Method for Sharing Real Objects with Different Syntax through Virtual Stickers between Distant Mixed Reality Spaces

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Abstract - In remote collaboration based on real objects, the differences in space structure between remote real spaces should be considered. In conventional methods, it is difficult for users to collaborate based on real objects which differ in syntax. In order to address this issue, we focus on a sticker or a sheet which can be attached to the surface of a physical object. Also, we propose a semantic information sharing method which involves Mixed Reality (MR) technology, where each remote user interacts with a real object by using virtual sheets which can be attached to the surface of each real object, and can eliminate the differences in syntax between these real objects. We implemented a prototype system, which has a pointing function, and conducted experiments. As a result, it was proven that it is possible to share information regarding the interactions without losing the meaningful relations between real objects which differ in syntax.

Keywords: Mixed Reality, Remote Collaboration, Computer Supported Coperative Work.

1 Introduction

Remote collaboration systems where remote users collaborate by sharing electronic data through a network were popular in the past[1]. In such systems, users could not treat information regarding real-world environments and objects, and therefore it was impossible to experience the sense of touch or to implement intuitive manipulation. Later, MR (Mixed Reality) made it possible to take information from the real world and transfer it to a virtual world. MR was applied to collaboration work, where users work at remote sites by sharing virtual information. It is hoped that remote work support systems or cooperative work systems where users feel as if remote participants are present at the same workspace will be realized in the near future.

However, there are two types of remote collaboration systems depending on how users manipulate real objects. One is an asymmetric remote collaboration system, and the other is a symmetric one. In asymmetric systems, only one worker manipulates his or her own real object, while the other user (a director or a supporter) issues directions while watching the progress of the worker. However, in asymmetric systems it is impossible for both users who have their own real objects in remote places to manipulate their own real objects and to collaborate through them. Such functionality is intrinsic to symmetric remote collaboration systems. Different manipulations implemented by each remote user result in discrepancies between the states of each real object, and therefore it is too difficult to reproduce the same state at the remote place. If the users attempt to actualize the state of the object, such as in a symmetric collaboration system, they must create the exact same structure of objects at both remote workspaces by using actuators or mechanical systems. In this research, a different approach makes it possible for remote users to have their own real objects and to collaborate naturally without discrepancies between the states of the real objects. We regard workspaces as based not on the world coordinate system but on a virtual sticker which is placed on the surface of the real object.

Remote users have their own real objects which represent the target of the work in each workspace. They place the virtual sticker on the surface of their real object and then manipulate the object. The processes of the manipulations and their effects are displayed with respect to the sticker and shared between the remote workspaces. The function of the sticker is flexibility to the form of surface. Even though they have real objects which differ in syntax (in other words, size, shape, and other properties), the users can place virtual stickers on various objects and collaborate through them by sharing information.

In this way, we aim for the creation of a remote collaboration environment where remote users can have their own real objects and can manipulate them freely without the need for mechanical synchronization. Users can share their manipulation procedures with each other, and can communicate instructions to remote sites even if the objects at the remote sites differ in syntax.

In this paper, we propose a method for sharing real objects with different syntax through the use of virtual stickers between distant mixed reality spaces. We also implement a prototype system referred to as ”MR Shared Surface” as a realization of our concept, and evaluate it.

2 Background and Problem

2.1 Remote Collaboration with Real Objects

There are some examples of remote collaboration or communication using real objects. Tangible interfaces provide interaction with the digital world through real objects. For example, ”PsyBench” [2], which was developed by Ishii et al., realized remote collaboration based on interaction with real object by applying tangible interfaces to remote environments. In the ”PsyBench” system, the XY stage is built by placing an electric magnet under a table at each remote site, and magnets are set under the bottom of the objects on the table. This makes the physical state of the objects on the table to coincide between remote sites.

Sekiguchi et al. developed ”RobotPHONE” [3], which realizes remote communication by sharing the motion of a robot shaped as a teddy bear through the Internet and making the respective motions at the two sites coincide. These systems, which use tangible interfaces, offer a sense of touch and make manipulation intuitive, however, there are also certain problems. One problem relates to the fact that there are physical restrictions with respect to the motion of the objects, as the effects of the manipulation to real objects are realized through magnetic or mechanic actuators. Another problem involves unnatural behaviors such as the sudden movement of real objects caused by the lack of information regarding the manipulations performed by the remote user.

