A Method for Appropriate Occlusion between a Mid-air 3DCG Object and a Hand by Projecting an Image on the Hand

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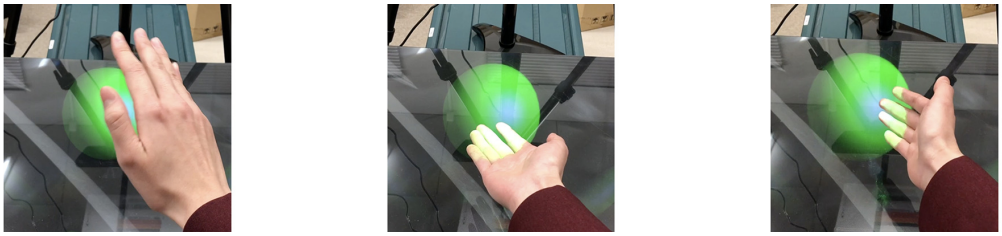

(a) Viewing from the user , the hand is in front of the mid-air 3DCG object, so the hand is occluding the 3DCG object.

(b) Viewing from the user, part of the hand is behind the mid-air 3DCG object. Occluding the hand with the mid-air 3DCG object realized by projecting an appropriate image to the hand automatically.

(c) Another example of occluding the hand with the mid-air 3DCG object based on projecting an image.

Figure 1: Examples of occluding a hand with a mid-air 3DCG object by projecting an image on the hand.

CCS CONCEPTS

• **Computing methodologies** → *Graphics systems and interfaces*;
• **Human-centered computing** → *Human computer interaction (HCI).*

KEYWORDS

Stereoscopic mid-air 3DCG, Occlusion, Interaction, Projection

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1 INTRODUCTION

A micro mirror array plate (MMAP) can present images in mid-air, and several studies using it have been reported [Kim et al. 2014] [Matsuura and Koizumi 2018]. We have also developed a method to observe and interact with a 3DCG object in mid-air using MMAP [Takazaki et al. 2018]. In our former method it is possible to observe a stereoscopic 3DCG object in mid-air and interact with it by hand directly. However, the mid-air image using the MMAP has a problem that the hand always occludes the image regardless of the positional relationship between the hand and the mid-air image.

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In this study, we aim to resolve the conflict of occlusion that may occur in direct hand interaction with a mid-air 3DCG object using a MMAP. We propose a method to project an image on a hand when a mid-air stereoscopic 3DCG object should occlude the hand by analyzing the positional relationship between the 3DCG object, the hand and the user's viewpoint (Figure 1).

2 METHODS

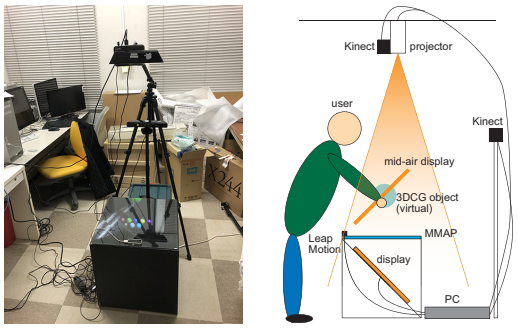
In our former system, a motion parallax stereoscopic 3DCG in mid-air is realized by tracking a user's viewpoint using a Kinect sensor and displaying 3DCG image for the viewpoint with a MMAP. Direct interaction with the mid-air stereoscopic 3DCG object is realized by tracking fingers using a Leap Motion sensor.

The improved system uses another Kinect to analyze the positional relationship between the mid-air 3DCG object and the hand while considering the user's viewpoint, and uses a projector to project images on the hand as needed. Figure 2 shows the improved system, and Figure 3 shows the concept of the proposed method.

When a user interacts with the 3DCG object in mid-air by hand directly, the Kinect installed above scans the user's hand. Then, the shape and the position of the user's hand are restored three-dimensionally using the scan data, and the 3D hand model is placed at the same position as the 3DCG object displayed in mid-air.

The positional relationship between the 3DCG object and the hand is analyzed by rendering the 3DCG object and the 3D hand model seen from the user's viewpoint. When the 3D hand model is colored in black, and rendered an image with the 3DCG object on a black background, only the region of the 3DCG object that should be visible to the user appears (Figure 4(a)).

