

Magical Projector : Virtual Object Sharing Method among Multiple Users in a Mixed Reality Space

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Abstract—This paper proposes a method to convey virtual objects to other users and share them for enabling collaborative game in a mixed reality space. The use of mixed reality has gained prominence for collaborative game with multiple people in recent years, it, however, is difficult to grasp users each other's operations. In addition, it is difficult to instruct specific virtual objects to the opponents. These problems arise from the collaboration using mixed reality contents through head mount displays and tablet-type devices; These devices can not present the virtual objects coherently because the devices do not recognize the common coordinates, hence it prevents to share the virtual objects. Our proposed method intends to solve the problem by projecting a pointer to the real space using a handy projector. The projected pointer can be used as a clue for establishing the common coordinates. As an example of the method, we implemented a system that can overlaid arbitrary virtual objects at the intended positions and manipulate them using gestures by using projected pointers as markers for mixed reality using head mount display.

Keywords-Projection Marker; Collaboration in Real World; Pro-Cam System; Mixed Reality;

I. INTRODUCTION

In recent years, mixed reality that virtually depicts things that do not physically exist on the spot has been attracting a lot of attention. A user can use a 3D virtual object without being constrained by physical space[1]. Applications of mixed reality are used in various fields including practical work as well as entertainment, and it is also anticipated that it will be used for applications involving multiple users such as conferences at offices in different locations and multi-player games. However, the way in which mixed reality is currently being realized needs the use of a head mount display (HMD) such as *Microsoft's HoloLens* and a tablet device such as *Google's Tango*¹. In that case, the user often visually recognizes the virtual object individually at each device. Therefore, when it is necessary to mutually confirm the specific spatial coordinates and virtual objects displayed on the device, it is necessary to show a rough position using a finger or by looking into the other user's screen, which results in a loss of the immersive experience. Alternatively, there is a method of recognizing a real space using a depth

sensor and visualizing operation by placing visual cues such as virtual pointers and objects, but in such cases, special equipment and enormous processing calculation capabilities are required.

To solve this problem, we propose a method for users to wear handy projectors in addition to HMDs and to project images that are pointers to real space. Thus, in addition to directly showing the spatial coordinates to the other users, the virtual object can also be superimposed at an arbitrary position by using the projected pointer as a marker. The superimposed object can be selected and manipulated using the gesture recognition technology.

II. RELATED WORK

In *Illusiontion Hole* of Kitamura *et al.* [2], cooperative work using stereoscopic images based on binocular parallax and motion parallax is possible. However, since special mask mounting and display are necessary, the viewpoint of each user is narrowed down and the display size of the image is reduced. Also, the operation on an object is limited to the change of rotation and size.

In Mizuno's research[3], cooperative work with stereoscopic images using motion parallax by following the user's head is possible. However, special mask mounting and display are required.

Even in previous studies, transmission and reception of information is regarded as important in face-to-face collaborative work conducted by multiple people using individual devices. Problems occurring when multiple users browse content on their own devices have also been pointed out in previous studies.

In Tang' research *et al.*[4], when multiple users watch the same movies on their respective devices with a 360° viewing device, they make visual conversations with the characteristic objects appearing on their screens. This was observed when the user's interactions with the screen from the direction of the conversation were observed.

In the research by Muller *et al.* [5], a system was developed that allows users to freely arrange virtual objects when performing remote collaborative work using a mixed reality space. The placed virtual object became a visual

¹<https://developer.leapmotion.com/orion/> (2018/01/31)

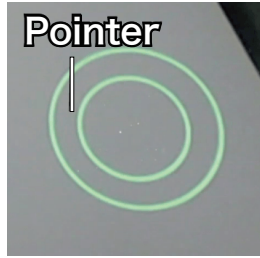


Figure 1. PointImage

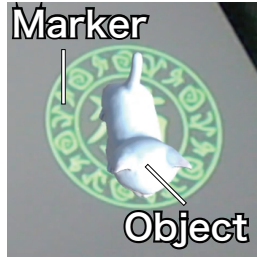


Figure 2. MarkerImage



Figure 3. PlayerA



Figure 4. PlayerB

clue to understand the work environment of the other user, making it possible to work while understanding each other's situation. In this research, in order to smoothly guess the viewpoint of the other user who performs the same work, we adopted a method of projection using a pointer, which provides a visual clue from a handy projector.

