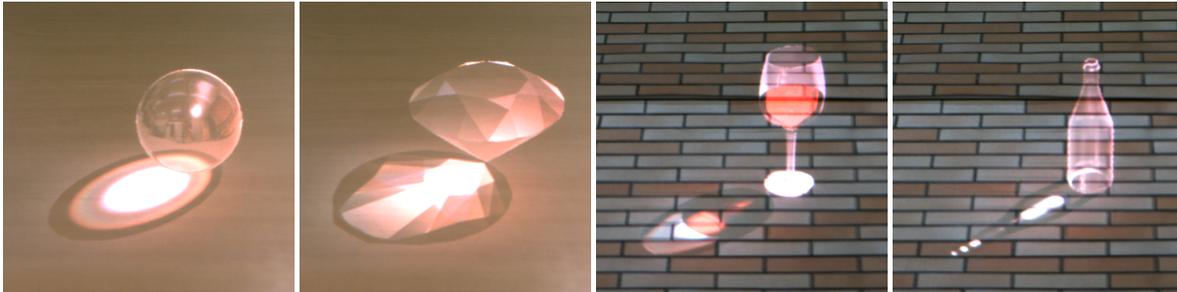# Can Transparent Virtual Objects Be Represented Realistically on OST-HMDs?

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| (a) Sphere on wood grain. | (b) Diamond on wood grain. | (c) Wine glass on brick tiles. | (d) Bottle on brick tiles. |

Figure 1: Example transparent objects rendered by Microsoft HoloLens.

ABSTRACT

In mixed reality using video see-through displays, various optical effects can be simulated for representing a transparent object. However, consumer-available OST-HMDs can not reproduce some of their effects correctly because of its mechanism. There has been little discussion concerning to what extent such transparent objects can be represented realistically. In this demonstration, we will show how effective each for combination of existing methods is.

Index Terms: Human-centered computingHuman-computer interaction (HCI)Interaction paradigmsMixed / augmented reality; Human-centered computingHuman-computer interaction (HCI)Interaction devicesDisplays and imagers

1 INTRODUCTION

Optical see-through head-mounted displays (OST-HMDs) are a major device for augmented/mixed reality (AR/MR), which allows for direct observation of a part from the light from the real world. As regards observation of real scene, OST-HMDs have advantages of preventing delay and contrast degradation as compared to video see-through (VST-) HMDs. However, consumer-available OST-HMDs are incapable of interception or attenuation of light ray from the real world because they are not equipped with spatial light modulator (SLM) [1] devices such as active-matrix liquid-crystal display (LCD), digital light processing (DLP), and liquid crystal on silicon (LCOS). This disadvantage poses the problem of rendering virtual objects with reality.

As virtual objects, transparent objects such as glass, water and diamond are challenging to simulate multiple optical properties even on VST-HMDs. The major optical phenomena that occur around such transparent objects are known to be reflection, absorption,

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refraction and shadowing on the real surfaces. Also in MR, it can be considered that highly realistic transparent objects can be rendered by simulating as many optical effects as possible and approximating them moderately for real-time performance.

However, OST-HMDs without SLM pose challenges in reproducing all the optical phenomena. To be specific, one of them is the shadows of the transparent objects that contains transmitted light. In order to represent the shadows, there is a need to attenuate the light in occluded areas from the light sources. Another challenge is distortion of the background image due ti reflection. Although it is possible to calculate the true image that is projected by refracted light by simulating light, when drawing the objects, there is a need to occlude the light of the true image. Therefore as seen from above, as to how there is a challenge in precisely drawing it physically, there has not been much discussion as to how transparent objects can be rendered to make it look realistic on OST-HMDs without SLM.

In this demonstration, in order to experiences how realistically transparent objects can be presented in OST-HMDs without SLM, various transparent objects will be displayed in consideration of several optical properties. The method used in this demonstration to render transparent objects applies existing computer graphics (CG) methods in regards to the reflection such as specular and Reflection maps on the surface of the transparent objects. For light transmission through the transparent objects, the path-tracing method [2] is used. For cast shadows on real surface, we adapt aperceptual approach [3] which presents shadows using two visual phenomena based on the brightness perception of can. Participants wearing the Microsoft-HoloLens (as an OST-HMD) move freely to observe virtual transparent objects. Participants can switch on and off each optical phenomena to confirm how its phenomena contributes to the reality.

