Friedrich-Alexander-Universität
Technische Fakultät

Referee Report on the thesis „Optimization Techniques in Computer Graphics and Appearance Fabrication “ by Tobias Rittig

Optimization techniques are a widely used tool in many areas of visual computing, such as computer graphics, geometry processing, or computer vision. In his thesis, Mr. Rittig applies optimization techniques to two separate areas in visual computing: appearance fabrication and sky modeling.

The larger part of the thesis looks at techniques to obtain visual appearance (mostly texture) of fabricated objects. Sophisticated 3D printers can print with different colors, making it possible to generate colored objects. Because of subsurface scattering, the final color of an object is not only determined by the top-most layer. In order to achieve a desired appearance, it is important to optimize also deeper layers of a 3D print. Simple techniques, such as the extrusion of the texture inwards, are not optimal, and lead to blurry appearance. For thin structures, the problem is particularly difficult, because a desired appearance for front and backside are competing goals that can be contradictory. Treating the problem by optimization is difficult, because the number of voxels in a 3D print is huge, and the evaluation of the resulting appearance requires costly volumetric rendering. Mr. Rittig is not the first to look into the problem to optimize the appearance of 3D prints, but he makes two major contributions to this problem in his thesis. First, he presents a method that can consider arbitrarily shaped objects, including thin structures. To this end, he extends prior work [Elek at al. 2017] that assumes flat, thick surfaces, to arbitrary shapes. He examines classical optimization approaches for patches of very limited size, but the long computation times to simulate the appearance make this not applicable to larger objects. Mr. Rittig thus extends the much faster and greedy optimization approach of [Elek at al. 2017] to arbitrary surfaces. Major contribution is a method to assign one or multiple relevant surface points to all inside voxels and to extend optimization updates accordingly. The results look convincing, and the method is thoroughly evaluated. As second major contribution, Mr. Rittig proposes a neural-network-based approach to simulate the appearance of a colored 3D print. Because the approach is orders of magnitude faster than a volumetric Monte-Carlo simulation, which is the bottle neck of prior approaches, this results in much faster convergence with only very little loss in quality. The approach requires extensive training data generation and a well-tailored network architecture, but generates convincing results. In two following, smaller sections, Mr. Rittig describes additional work on the measurement of material parameters and a comparison with latest gradient-based optimization approaches.

In the second part of the thesis, Mr. Rittig looks into the generation of high-dynamic-range sky maps. His major contribution in this area is a GAN-based approach to augment a clear sky by clouds and a horizon. The approach starts with a parameterized clear sky model, which is then augmented with clouds. The approach is based on a huge data set of sky images with registered sun positions. The proposed method generates satisfactory, but not high-quality results, but the

task is also very ambitious, so the work can be seen as a first important step for a practically very relevant problem.

From a technical perspective, I think that Mr. Rittig made innovative and original contributions. The presented approaches seem to be technically sound. I was most impressed by the neural approach to estimate the appearance of a 3D print, as well as the idea and the technical implementation of the network architecture for cloud augmentation. The quality of Mr. Rittig's research is also visible in a very good number of publications in the important venues of computer graphics – in particular Siggraph, Siggraph Asia, and Eurographics.

It must be noted that Mr. Rittig had strong collaborations during his thesis, and that the contributions of all these papers are only partially his. In the thesis, the contributions of the different authors are described and separated well. The magnitude of the contribution of Mr. Rittig in the sections is varying much, which makes sense to get a consistent document, but makes it sometimes difficult to judge the overall contribution of Mr. Rittig. The structure of the thesis follows the series of publications Mr. Rittig participated in, including iterations of approaches over time. All in all, the thesis is self-contained and consistent. The two rather separate parts of appearance fabrication and sky generation are combined using the common bracket of optimization, even if this bracket is a bit weak.

The thesis is generally well written. It is well structured and easy to follow. The state of the art is well summarized, even if the thesis is based on a large spectrum of prior work. I appreciate the good motivations and introductory experiments that help to understand the made decisions and the chosen path. The developed approaches are described and illustrated well. It seems that enough information is given to reproduce the results, which are evaluated and discussed thoroughly and honestly.

In summary, I think that Mr. Rittig has submitted a technically strong and well written dissertation. The thesis clearly shows that Mr. Rittig is able to achieve original, creative, and important scientific results that advance the state of the art in his research area. This is also demonstrated by a number of high-class publications that prove the international visibility of Mr. Rittig's work. I thus recommend to accept the thesis without any reservations.

Erlangen, 11.09.2023

Marc Stamminger