : they will be used as a basis for the development of microfacet models later on. This part is clear, concise and rigorous, focusing only on things that are essential for the rest of the demonstration.

Part 3 : Microfacet Theory
This is also an introductory chapter, focusing this time on the specific developments of microfacet-based models (statistics, distribution, masking/shadowing and anisotropy). The part is again concise but very well written, setting up well the problems addressed in the two following parts (combined BRDF, sampling and anisotropy). These introductory parts 2 and 3, explaining the backgrounds, while being short, show a capacity of synthesis and mastery of the subject. Asen Atanasov cleverly avoids the pitfall of trying to put too much into the text and thus helps the reader to focus on the real themes of the thesis.

Part 4 : Linearly Transformed Microsurface
This part presents the first contribution of the thesis work. The distribution of the normals is a key element in the statistical representation of the micro-surface. However, only a sub-class of analytical distributions defined isotropically can be extended to takes into account anisotropy. The work proposed in this section consists in developing a new way of defining this anisotropy for any valid distribution of normals under the assumptions of the microfacet theory. Starting from an analysis of the impact of linear transformations on surface statistics (shadowing function, distribution and sampling micro-normal), Asen Atanasov arrives at an elegant generic expression of the representation of anisotropy, independent of the distribution chosen upstream. The mathematical demonstrations and the accompanying text are extremely clear. The figures are relevant and perfectly illustrate the geometrical intuition behind the mathematical proofs. I am quite convinced that the contribution of this work is an interesting advance in the representation of the appearance of materials. Asen Atanasov clearly shows this in the results section by using his framework for the case of the GTR distribution for which anisotropic representation was not available before. I would make a small reservation on this part concerning the discussion of the limitations. Indeed, the proposed method allows to define the anisotropy for any valid distribution, but the development of the other statistics (shadowing and sampling) depends on the knowledge of these functions beforehand. If we do not know how to define the masking for the initial distribution, we will not be able to do it for the transformed distribution (Equation 4.3 and 4.4)... These limitations do not detract from the quality of the work and the relevance of the choices. The proposed contribution clearly advances the problem of representing anisotropy independently of the chosen distribution (thus offering more control over the desired appearance) and its limitations offer interesting work perspectives.

Part 5 : Multiscale Microfacet Model
The second contribution is about the multiscale microfacet model and more precisely efficient normal map filtering during rendering. This problem has been the subject of several publications in recent years. The manuscript therefore focuses on discussing these developments as well as proposing a classification of existing methods, taking into account the new methods proposed [Deng,2022] since the publication of Asen Atanasov's paper (2021). This greatly facilitates the understanding of the problem. The choices made and the proposal of the new IBM data structure (for Inverse Binned Map) are very well presented and justified, in relation to the problem statement. Results and their discussion prove quite clearly the usefulness of such a method, with a low memory consumption and efficient in pre-computation and execution time. These results are also well discussed and highlighted in comparison with existing methods. Perhaps the most recent method [Deng,2022] could have been evaluated in more detail, or at least added to the comparison Table 5.2 on the properties that normal map filtering techniques must have, or Tables 5.3 and 5.4 on the memory and pre-computation costs respectively.

Conclusion
The conclusion focuses first on the limitations of the two contributions and on the perspectives for future work. Even if this part is short, it answers some questions that I could have during the reading of the 2 chapters related to the proposed contributions. It seems to me that the stated perspectives offer interesting future research directions for the community. Finally, the part concerning the use of the techniques presented in a commercial tool (Chaos V-Ray) shows

that the work of Asen Atanasov fits perfectly in a practical context and answers directly to concrete problems. This shows the relevance of the choices made.

Appendices
The 4 appendices add some additional information to the manuscript. I think that the appendix C.4 on the improvement of the GTR sampling could have been put directly in the manuscript. It is in my opinion a contribution, certainly modest in comparison with the 2 contributions put forward, allowing to make more practical the use of this distribution.

Avis général sur le mémoire de thèse

The thesis presented by Asen Atanasov shows a meticulous and successful research work in several respects : the bibliographical study is pertinently carried out in relation to the addressed problems. The necessary scientific bases are effectively summarized, putting the reader in a position to finely understand the choices made. Finally, the two contributions presented show great originality in the choices made to respond to concrete problems. The results of each approach are discussed in depth, they are of very good quality, and the conclusion is clear with interesting perspectives. The whole manuscript is very pleasant to read and I underline the conciseness and the concern of synthesis. Finally, the scientific work done is validated by several publications in conferences and recognized international journals but also via implementation in a major production tool in the industry of realistic image synthesis. For all these reasons, my opinion for the defense of the thesis is very favorable.

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