2.2 Remote Collaboration in Mixed Reality

Mixed Reality (MR) represents technology which transfers electronic data, such as CG or a letter into real space, and this technology is applied currently in various fields, such as work support in the field of industry [4], entertainment [5] or medical care technology [6]. MR lets users communicate or collaborate by manipulating information from the real world. Simon et al. developed ”3-D Live” [7], where observers can observe a real-time 3D image of the whole body of the remote user from all angles, as in real space.

Furthermore, Dieter et al. developed a system called ”Studierstube” [8]. In ”Studierstube”, users share a 3D window displayed in real space and can collaborate through interaction with the 3D window. Not only do face-to-face users work in the same real space, but in remote places they also collaborate by sharing the 3D window.

There is also an example where users directly manipulate real objects in remote collaboration. Suzuki et al. proposed a remote support system [9] which assumes a relation of a worker and a director between the users, where the director directs the worker by pointing while observing the manipulation from an immersive point of view from the perspective of the worker. From a remote place, the director can observe a stereo image of the object from the perspective of the worker through an HMD (Head-Mounted Display) and can manipulate a virtual pointer displayed in the worker’s real space by using his or her finger. The worker sees where the remote director is pointing in his or her work space. In this system, one user, namely the worker, can manipulate real objects directly, while the other user, namely the director, can manipulate only virtual objects. There is also ”Lazy Susan” [10] developed by Uesugi et al. as an example of collaboration between remote users which have their own real objects in MR. In ”Lazy Susan”, the effects of interaction with real objects are passed on to the remote site by shooting a video of the manipulation and projecting it onto a table in the remote workspace. There is a disc which can rotate on the table, and its motion coincides with the motion produced at the remote site. This system makes the user aware of the other users, the collaboration is lively, and the sense of sharing the workspace is enhanced. However, there is a problem which causes trouble with manipulation if the view is changed when the remote user performs a rotation of the object without the same motion being performed by the local user. Also, it is a tabletop system, and therefore the workspace is essentially fixed. Iso et al. proposed a system adapting to the differences in room structure. In ”ComAdapter”, they attempted to describe the user’s posture, the physical relations, and so on, in different rooms. Some discontinuous scenes arise when dynamic situations in the rooms or user motion is described. This system targets natural living-room communication when the structure of the respective rooms is different. On the other hand, we present a remote collaboration system targeting the manipulation of a single target object.

In a previous work, we proposed the sharing of virtual information on the basis of real objects in remote workspaces [11]. Remote users have access to the same replicas of the target real object in each workspace, and then each replica has a coordinate system based on the object itself (referred to as object coordinate system in this paper). Manipulations to the replicas and their effects are displayed by using virtual objects with MR and are shared based on the replicas between remote places. However, remote users were required to have the same replicas in the previous research.

3 Proposal

3.1 Sharing Semantics between Real Objects with Different Syntax

In remote collaboration systems based on real objects, it is necessary that the semantics of the work is shared between remote workspaces, even if there are differences in the syntax of the objects. We explain how the semantics can be shared in various ranges of differences and in which relation the collaboration is realized by sorting out the range of differences in syntax and the relations between pairs of any two real objects.

Figure 1 shows the classification of a pair of real objects. The first classification is used when two real objects which are used in collaboration share a common function. The common function indicates the capability to share the semantics of the work. On the other hand, if they do not have share a common function, it is impossible to share the semantics. For example, sharing the semantics is possible between two objects whose function is to input sentences. However, if one object is used for inputting sentences and the other is used for inputting musical performances, the objects do not share a common function. Therefore, the semantics is impossible to share in such a case.

