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Optimization Techniques in Computer Graphics and Appearance Fabrication

Optimization, the process of improving an intermediate solution, has been applied in numerous fields of computer science and beyond. Visual computing has throughout been at the forefront of developing new techniques and applying them to synthesize or analyze visual reality. At the latest, the recent boom of deep learning has given attention to large-scale differentiable computation and the application of gradient-descent optimization.

This thesis spans parts of this development in four shared first-author publications (three journal, one conference) and three co-authored journal papers. It shows how optimization algorithms are used in two distinct fields of computer graphics.

First, the focus is on the emerging field of Appearance Fabrication using full-color 3D printing. We show the benefits of an iterative optimization loop on the sharpness and color accuracy of translucent printouts. Such a loop, consisting of a forward prediction and backward refinement, can be composed of various building blocks developed throughout the thesis. The forward prediction can be driven by accurate Monte Carlo path tracing or an approximate neural rendering solution. The backward refinement can rely on a heuristic or a gradient-descent optimization algorithm, the latter in combination with differentiable rendering. Additionally, we analyze the application of differentiable rendering for measuring the optical properties of translucent 3D printing materials.

The second application highlighted in the thesis is Sky Modeling, where we show how an optimization process is used to train a generative neural model to produce hemispherical cloudy sky images. Effectively this is a data-driven approach to embed a large set of real-world observations, namely HDR sky photographs , into a common latent space. Re-sampling this space then forms new sky imagery useful for realistic lighting of 3D scenes in rendering with the added benefit of continuous parameters that foster artistic freedom.