In addition, in a mixed reality space, it is desirable to utilize the operation design in a way that we can derive optimum benefit of virtual reality without impairing our own body. In the study by Tiare *et al.* [6], we investigated whether the user feels the same physical body as the actual body and can operate the separated object without discomfort, even when the virtual arms that extend and shrink are superimposed on their own body. In this research, we implemented the operation on a remote virtual object by using a method of superimposing a virtual laser pointer on the user's hand.

III. COLLABORATIVE GAME IN MIXED REALITY SPACE

Since collaborative game in mixed reality space involves personnel and constraints that are different from ordinary collaborative game, it is not easy for the user to game smoothly. In this section, we set scenes and functions that are supposed to be mainly used for entertainment. Assume the following cooperative game.

- 1) Possession of a device for recognizing a virtual object. In collaborative game in a mixed reality space, an HMD or a tablet device is attached or gripped, and each device visually recognizes the virtual objects individually. Therefore, operations of other users are not shared without special synchronization.
- 2) Presentation and viewing of virtual objects for real space.

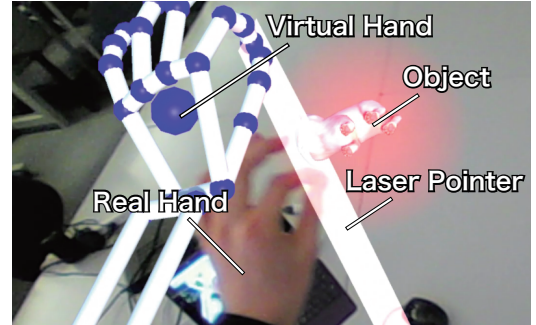


Figure 5. GestureImage

In cooperative game, it is desirable to present arbitrary virtual objects such as characters operated by themselves and opponent characters in the real space, and to game while sharing with the opponent. For that purpose, there is a method of setting a marker serving as a starting point to superimpose a virtual object. However, the overlapping range is fixed, and in order to change the type of the virtual object, it is necessary to replace the installed marker.

- 3) Selection and manipulate of virtual objects.

During the execution of cooperative game, the user wants to select what to use from among multiple virtual objects and what to send and manipulate with the opponent. It is desirable that basic interactions such as movement, rotation and scaling of virtual objects can be performed.

IV. DESIGN GUIDELINES

In this study, we aim to facilitate collaborative game in a mixed reality space used by multiple users in the same place. Based on the scenario propounded in the second chapter that the system should satisfy the following requirements: (1) The user's operation and gazing point can be communicated to the other users, (2) The virtual object can be superimposed on an arbitrary position, (3) It is possible to select and manipulate an arbitrary one of the virtual objects superimposed by other users. In this study, we focus on mixed reality experienced by wearing HMD.

First, to realize (1), we use a handy projector. By grasping the handy projector, the user can freely project the pointer to the real space. This makes it possible to point the space coordinates that the user wishes to point.(Figure 1).