2 RENDERING TRANSPARENT OBJECTS WITH SHADOW

In this demonstration, in order to confirm how realistically a transparent objects can be represented in OST-HMDs without SLM. They are represented while changing their optical properties. The selection criterion of reproduce optical phenomena is whether it satisfy two conditions or not. First condition is that object and light fixed, second condition is that the person can observe transparent objects from freely view point. Specifically, to render transparent objects
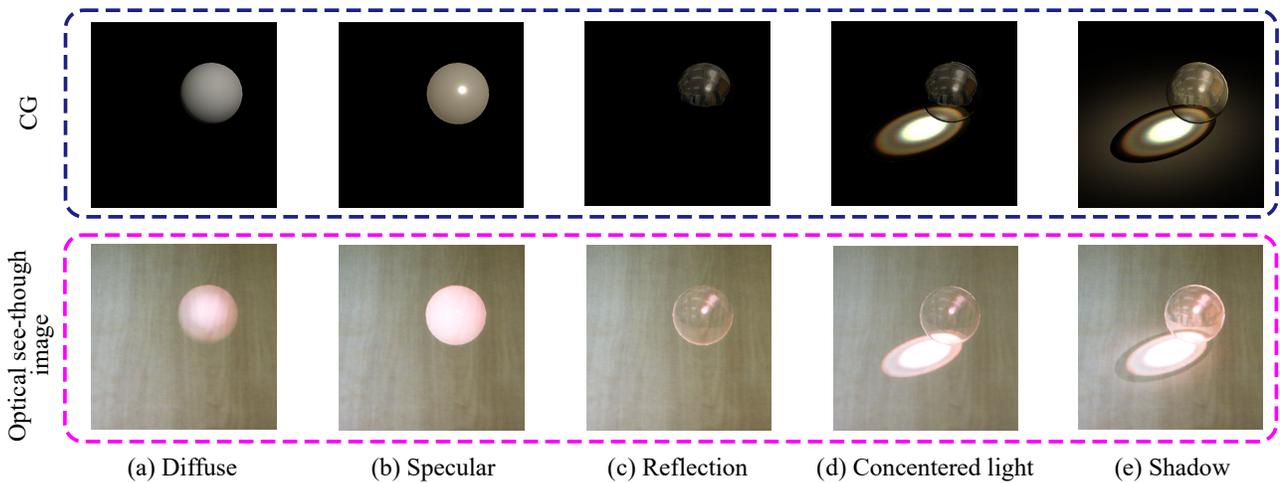
Figure 2: Contributions of optical properties to transparent objects.

applies the use of existing CG methods in regards to the reflection such as specular and reflection maps on the surface of the transparent objects. To cast shadows of transparent objects, it uses our proposing method.

The specular of surface of transparent objects is calculated by point light placed in virtual world and image of periphery of them is are reproduced by using Reflection-mapping. The texture required by reflection-mapping is captured the surroundings from the position where the transparent object is placed on in real world by using the Omnidirectional camera.

Shadows cast by transparent objects on real surfaces are represented by adding the shadow inducer [3] to the origin pattern of transmitted light. The shadow inducer is a virtual object placed around the shadow region. The brightness of the shadow inducer is higher than that of the shadow region and is decreased gradually with distance from the center.

The refracted background image seen through the transparent objects can be simulated by using real world texture and a ray-tracing method. Using reflection-mapping and real world texturing to surround the object, and searching for the intersecting point of the texture and ray, it allows for the simulative calculation of the pseudo-reraction background image. However, since it is a challenge to occlude a real image from the real world in an OST-HMDs without SLMs, as of current circumstances, there are only two choices: to overlay the simulated refraction image or not to overlay anything at all. In this demonstration, to guarantee the real-time performance for the user experience, we choose the former method.

3 IMPLEMENTATION

To represent transparent objects as virtual objects, the Microsoft HoloLens (as an OST-HMDs) was used. By placing the virtual objects in the layout of the real world, and to allow the user to freely move around the object to observe it, devices such as the environmental camera which is equipped in the HoloLens are used to predict the positioning and inclination.

The virtual world that is represented in the HoloLens is made using Unity. Transparent objects such as glass ball, diamond and more are placed on the designated origin point. The point light used to illuminate the objects are positioned at coordination of (1.0m,1.0m,1.0m). The specular of the surface of the objects are recreated using CG/HLSL. The real world texture need in reflection mapping is made by the use of an omnidirectional camera, Kodak PIXPRO SP360. The camera placed beforehand on the position where virtual transparent objects are rendered on in real world, then

the picture captured.

The transmitted light pattern embedded in the shadows of a transparent object, in reality, is made through rendering by the path-tracing method on the Cycles Render which is equipped in Blender, one of 3DCG software. The size of the object, the strength of the light source, and positioning is in the same setting as the virtual world created on Unity. In regards to the strength of the light source, in Unity there is no unit of a light source that correlates to the real world and therefore, to produce enough permeating light, it is set on $100.000\,\mathrm{W/m^2}$. When rendering, to prevent the object from being rendered, the two layers of projection of shadow and object are separated. The inducer that is added on to the shadow is created based on the method [3]. The real world texture that is needed to calculate the brightness is created using a wood grain and brick tiles, with the picture captured from above using the camera Canon EOS Kiss X8I that was prepared in advance.

4 RESULTS

According to 6 participants, the object with a low alpha value (Fig. 2(a)) and the object with specular (Fig. 2(b)) did not seem to have an appearance of transparent objects. The object with reflection-mapping shown in Fig. 2(e) became closer to a transparent object than Fig. 2(a) and Fig. 2(b). However, some participants answered that it looked like metal. The object rendered by the proposed method was the best as shown in Fig. 2.

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