The second classification is used in the case where the first classification holds. It reflects the case when two objects share a common way of operation. If we consider objects for inputting sentences, an example of objects which do not share common way of operation can be given with a keyboard and a pen. A keyboard inputs sentences electronically and a pen does that mechanically. In such a case, only the information is shared, namely the sentence. The sentence is not tangible information, and therefore users can not take advantage of using real objects. Two objects should therefore share a common way of operation.

The third classification is implemented in case the second classification holds. It is used if the objects share the same alignment in the contexture. The difference in alignment of the contexture between remote sites causes a discrepancy between the structures of real objects or world environments. Fortunately, alignments in the contexture are maintained in most objects which share a common way of the operation. Finally, the fourth classification is implemented if the third classification holds. It is used if the sizes and shapes of the objects are exactly the same. There are many objects which share the same function, way of operation and alignment in the contexture, but have different sizes or shapes. It is very useful for remote users to be able to collaborate by sharing objects which differ in seize or shape. Since they share common functions and ways of operation, it is possible to share such objects.

3.2 Method for Sharing Real Objects with Different Syntax

In the past, it was too difficult for remote users to collaborate by manipulating their own real objects. Even in our last research, each user was required to have an object of the same shape and size. Collaboration with real objects has severe restrictions, and therefore we propose a method for sharing real objects with different syntax through the use of virtual stickers between distant mixed reality spaces. We focus on the properties of stickers which can be attached to the surface of a physical objects, and can bring the object into the MR. In our approach, the virtual sheet which is placed on the surface of real objects is defined, and the information regarding the processes and the effects of the work is shared flexibly by utilizing those stickers. Using virtual stickers makes it possible for participants to collaborate if they are located at distant workspaces by keeping the essential semantics, even if they have real objects which are different in syntax (syntax refers to the shape, the size, or the structure of the objects in this paper). Users can collaborate by focusing on the interaction between remote participants and objects through the virtual sticker.

3.3 Functions of the Virtual Sticker

There virtual sticker has two main functions.

(1) Sharing information regarding the interaction between real objects in remote workspaces

The information regarding the interaction between the user and the real object is transformed into a model of the virtual object (referred to as sharing virtual model). Sharing the information of the interaction is actualized by sending and receiving the data regarding the sharing of the virtual model bi-directionally through each virtual sticker.

(2) Resolving the differences in syntax between the objects by implementing the virtual sticker flexibly.

Generally, users can place stickers on surfaces of objects of various shapes with some kind of picture printed on the sticker. The virtual stickers also have this function. By drawing the information regarding the interaction with the sticker instead of the picture (the sharing virtual models are transformed as stickers), the information of the interaction is displayed on each real object while matching their syntaxes.

3.4 Differences in Syntax

Virtual stickers resolve differences in syntax. We explain these differences in the following section.

(1) The combination of real objects of different size

Although there are many types of differences, the most common case involves difference in size. Even the same kinds of objects (for example, controllers, calculators, phones, and so on) often have various sizes. Sizes can be big or small, and various editions might exist, such as professional, abridged, portable, or ones for children. By using virtual stickers, collaboration can be realized by using objects characterized by such differences.

(2) Combinations of 2D and 3D real objects

By using virtual stickers. the information of the interaction can be shared between 2D and 3D objects. When two participants perform work one user might utilize a 3D real object while the other user utilizes a 2D object, such as the development plan, the design scheme, or the manual of the 3D object. The semantics of the information of the interaction with objects is shared in order to be able to realize remote work support or remote collaboration even between 2D and 3D objects.

3.5 Mechanism for Sharing Interaction Information

This section explains the way of sharing information regarding the interaction between remote users in our research. We begin by defining two coordinate systems.

(1) The coordinate system of the shared virtual sticker

This is the coordinate system of the original virtual sticker before the sticker is placed on the surface of the object. In this research, the sharing of virtual models is transformed into this coordinate system when the interaction information is transferred between remote workspaces.

(2) The coordinate system of the local virtual sticker

This is the coordinate system of the virtual sticker after the sticker is placed on the surface of the object. In our research, the interaction information, which is shared between remote workspaces, is displayed based on this coordinate system in each workspace.

