Light-field Projection for Tangible Projection Mapping

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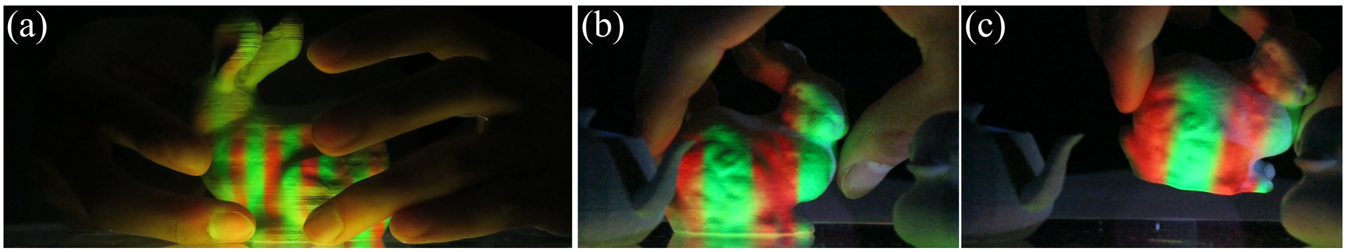

Figure 1: Results of tangible projection mapping. (a) Occluding a target object with a hand. Effect of finger shielding is reduced. (b) and (c) Object is moved. A texture is projected according to the movement of the object.

ABSTRACT

In the present study, we propose a novel projection mapping using a 3D light-field image as a light source. In recent years, spatial augmented reality has evolved into dynamic projection mapping that extends the target to moving objects. However, spatial augmented reality causes multiplexing of projection and measurement equipment, which causes various problems, such as increased psychological pressure on users and a reduced production effect. Therefore, based on the concept of stealth projection, which hides the projection device using aerial imaging technology, we propose a dynamic projection mapping method using a 3D light-field image generated in real time according to the position and orientation of the target object. As a result, a simple light-field projector consisting of an LCD panel and a lenticular lens provides projection mapping for moving objects while visually hiding the projection devices.

CCS CONCEPTS

• **Human-centered computing** → **Mixed / augmented reality**.

KEYWORDS

spatial augmented reality, projection mapping, light field, stealth projection, retro-transmissive optics

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1 INTRODUCTION

In recent exhibition events and theatrical performances, projection mapping is an indispensable means of expression. In particular, dynamic projection mapping, which evolves a projection object into an object that moves or transforms, has attracted a great deal of attention, and various techniques have been proposed. However, on the other hand, in order to realize projection onto a dynamic object and advanced image expression, the projection equipment is arranged in a complicated manner so as to surround the target object, which causes various problems, such as interfering with the projected image by creating shadows and a feeling of discomfort in the user.

In order to overcome this situation, we proposed a stealth projection in which the projection device was visually concealed by applying aerial image presentation technology[Masumi Kiyokawa, Shinichi Okuda, Naoki Hashimoto 2019]. In this approach, projection mapping is realized by preparing a light source having the same shape as the target object and projecting the light onto the target via a retro-transmissive plate (RT plate). However, it is difficult to realize a light source synchronized with a moving or deforming target object, and this requires complicated mechanisms and special equipment, such as a high-speed projector[Masumi Kiyokawa, Naoki Hashimoto 2021].

2 PROPOSED APPROACH

In the present study, we propose a method of projecting 3D images using a light-field display (LFD) onto target objects via an RT plate, by considering the device as a light-field projector, which could form real images. Using simple devices that generate a light field, projection mapping onto an object that can be grasped and moved by hand, i.e., tangible projection mapping (TPM), is realized while the projection devices are hidden. The proposed method is referred to as light-field projection in the present study. An overview of the proposed method is shown in Figure 2.

In Figure 2, we used a smartphone and a plastic lenticular lens to realize the LFD. These devices are suitable for realizing an LFD

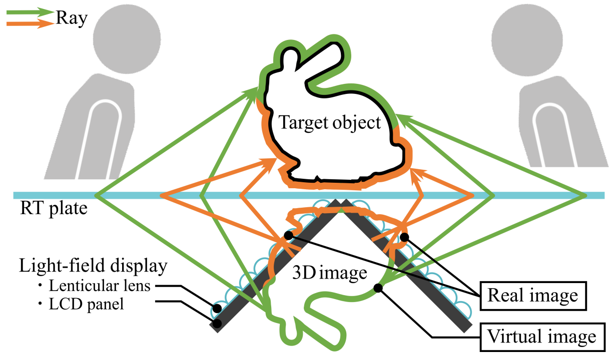


Figure 2: Overview of light-field projection.

