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Review of dissertation entitled "Improvements of shadow rendering", by Ph.D. student Ing. Jozef Kobrtek

The presented dissertation is a revision of a previously submitted thesis that deals with several incremental improvements of shadow volume-based techniques for real time rendering of hard shadows. Apart from that, the thesis also presents results of two comparative studies, one focused on shadow map rendering techniques, and the other dealing with the current state of the art in rendering precise shadows. The author has been working on this topic for many years (the oldest publication of the author on the topic dates from 2012), and the thesis represents a summary of his contributions.

The topic of hard shadow rendering is undoubtedly an important one, even though I believe that current applications mostly demand an approximation of soft shadows, as they are more realistic than exact hard shadows. On the other hand, I appreciate the focus on the robustness of the algorithms, addressing issues related to general data (triangle soup) and singular cases.

The chapters 2 and 3 provide some background information on shadow rendering. The exposition is reasonably structured, although it is sometimes hard to follow, and there are some questionable choices present as well. For example, figure 2.14 comes from a source that is currently inaccessible, and it is supposed to present an example of filtered drop shadow. Having discussed the image with several computer graphics researchers, I am confident that the image was created using some global illumination method with an area light source. Either the image is chosen by mistake, or it demonstrates some extremely advanced version of the drop shadowing technique not discussed in the rest of the chapter. The used terminology that I have previously challenged has been improved, although some minor issues remain (section 3.1.4 for example seems to implicate that "precise shadows" are the opposite of "soft shadows", which is in my opinion wrong).

The chapter 4 refers about experiments done with shadow mapping, mainly comparing cube map based algorithms against dual paraboloid mapping. I do agree that comparing the two is an interesting topic of study, and the experiment design has been improved by including results measuring the accuracy of the rendered shadows. Still, however, the results leave room for improvement. For one, the compared images were blurred for reasons that are not explained (page 47). The measure description is somewhat confusing, stating that unmarked (differently marked lit/shadowed in comparison with reference?) pixels are weighted by a value of 15. Why this value in particular was chosen and whether or not it has any impact on the qualitative (i.e. win/lose) results is not explained, however, the values are used for reporting percentual differences, which I find odd.

The chapter 5 discusses an improvement of silhouette extraction focused on mitigating problems with triangles that are almost tangential to the silhouette. A solution is presented that seems sound, and results were added regarding the success in eliminating the artifacts caused by triangles almost parallel with the light direction. It remains unclear why in table 5.2 the measurement on HD4000 using geometry shader is marked "n/a" for baked meshes.

The chapter 6 deals with shadow volume based shadowing implemented using either a geometry shader or a tessellation shader. The results are interesting, and additional results were provided with respect to the previous version of the thesis detailing the performance on more recent hardware, which I appreciate. The presented results are, however, not particularly well discussed: for example, in fig. 6.10, it seems that the difference in performance is mainly exhibited at low per-frame times, while at higher per-frame times the GS and TS implementations perform equally. This phenomenon is, however, not explained.

The chapter 7 discusses an acceleration technique for silhouette extraction based on preprocessing and spatial subdivision of the possible light source locations. The proposed improvement seems sound, trading memory efficiency for runtime performance. The practicality of such endeavor is, however, uncertain, since even the tests shown in chapter 7 report less than 25% performance improvement at the cost of using up gigabytes of memory and sacrificing the applicability to deforming shadow casters.

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In chapter 8, a comparison of several hard shadow algorithms is presented. The conclusion states that the results demonstrate that shadow volume methods remain competitive with RTX based shadows, which is in my opinion not fully justified by the presented tables and figures, where RTX shadows seem to outperform the competition by a margin. Some previous results where raytraced shadows exhibited artifacts were fixed. Still, there are some issues present, e.g. in 8.3.3, the author states that "…PTSV was able to outperform CPTSV…", which is in my opinion in contradiction with the table. It is also unclear whether the methods are in fact all precise (which seems to be assumed), or whether there is a variance in the quality of the shadows, as indicated in 8.5 ("… the method has the most accurate shadows of the tested algorithms"). If the latter is the case, then the experiment design is dubious again, since the quality of the results is not discussed (naturally, for example, completely wrong shadows can be computed even quicker than using HW accelerated raytracing).

