Shadow Inducers: Inconspicuous Highlights for Casting Virtual Shadows on OST-HMDs

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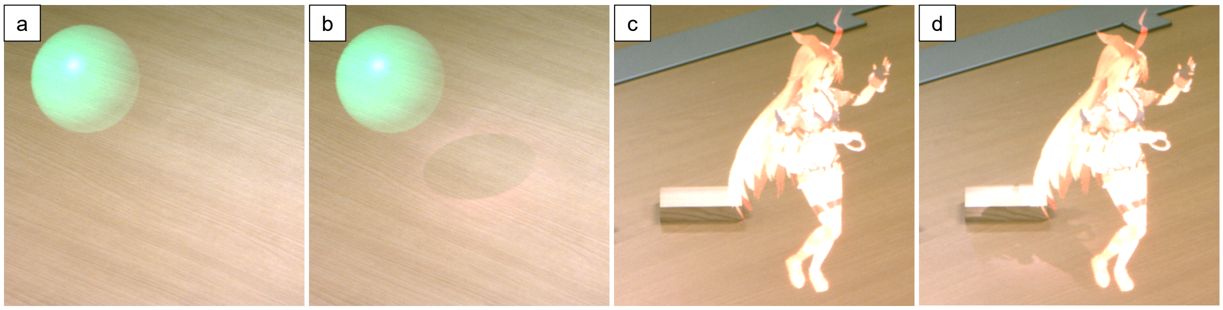

Figure 1: Virtual shadows on a real surface taken through an OST-HMD (Microsoft HoloLens). (a) A virtual sphere without a virtual shadow. (b) A virtual sphere with a virtual shadow. (c) The virtual humanoid character without a virtual shadow. (d) The virtual humanoid character with a virtual shadow. The virtual shadows are presented by a shadow inducer that surrounds the shadow area to amplify the intensity of the real surface. To make this amplification inconspicuous, the luminance of the surrounding region is gradually decreased with distance from the center. A virtual shadow can be cast even on a non-planar surface like the wood blocks.

Abstract

Virtual shadows provide important cues to determine the positional relationship between virtual objects and a real scene. However, it' s difficult to render shadows in the real scene on optical see-through head-mounted displays without occlusion-capability. In the previous work, we cast virtual shadows not with physical light attenuation but with brightness induction caused by virtual objects, referred to as shadow inducers, which surround the shadow area to gradually amplify the intensity of the real scene pattern [4]. However, because the shadow inducer was prepared beforehand, the shape of the shadow is constant, the real scene shadowing is limited to a flat surface, and a large of viewpoint change is impossible. In this demonstration, we propose a method to generate shadow inducers in real time that can change the shape of virtual objects and the viewpoint of users. In this method, depending on the appearance of shadows, the surrounding luminance is gradually amplified with the difference of gaussian (DOG) representing characteristics of human vision. Users can observe shadows of moving and deforming virtual objects on a real tabletop and other non-planar objects.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed / augmented reality; Human-centered computing—Human computer interaction (HCI)—Interaction devices—Displays and imagers

1 Introduction

Shadows are an effect in which the illuminance to a surface is relatively lower than that of the surrounding area. In mixed reality, virtual shadows, even with shape simplified, play important roles in the position and depth perception of virtual objects [5]. For rendering shadows on a video see-through HMD, many of existing computer graphics (CG) techniques can be diverted. For an OST-HMD, however, it is not trivial because attenuating the intensity of light from real scenes is difficult.

Bimber et al. proposed a method to present shadows by raising the illuminance of the whole region to expect the shadow area within the context of spatial augmented reality [1]. The adaptation functions of the human visual system, such as pupillary light reflex and brightness constancy, work much as the auto gain control system in cameras does. As a result, observers feel that the brighter the surrounding become, the darker the shadow part becomes. The same technique can be applied to OST-HMD, however, this method is not available when overlay field of view (FOV) is narrower than peripheral FOV. Although a similar concept for OST-HMD has been patented [3], no experimental evidence was provided. Manabe et al. proposed shadow inducers which are virtual objects placed around the shadow region and amplify the intensity of the real surface [4]. They have demonstrated that the perceived brightness inside the shadow inducer is darker than the surrounding area even when the physical luminance is equivalent. In their experiments, the intensity and shape of the shadow inducer were empirically decided. Therefore, they have not clarified how to generate shadow inducers in the cases of various shapes, e.g. non-convex and torus, non-planar backgrounds, and large viewpoint change.

This paper shows a novel method for casting virtual shadows with various shapes on the real scene for an OST-HMD in real time without any light attenuation devices or projectors. The method presents shadows as a result of brightness induction caused by additional the shadow inducer that surrounds the shadow area to amplify the intensity of the real scene pattern. For the generation of a shadow inducer, the shadow map is used to decide the shadow shape of the virtual object. By convoluting the difference of gaussian (DOG) to the appearance of the shadow to generate gradually luminance amplification, shadow inducers are made inconspicuous and large viewpoint changes are made possible. In the demonstration, the proposed method can cast the shadow of a moving and deforming virtual object on a real tabletop and other non-planar objects.