Secondly, in order to realize (2), use the projected pointer as a marker. As a result, the virtual object can be superimposed on the pointing position (Figure 2). Since the marker can be changed by switching images, it is possible to select and superimpose arbitrary objects from plural types of virtual objects. By recognizing the size and inclination of the marker with the camera of each user, the virtual object of the angle viewed from the player A is displayed on the

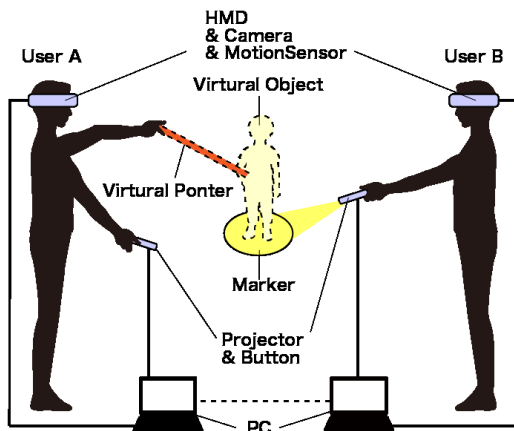


Figure 6. SystemConcept

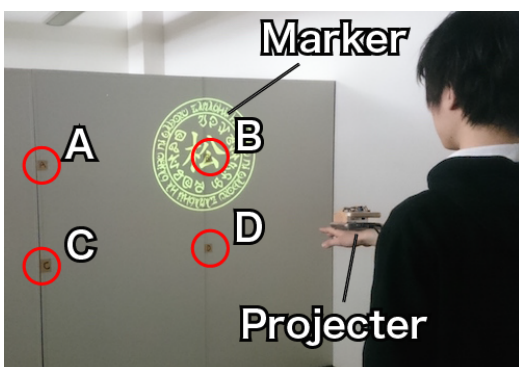


Figure 7. ExperimentImage

player A, and the virtual object of the angle viewed from the player B is displayed on the player B (Figure 3,4).

Thirdly, use gesture operation to realize (3). By emitting a virtual laser pointer from the user's finger, it is possible to select distant objects. The selected virtual object is manipulated by a pinch operation (Figure 5).

V. IMPLEMENTATION

This system is implemented using *Unity (ver.5.4.0f3)*². It consists of an HMD equipped with a web camera and a motion sensor, and a handy projector equipped with a physical button connected to the PC. By preparing a number of these, more than one user can game simultaneously. Figure 6 shows the system configuration.

HMD uses a non-transparent HMD (*SONY HMZ-T2, HTC Vive*) with a Web camera (*Buffalo BSW 200 MBK, Vive built-in camera*) attached, and performs the role of pseudo see-through HMD and recognizes markers. The web camera was selected based on it being lightweight and compact so as not to be a burden to the user. It was also chosen since it has a

wide viewing angle capable of securing a wide field of view of the HMD.

As a handy projector, *Canon's C-10W* is used. A user can wear it on his arm. The *Arduino* is carried as a physical button for switching markers. *Vuforia SDK (ver. 6.0.114)*³ was used for marker recognition.

A *LeapMotion* sensor is used as a motion sensor. In this system, since the user superimposes the virtual object in various directions, installed type sensors, in which the directions of movement of the user are limited, are not suitable. For this reason, we adopted a method to attach LeapMotion, which is a compact infrared sensor, to the front of the HMD. In addition, *LeapMotion SDK (Orion Beta)*⁴ is used to implement gesture operations and pinch operations when the virtual objects being manipulated are recognized.

VI. EXPERIMENTS

Since the recognition accuracy of the projection marker depends on the brightness of the projector and the projected place, as a method of examining recognition accuracy, projection was performed from a short distance or a long distance. Experiment participants were 11 college students enrolled in the department of information system.

Experiment participants projected to 4 places in total, 2 places with a height of 140 cm assuming a position where the markers are not distorted, 2 places with a height of 90 cm assuming a position where the markers are distorted (Figure 7). Experiment participants projected the markers while changing the distance at 50 cm intervals in the range of 50 cm to 300 cm from the projected place. The system measured success or failure of recognition at each position.

The average recognition rate of the markers by 11 experiment participants. In case of A and B projected on the front, an average recognition rate of 77.2% was obtained. For C and D projected obliquely downward, distortion occurred in the marker and the recognition rate remained at an average of 41.0%. However, when projected from the shortest distance of 50 cm, the reflection of light from the projection surface hindered recognition by the camera, and the recognition rate was 0%. The recognition accuracy was kept to a certain extent even when the distance was increased because the projected image becomes larger as the distance from the projector becomes larger, supposing that the difficulty in recognizing the distant portion is supplemented.