Sharing interaction information is actualized by changing its translation and orientation in each coordinate system, as

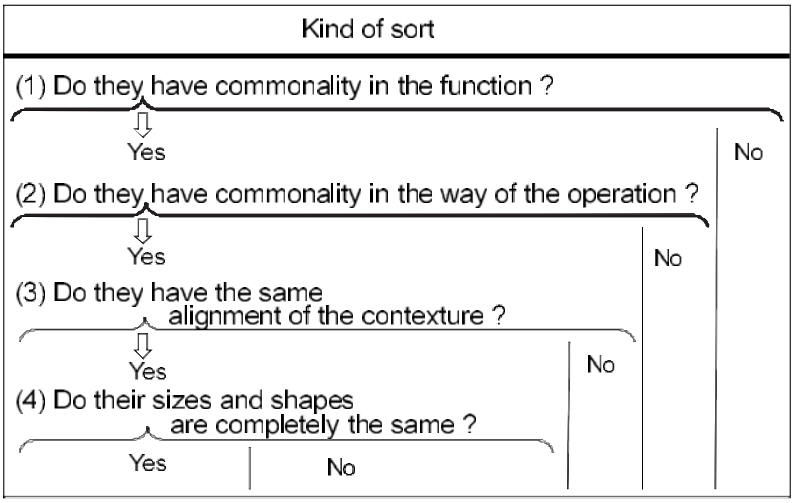

Figure 1: Classification of a pair of real objects

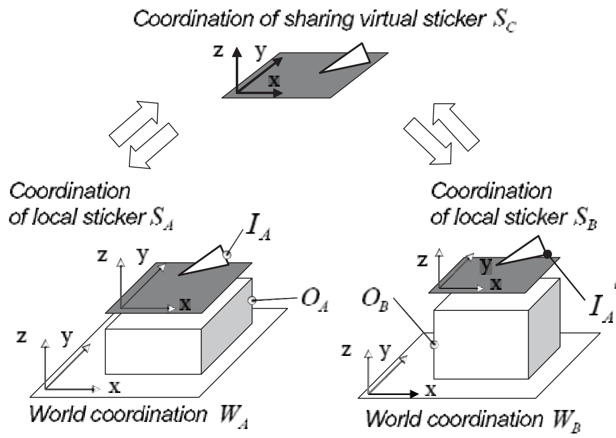

Figure 2: Mechanism for sharing information

shown in Figure 2.

First, the information I_A which indicates that user U_A interacts with the real object is based on the world coordinate system W_A. It is changed into the translation and orientation based on the coordinate system of the local virtual sticker S_A. Then, it is changed into the coordinate system of the sharing virtual sticker S_C, and is also transformed into the coordinate system of the local virtual sticker S_B which is set on the real object O_B manipulated by user U_B. Finally, it is changed into the translation and orientation based on W_B and displayed as the sharing virtual model I'_A. By performing these operations in the same way with respect to the interaction information I_B of user U_B, the information of the interaction can be shared.

Its processes are described by using the following expressions. We set I_{SA} as the translation and orientation of the virtual objects based on S_A. I_A and I_{SA} are described that,

$$I_A = \begin{bmatrix} x_a \\ y_a \\ z_a \\ 1 \end{bmatrix} \tag{1}$$

$$I_{SA} = \begin{bmatrix} x_{sa} \\ y_{sa} \\ z_{sa} \\ 1 \end{bmatrix} \tag{2}$$

$$I_A = M_A I_{SA} \tag{3}$$

By using the modeling matrix M_A, which is a homogeneous matrix, the translation and orientation are transformed from the world coordinate system into the coordinate system of the local virtual sticker.

On the other hand, when the position is transformed the opposite way, it takes an inverse matrix S_A^{-1}.

4 Implementation of MR Shared Surface

4.1 The Architecture of the Implementation

In this research, we implemented a "MR Shared Surface", which is one of the prototype systems for virtual stickers. Two participants located at remote workspaces can collaborate through the "MR Shared Surface". Figure 3 shows the architecture of the shared surface. "MR Shared Surface" is constructed with the local MR system that controls the devices and the sharing of the virtual sticker, which makes it possible to share interaction information between remote places.