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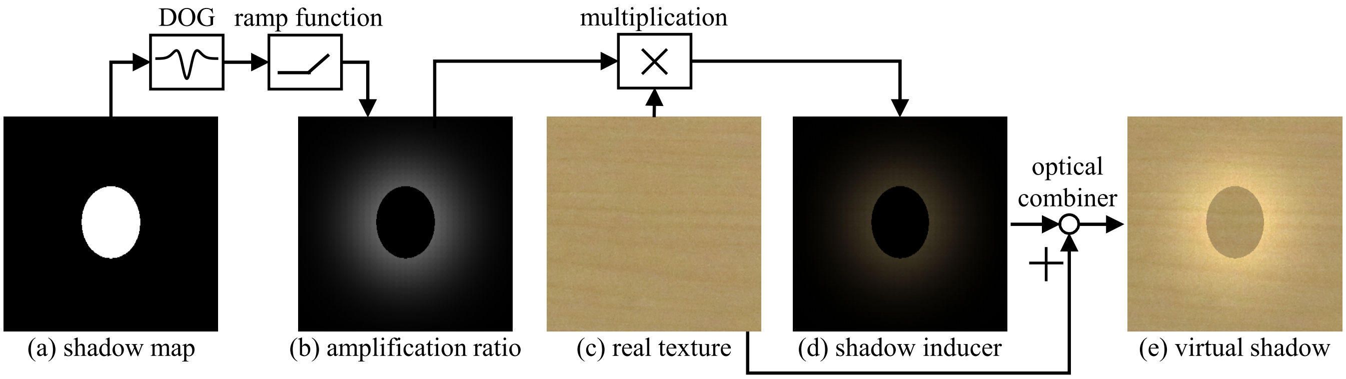

Figure 2: Data flow of the shadow inducer generation. (a) The shadow region is computed by the shadow mapping. (b) To calculate the ratio of the amplification, (a) is convolved with the DOG filter and cut of the negative. (c) Texture of the real scene can be taken from the user-perspective camera. (d) The shadow inducer is generated by multiplying (c) by (b). (e) Virtual shadow can presented by overlaying (d) on the real surface.

2 Shadow inducer generation

In our method, premises for casting a virtual shadow are that the 3D model of the real scene including a light source estimated and aligned in advance. Under these premises, we describe the procedure of generating the virtual object, referred to as shadow inducers, which amplifies the luminance of the area around the shadow used for the shadow representation of the virtual object.

1. From the shadow map, a shadow area to be cast to the 3D model of the real scene is defined by the virtual light source.
2. The observer's position of the eyes is determined by HMD tracking. The shadow appearing on the camera which is set in the same position of eyes in the virtual space is stored as texture and thresholded like fig.2(a).
3. The shadow region image calculated in Step 2 is convoluted with the DOG function, and the negative is set to 0. As a result, a texture like fig.2 (b) is generated which the shadow area is dark and its surroundings are gradually amplified in brightness.
4. Shadow inducer is generated by multiplying the texture created in Step 3 by the texture of the real object model, as fig.2 (c) multiplied by fig.2 (b).
5. As shown in fig.2 (e), the virtual shadow is cast by shadow inducer being overlaid on the position where there is no deviation from the real scene and amplifying the real object brightness.
6. By repeating 1 to 5 in real time, it is responded to change of viewpoint, shadow shape and shadow position.

3 Demo applications

In this demonstration, We cast a shadow of a virtual object that does not move and deform with a simple shape like a sphere, or that moves and deforms in a complicated shape like a humanoid virtual object. The shadow of the virtual object is not limited to the plane, but it is also cast on the wood piece which is the real object prepared beforehand. We used HoloLens from Microsoft for OST-HMD and "unity-chan!" for humanoid virtual object released by Unity Technologies Japan G.K.(©UTJ/UCL). We used "Candy Rock Star" for motion data released by UTJ. The wearer of the HMD can observe the virtual object and its shadow cast by the proposed method at various viewpoints while moving. The shadow can be switched between display and non-display, and it can be confirmed that the virtual shadow contributes to the position recognition and presence of the virtual object.

We explain the concrete scene setting that realizes it. We created the 3D model of the real object beforehand by the image-based modeling method and rendered the texture of the real object whose color was corrected by a color correction method for the HMD [2]. We adjust the position of the real object and the model of the real scene manually by visual observation. We use a parallel light as a virtual light source, set a parallel projection camera as a light source, thereby creating a shadow map. Using the HoloLens space recognition function, track the position of the user's head, place the camera in the same position, and save the shadow as a 1920×1080 texture that matches the HoloLens display aspect ratio. The standard deviation of DOG is empirically set to $\sigma_1 = 8pixel, \sigma_2 = 0.7pixel$. A shadow inducer was generated by our method and a virtual shadow cast within the range of 800 mm $\times$ 800 mm on the real surface.

4 Conclusion

In this paper, we proposed a method for casting virtual shadows of various shapes on the real scene in an OST-HMD in real time without any light attenuation devices or projectors. Shadow inducer which amplifies the luminance around the shadow to cast the virtual shadow was generated in real time to adapt to shadow shape change and user's viewpoint change. Specifically, depending to the appearance of shadows, the surrounding luminance is gradually amplified with the DOG. Example of the proposed method, we have created a demonstration that the user can observe the shadow of a virtual object that moves and deforms in a real scene including non-planar.

Currently, the DOG parameter of σ_1 and σ_2 for creating shadow inducers is set empirically. Future work is generation of optimal shadow inducers based on human vision models.

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