The thesis is still written in English of a rather mediocre quality, despite the fact that the rebuttal states that the text has been proofread by a native English speaker. Not being a native speaker myself, I do feel confident that there are dozens of language problems that must be obvious even to a reader who is not familiar with the technical content of the thesis. There is no way of and no point in listing all the problems here, but to name a few there are repeated words ("of of", page 6, "only compressed only one level", page 77) and even a complete repeated sentence (page 46), wrong prepositions ("with contact" vs. "in contact" page 6, "independent on" vs. "independent of", page 29 and 105, "discarded for" vs. "discarded from", page 39, "in average" vs. "on average", page 68, "consists from" vs. "consists of", page 86, "aim to" vs. "aim at", page 91), wrong declination ("frustums" vs. "frusta", page 17, "the methods computes multiplicity", page 53, "pack two 4-component vectors into a single registers", page 54, "we saw opportunity in this new rendering pipeline stages", page 57), strange/wrong wording ("opened scene" vs. "open scene", page 17 and 106, "uneven" vs. "odd", page 25, "as see in the Figure 3.14", page 37, "first couple of images" vs. "first pair of images", page 55, "concluded tests" vs. "conducted tests", page 65, "eight siblings of one parent", page 75, "containment test", page 77, "disclosed in the Algorithm 14", page 78, "we computed X and Y from each scene", page 84, "omni directional light source can demonstrated be very well", page 98, "triangle dependency" vs. "triangle count dependency", page 104 and 105. "if not for …" vs. "apart from…", page 106, "fastest time behind ray tracing" vs. "fastest time after ray tracing", page 106), missing subject ("…, otherwise produces artifacts due to linear interpolation of the rasterization unit", page 18, "…, although consumes only a third of the memory…", page 46, "… single object was drawn. was able to outperform …", page 68), typos ("poasses", page 42, "cuba mapping", page 44, "the projects them" vs. "then projects them", page 58, "processed at one", page 79), missing verbs ("…, thus able to read all opposite vertices and compute the multiplicity", page 59, "…, instead a series if incremental performance and robustness improvements to stencil shadow volumes as well as silhouette extraction.", page 107) and many others.

These problems mostly do not fully obscure the meaning, apart from a few more pronounced cases, such as for example on page 59, where I believe the sentence should read "As edges may have different number of opposite vertices, …", rather than "As vertices may have different amount of opposite vertices, …", or the caption of figure 6.7. On the other hand, the sheer number of the problems clearly points at a certain carelessness and lack of rigor in finishing the thesis and even calls into question the truthfulness of the authors statement that the text has been proofread.

The publication record of the author is unfortunately not particularly convincing. The thesis lists 6 papers, 3 of which were published at the WSCG conference (one of those is a poster) and three at other conferences. One of them seems completely unrelated (Dielectric Properties of Epoxy Resins with Oxide Nanofillers and Their Accelerated Ageing) and the author is the first author of only one paper. The contribution of the author is specified in each chapter, and sometimes seems rather minor (implementation of an algorithm using specific CPU instructions), although I do appreciate that this information is being disclosed. The author did not bother to include the recently accepted journal publication into the list of publications in Appendix A. It is also somewhat questionable whether or not a comparative paper can be considered a full technical contribution. Web of science lists only two references to works done by the author, unfortunately only to the unrelated paper.

The presented thesis undoubtedly has been improved with respect to the previously evaluated version. Many of the problems were addressed, however, more than a few still remain. The publications are still unfortunately underwhelming, although now there is a journal paper first authored by the thesis author. I have spent a lot of time contemplating the verdict, since the overall level of the thesis is borderline at best, perhaps slightly leaning towards insufficient when more stringent assessment is applied. On the other hand, the author has indeed demonstrated that he is capable of improving his work, and for this reason **I do recommend the thesis for defense** in the sense that I wish an opportunity to be granted to him to present the thesis to the committee and to defend it.

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I suggest following topics to be discussed during the thesis defense:

- Is there a particular reason to use any other shadowing method than raytracing given a GPU that supports RTX?
- How exactly is the shadow quality evaluated in chapter 4 and why?
- Do the methods compared in chapter 8 all provide exact shadowing? If there are artifacts, were they evaluated/quantified?
- Please discuss the results in Figure 6.10 and the image in figure 2.14.

In Pilsen, on 28. 2. 2022

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