Since this system is intended to be used by multiple users, users need to confirm other user's operation while use system. I investigated the stability of the system through experiments that make users perform the designated operation. The participants in the experiment are university students belonging to the Faculty of Informatics. Because the users perform the experiments in pairs, we conducted a total of seven experiments.

³<https://developer.vuforia.com/> (2018/02/05)

⁴<https://developer.leapmotion.com/orion/> (2018/01/31)

²<http://japan.unity3d.com/> (2018/01/31)

In the experiment, the users play the roles of Player A and Player B. Player A projects the marker using the projector and designates the object to be operated upon by Player B. Player B manipulates the object designated by Player A. The experimental flow is as follows:

- 1) Player A projects the marker using the projector.
- 2) Player A and B overlays the object by recognizing the projected marker with the camera.
- 3) Player A verbally communicates to Player B, specifying the object that Player B needs to operate.
- 4) Player B selects the specified object using a Laser Pointer (the color changes on selection).
- 5) Player A confirms that the specified object has been selected.
- 6) Player B performs the selected operation (the object is deleted).
- 7) Player B confirms the operation performed on the object.

The user of player A performs the role of player B after the role of player A. The user of player B performs the role of player A after the role of player B. After experiencing, the users answer the five-stage evaluation questionnaire.

Evaluation when playing the role of Player A

- 1) I was able to confirm that an object appears at the position of the marker I projected.
- 2) I was able to confirm that the other party selected the object I specified.
- 3) I was able to confirm that the other person operated the object specified by me.

Evaluation when playing the role of Player B

- 1) I was able to confirm that the object is displayed at the position of the marker that the other user projected.
- 2) I was able to confirm that I selected the object specified by the other user.
- 3) I was able to confirm that I operated the object specified by the other user.
- 4) After experiencing this system, please feel free to fill in any points I noticed or thought.

The average obtained from the responses of 14 people for item 1 was 5, item 2 was 4.64, item 3 was 4.07, item 4 was 4.57, item 5 was 4.21, and item 6 was 4.14. The dispersion value for item 1 was 0, item 2 was 0.66, item 3 was 2.21, item 4 was 0.67, item 5 was 0.88, and item 6 was 1.98.

VII. DISCUSSION

In this research, we use a video see-through using a monocular camera, and stereoscopic vision due to binocular parallax is not considered. Therefore, by using multiple cameras and optical see-through HMDs, it is thought that real world depth information can be acquired, enabling richer stereoscopic representation.

Also, in this study, since the projection by the projector is used, the recognition rate depends on the brightness of the

room and the reflection of the projection plane. Therefore, it is necessary to use projectors with even higher brightness, to create markers with high recognition precision, and to use advanced image analysis. Also, since it requires a projection plane, it is difficult to place in the air. In this paper, we have taken measures to create a projection plane temporarily and place it in the air by operation, but trial manufacture using a simple distance sensor is also conceivable.

In addition, the marker used in this implementation projects from the projector, and the area increases as the distance between the user and the marker increases. However, when actually experiencing the system, it is conceivable to use it in an environment where there are steps or other environments, and as the marker is larger, the markers are more likely to be distorted due to steps or other things. Conceivable. Therefore, considering the recognition accuracy, we will consider that the size of the marker can be changed according to the distance between the user and the marker by using the distance sensor.

VIII. CONCLUSION

This paper proposed a method to convey virtual objects to other users and share them for enabling multi game in a mixed reality space. In future, We verify the effectiveness of the system in game content and collaborative work. In this study, we implemented it for HMD, but we also considered using it on a tablet device, by working with users who have HMDs installed and users working with tablet devices.

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