In a CG space, the rendered image of the part of the 3DCG object is projected and mapped on the 3D hand model from the user's viewpoint (Figure 4(b)). The mapping result is a simulation of the image to be projected on the user's real hand. The system constructs a CG space that reproduces the positional relationship between the



(a) Overview (b) Components of the system

Figure 2: The proposed system.

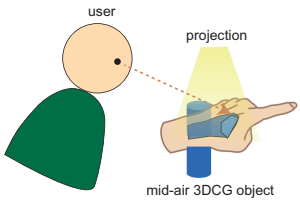
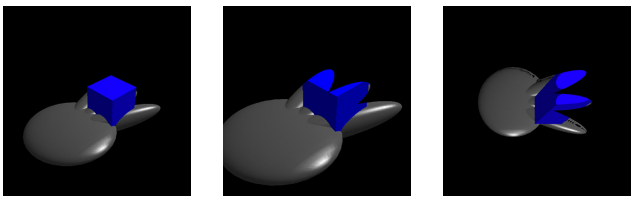


Figure 3: The concept of the proposed method.



(a) A 3DCG object and a 3DCG hand viewing from the user's viewpoint (b) Projecting and mapping the rendered image (a) on the 3DCG hand (c) The mapped 3DCG hand viewing from the position of the projector

Figure 4: The process of generating an image for projection.

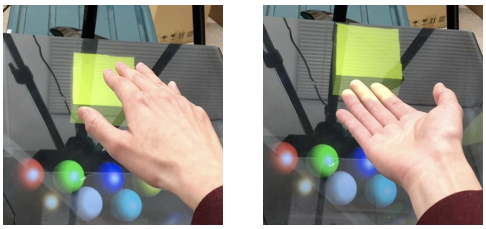
projector installed above and the user's hand, and renders an image of the 3D hand model on which part of the 3DCG object image is mapped seen from the projector (Figure 4(c)). When the image is projected by the projector installed above, it complements the part of the mid-air 3DCG object that is occluded by the user's hand and should be visible to the user.

3 EXPERIMENTS

We implemented a prototype system and carried out experiments of interaction with a mid-air stereoscopic 3DCG object by hand.

Figure 5 shows an experiment of moving a mid-air 3DCG object by hand. When pushing the mid-air 3DCG object from above, the hand occluded the 3DCG object. On the other hand, when lifting the mid-air 3DCG object from below, the 3DCG object had to occlude the hand. The proposed method properly projected an image with motion parallax on the part of the hand where the 3DCG object should occlude.

Figure 6 shows an experiment of deforming a mid-air 3DCG object by hand. When fingers entered the inside of the mid-air 3DCG object, an image was properly projected on that part of the fingers.



(a) Pushing a mid-air 3DCG object from above (b) Lifting a mid-air 3DCG object from below

Figure 5: Moving a mid-air 3DCG object by hand.

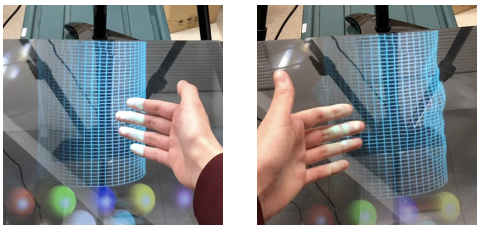


Figure 6: Deforming a mid-air 3DCG object by hand.

Figure 7: Drawing a mid-air 3DCG picture by hand.

Figure 7 shows an experiment of drawing a mid-air 3DCG picture by hand. When a finger was moved three-dimensionally in space, a 3DCG picture was drawn in mid-air. By sequentially analyzing the positional relationship between the hand, the viewpoint, and the 3DCG picture, an image was appropriately projected on the part of the hand where the hand should be occluded by the 3DCG picture.

4 CONCLUSION

In this study, we proposed a method to realize appropriate occlusion between a mid-air stereoscopic 3DCG object and a hand in direct interaction with the 3DCG object by hand. Our method analyzes the positional relationship between the 3D scanned user's hand and the 3DCG object while considering the user's viewpoint, and projects an appropriate image onto the hand.

Realizing more accurate occlusion by installing a high-resolution depth camera and a high-precision installation is one of future works.

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