Towards Understanding and Editing the Appearance of Translucent Materials

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Abstract

In computer graphics, the ability to edit and manipulate material is crucial for creating realistic and believable images. While this ability has always been related to the film and video-games industries, lately more and more product companies want to let their users customize their own product, before buying. Moreover, the recent advances in 3D printing technologies follow this trend. In this context, the usual tools for editing complex materials need to be revised, to simplify the editing phase for novice users. Therefore, we focus on translucent materials, a class of materials that is widely present in the physical world that surrounds us and encompasses both natural substances like food or human skin, as well as synthetic materials such as plastic or jade. While multiple models for translucent materials exist, understanding how we perceive translucent appearance, and how it is affected by illumination and geometry, remains an open problem. In this study, we investigate how accurately human observers can estimate the density of translucent objects under static and dynamic illumination conditions. Surprisingly, our findings suggest that dynamic illumination may not be essential for accurately assessing the nature of translucent materials.

Introduction

From a physical point of view, translucent materials can be described as a medium enclosed by a dielectric surface. In computer graphics, the simulation of dielectric surfaces is often parametrized by two optical parameters: the refractive index of the material and the roughness parameter. The medium that is embedded inside the surface is parameterized by three others optical parameters, the single scattering albedo, the phase function and the optical density. Specifically, the optical density is used to model density of the object, thus lower values lead to glass appearances, while higher values create more opaque and thicker appearances.

Although the physical simulations to model the behavior of these materials are well understood, the way these optical parameters influence the final appearance is still an open question in the research area. Working towards this goal, researchers have shown how the perception of translucency can be influenced by, e.g., the position of the light, or the material density and phase function [1,2].

Building upon these investigations, we extend the research to a dynamic context. Previous research has demonstrated that dynamic stimuli can enhance appearance perception, including glossiness constancy [3]. Inspired by these findings, we devise an experiment to assess whether dynamic illumination contributes to an improved perception of translucency compared to static conditions.

To achieve this, we employ a matching task where participants are tasked to matching the optical density of a match image to that of a reference stimulus. This matching is conducted across various light positions and density levels. Interestingly, our findings indicate that dynamic illumination does not yield superior perception of translucent material density and therefore, a simpler static illumination is sufficient to convey the translucent property of the material. Our work has been accepted at the ACM Symposium on Applied Perception (SAP 2022) [4].

Method

In our study, we employ an asymmetric matching task, in which each participant is required to match the optical density of the match image to that of the reference stimulus, following previous work [1]. Reference and match stimuli are shown side by side and depict the same object (the “Lucy” statue). The Reference and the Match are both rendered with the same optical properties (surface roughness, index of refraction, single scattering albedo, and phase function), except for the optical density (extinction coefficient). The matching task is conducted for four distinct levels of optical density, while the other optical parameters are fixed, following previous work [2]. The match image can be illuminated under three static conditions: side, back, and front (refer to Figure 1).

Twelve participants with normal or corrected-to-normal vision take part in two separate matching experiments, conducted in random order and across two different sessions. One experiment involves a tatic reference, while the other incorporates dynamic illumination.

Results and Future Work

In our study, we examine the participants' ability to estimate the density of translucent objects by comparing their estimations of the optical density in the match image with that of the reference stimulus.

The data are subjected to a repeated measures ANOVA, which reveals a significant effect of the match light position ($p < 0.05$). Depending on the position of the lighting, participants tend to either overestimate or underestimate the density, aligning with previous findings [1]. Interestingly, we find no statistically significant differences ($p > 0.05$) between the static and dynamic illumination conditions of the reference stimulus.

The estimation of density remains similar in both conditions, contrary to expectations given that dynamic lighting conditions offer additional information, such as variations in incoming light directions. However, previous work has demonstrated improved perception of appearance under motion for other material properties [3]. One possible explanation is that participants are unable to effectively utilize the extra information provided by the uncontrolled motion of the light source. Nevertheless, further investigation is necessary to fully comprehend the relevant factors influencing the perception of translucency. Specifically, conducting a more diverse set of experiments incorporating various shapes, light configurations, and different optical parameters levels (e.g., roughness, albedo and pase function) would be of great interest.

As a promising direction for future research projects, we want to highlight the exploring novel way to *edit* translucent materials. This task is nontrivial due to the non-linear relationship between optical parameters and perceptual space. Even a slight alteration in the parameter space can result in a substantial change in the visual perception. Additionally, the interdependencies among multiple parameters further complicate users' ability to predict the outcome of modifications accurately. Furthermore, the impact of different lighting conditions on translucent materials remains an unresolved issue that requires careful investigation

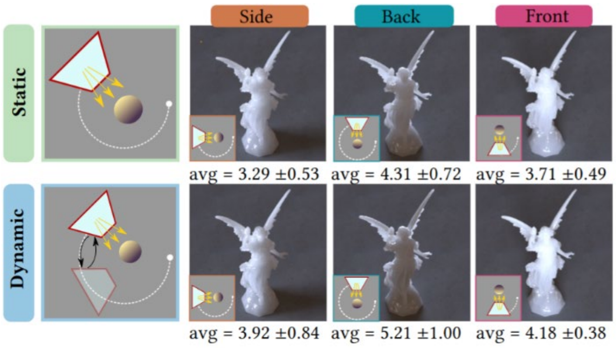

Figure 1: We analyze the effect of dynamic illumination on the perception of translucent materials. We design a matching experiment where participants estimate the optical density of a reference object with a static (top row) or dynamic (bottom row) illumination, for three light conditions. Below we report the average estimated density by participants with their associated standard deviation.

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