Gloss-aware Color Correction for 3D Printing

Supplemental Material

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CCS CONCEPTS

• **Computing methodologies → Reflectance modeling**.

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1 INTRODUCTION

In the supplementary materials we provide implementation details, technical details of the experiment and other considerations regarding the physical fidelity of our rendering pipeline. We include a figure featuring all samples used in our final validation and ablation studies (Figure 1).

2 PSYCHOPHYSICAL EXPERIMENT: EXTRA DETAILS

Hardware and Extra Stimuli Details. The experiment was conducted under constant and controlled office illumination with no contribution of natural light. We used a color-calibrated DELL U2718Q display with 97.3% coverage of sRGB , 3840x2560@60 resolution and frequency, and a maximum SDR brightness of $335 cd/m^2$. No extra tonemapping is performed on the videos apart from the sRGB color mapping and gamma correction for a standard IPS display.

Participants. 11 subjects participated in our experiment (10 male and 1 female, 20-39 years old), all naïve to the purpose of the experiment.They all had a normal or corrected-to-normal vision and showed perfect color perception according to Ishihara charts [Ishihara 1917] and Farnsworth's 100 hue tests [Farnsworth 1943], which were administered before subjects could take part in the experiment. All participants were financially compensated for taking part in our experiment.

3 RENDERING FRAMEWORK SELECTION

Any alteration of the printing material results in a complex change of the object's final surface color due to light scattering in the varnish coating and sub-surface scattering within the printed object. We simulate these effects by employing physically-based rendering. For the highest rendering accuracy, an expensive volumetric simulation to model the sub-surface scattering within the highly translucent printing plastics would be required. Instead, we assume that the 3D printing software already accounts for the scattering effect to produce a desired surface color. Consequently, we simplify the process by assuming a diffuse base covered by a rough dielectric coating. In a typical ink-jet full-color 3D printing setup [?], we have two main ways of reproducing a desired surface gloss: printing micro-geometry and using varnishes. By altering surface roughness, we can create samples that appear as more matte (high roughness) or more glossy (low roughness). While surface roughness makes incoming light reflect in many directions, and thus create a more diffuse and matte appearance, reflections at the surface level will suffer from much less absorption due to the translucency of the material; if the incident light was to be pure white, the resulting surface color would appear as a lighter, de-saturated version of the intended printing color. A similar process occurs when adding a varnish. Matte varnishes are manufactured by introducing additives into otherwise clear varnishes. These additives are usually silicas, polymethylurea resins or different kinds of waxes, with two main properties: low particle size (less than $10 \mu m$) and an index of refraction as close as possible to that of the clear varnish, to avoid hazing. During the drying process, these particles rise to the surface, creating a micro-roughness which scatters incident light, creating the matte appearance[Marrion 2007]. Scattering events on the surface undergo almost no absorption whatsoever, making the surface color appear lighter and de-saturated when compared to its un-varnished counterpart, as less rays penetrate the substrate. Inversely, glossy varnishes enhance color contrast due to surface levelling [Berns and de la Rie 2003].

4 DIFFERENTIABLE RENDERING OPTIMIZATION

We solved the differentiable rendering optimization using Mitsuba 3's [Jakob et al. 2022] differentiable rendering capabilities, which performs automatic differentiation to compute gradients with respect to the base diffuse material color. We used the Adam optimizer [Kingma and Ba 2014] and empirically found a learning rate value of 0.015 to work well with all tested colors and surfaces. In all our experiments, it was sufficient to perform from 50 to 400 iterations for

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the optimization to converge. On average, the whole optimization (including the rendering of references for the mask) takes around 5 minutes.

As a precomputation, we estimate the pooling mask on a high-samples-per-pixel image. Next, at every iteration during the optimization, we render a new low-samples-per-pixel image with the target coating (i.e. matte or glossy). In practice, we initially disturb the original surface color to smoothen the optimization. Once the optimization is computed for a matte-gloss-color triad the results can be reused on any geometry, allowing for potential computations of large look-up tables for gloss-aware color in a 3D printing software.