4.2 The Local MR System

We used the video see-through HMD by CANON. A video camera and a liquid crystal display are mounted in the HMD.

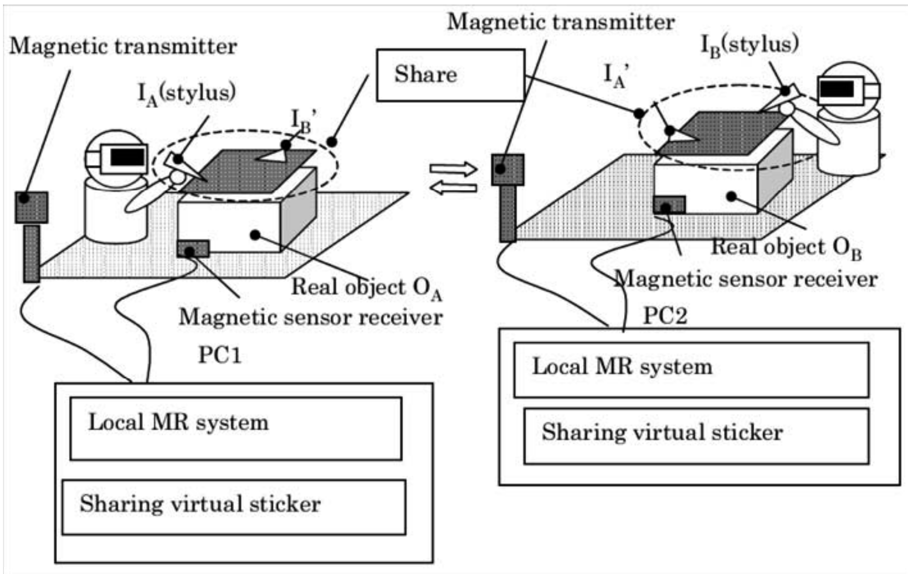

Figure 3: Architecture of the MR Shared Surface

This HMD and the stylus have a Fastrak receiver, which is a magnetic sensor allowing six degrees-of freedom, where is the position and the orientation are ignored. Other sensor receivers are mounted on the replicas, which are the target of the work. Alignment of real space and virtual space is performed by using a hybrid method involving a magnetic sensor and marker. For the purpose of displaying and manipulating the virtual objects, we used a MR Platform Plus [12] system by CANON. Two PCs, representing remote sites, were connected through a network.

4.3 The Sharing Virtual Sticker

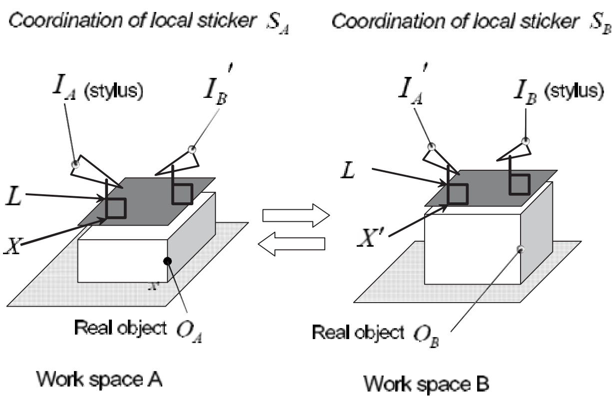

Figure 4: The display of the sharing virtual model

"MR Shared Surface" detects the position of the stylus utilized by the user, and overlaps it with a virtual pointer. This represents the sharing virtual model in "MR Shared surface". As shown in Fig. 4, the sharing virtual model is displayed, and a perpendicular line is drawn from the stylus handled by the user. L is defined as the distance between the perpendicular lines, and $X$is the foot of the perpendicular line. In the other workspace, point X' is also defined in relation to X on the virtual sticker. The virtual pointer is displayed at the position of the normal direction at length L from X'. "MR Shared Surface" performs this process bi-directionally.