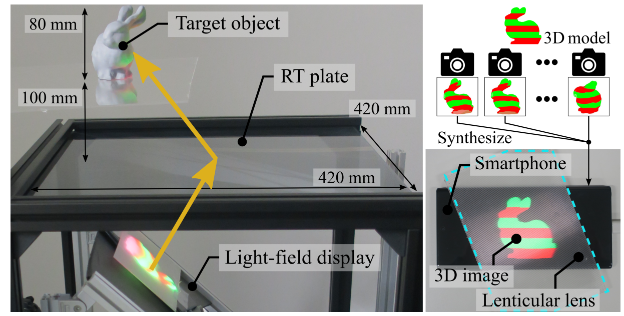
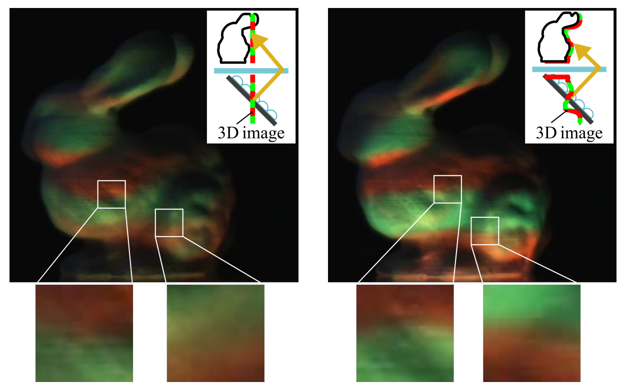


Figure 3: Prototype with a single light-field display.



(a) Projection of a flat 3D image **(b) Proposed method**

Figure 4: Projection results for a static target object.

because of their low cost and high resolution. However, even with these devices, it is difficult to form a real image at a position far from the screen surface. Therefore, in this approach, by taking advantage of the feature of stealth projection using the RT plate, the virtual image geometrically generated inside the LFD is also used for projection. In Figure 2, the orange part indicates the real image and the green part indicates the virtual image among the 3D light-field images displayed by the LFD. Furthermore, in Figure 2, multiple LFDs are used to enlarge the absolute projection area. This is an approach unique to the method of constructing an LFD using an inexpensive smartphone and lenticular lens.

The images to be displayed in the LFD are generated by synthesizing images obtained from multiple observation directions based on the integral imaging method. In this system, we created images taken from 139 horizontally placed virtual cameras to simulate observations from multiple directions using Unity (Ver. 2019.4.3). Using these images, an integral imaging image that takes into account the positional relationship between the pixel arrangement of the display and the lenticular lens is generated in real time. Since high-speed synthesized sub-pixel processing is required, it is implemented using a GPU.

Aerial images realized by the LFD are reimaged on the user-visible workspace by the RT plate. At the same time, the LFD itself is visually hidden under the RT plate. The position of the target object is assumed to have been tracked in real time using another method. An aerial image is generated according to the position and orientation of the target object, and when the aerial image is recombined on the workspace, the image is projected onto the surface of the target object. Due to the characteristics of the RT plate, the light emitted from the 3D image is recombined, so even if the user directly touches the target object, shadows are unlikely to be formed.

3 RESULTS

We implemented a simple prototype using an LFD, as shown in Figure 3. A smartphone (resolution: 3,040 pixels × 1,440 pixels, display size: 6.8 inches) and a lenticular lens (pitch: 40 lpi) were used to configure the LFD. An ASKA3D-Plate (size: 420 mm × 420 mm × 5.6 mm) was used as an RT plate.

Figure 4 shows the result of projection mapping on a 3D printed Stanford bunny. When a flat 3D image assuming projection by a normal projector was projected, the projected stripe pattern was distorted and some part of the pattern was blurred, as shown in Figure 4 (a). On the other hand, in Figure 4 (b), in which the shape of the 3D image reproduced that of the target object using the proposed method, the pattern was projected correctly, and the blur was suppressed.

Next, we performed projection mapping, which is a TPM, with the target object being moved directly by hand. The position and orientation of the target object were tentatively acquired using motion capture. As shown in Figure 1, projection mapping was realized according to the change in the posture of the object, and the influence of shadows due to grasping is suppressed. Integral imaging images were displayed at 22 fps with a resolution of 3,040 pixels × 1,440 pixels using an Intel® Core™ i7-6700K and an NVIDIA GeForce RTX 2070. In the future, we plan to improve the image quality and brightness and to expand the movable area.

ACKNOWLEDGMENTS

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