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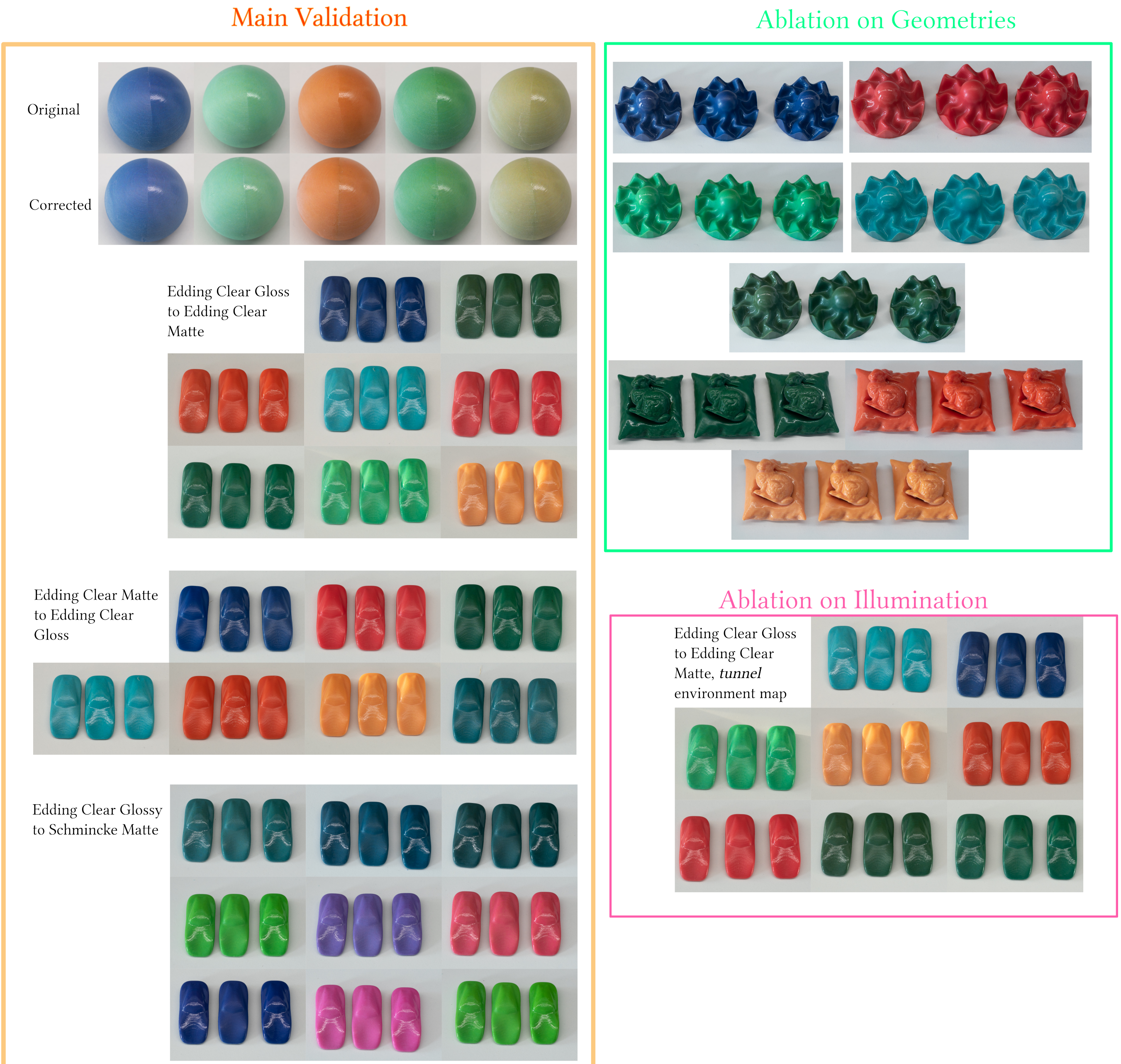

Figure 1: All samples used in our second experiment, both main validations and ablations. For all samples, references are middle (sample to match) and right (uncompensated sample), and left is our color-corrected sample.