4.4 Conversion Through the Virtual Sticker

This section explains the communication of expansion and contraction between the local virtual sticker and the sharing virtual sticker. 2D projective transformation from a rectangle to any convex quadrilateral is that,

$$\lambda \begin{bmatrix} x_2 \\ y_2 \\ 1 \end{bmatrix} = \begin{bmatrix} h_0 & h_1 & h_2 \\ h_3 & h_4 & h_5 \\ h_6 & h_7 & h_8 \end{bmatrix} \begin{bmatrix} x_1 \\ y_1 \\ 1 \end{bmatrix} \tag{4}$$

$$\begin{cases} x_2 = \frac{h_0 x_1 + h_1 y_1 + H_2}{h_6 x_1 + H_7 y_1 + 1} \\ y_2 = \frac{h_3 x_1 + h_4 y_1 + H_5}{h_6 x_1 + H_7 y_1 + 1} \end{cases} \tag{5}$$

In order to transform any convex quadrilateral A into another convex quadrilateral B, A is converted into a normal rectangle once and then converted inversely into B.

4.5 Synchronization of the Virtual Information

In order to share the virtual scene between remote places, any changes in the state of the virtual object must be passed on to the other workspace, and the changes must coincide when one of the virtual objects changes in the local workspace. First, all virtual objects are registered with an ID number. Second, when one of the virtual objects changes, the system detects it and passes on the ID number and the kind and magnitude of the change to the other workspace.

5 Evaluation

5.1 Purpose of the Evaluation

The purpose of the evaluation is to confirm whether or not ”MR Shared Surface” realizes our proposed concept. In other words, we evaluated whether the semantics of the works were shared through the ”MR Shared Surface” in the case where there were differences in syntax between real objects located in remote workspaces.

In this paper, we evaluated whether ”MR Shared Surface” realizes our concept with respect to a pointing manipulation implemented with the stylus, which is the most basic type of interaction.

5.2 Evaluation of the Pointing Manipulation

In this evaluation, two participants located at remote workspaces performed one task at a time. One participant played the role of the experimenter, and the other was the subject. The virtual sticker which was placed on the real object was divided into a number of square tiles (with 6 cm sides), and serial numbers were attributed to each tile.

The experimenter pointed tiles on the virtual sticker spread on the surface of the real object one by one. The experimenter performed three pointing manipulations (as shown in Fig. 5 shows).

pointing motion ”a”

The experimenter pointed a random tile by drawing the shape of a mountain with the pointer.

pointing motion ”b”

The experimenter pointed a random tile by moving his or her pointer at a right angle.

pointing motion ”c”

The experimenter pointed any tile by sliding the surface of the object.

These pointing motions were coincided when the subjects were observed from directly above. The point was to confirm whether it was possible to detect a 3D movement which generally could not be displayed with a 2D pointer.

The experimenter followed random combinations of motions ”a” to ”c” and a tile number . The subject, who was unaware of the pattern, observed the pointing motion performed by the experimenter located at the remote site on the virtual sticker and answered what kind of pointing motion was performed and the number of the tile at each iteration.

There were two sets of trials, where each task scored five points. The combinations of the virtual stickers between the experimenter and the subject were switched at every task, except for congruent squares. Table 1 shows the combinations of the virtual stickers, and figure 6 shows the object used in trials No. 8 and No. 9 in Table 1. The subjects were 15 males and females aged 21 to 25.

In this evaluation, all answers of the subjects were recorded, and the accuracy rate was calculated.

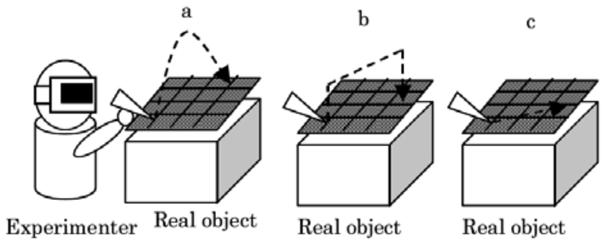

Figure 5: Type of pointing motion

Table 1: The combinations of virtual stickers

No.	Experimenter	Subject
1	Square	Square
2	Small square	Square(normal)
3	Square(normal)	Small Square
4	Box	Trapezium
5	Trapezium	Box
6	Box	Cylindrical surface
7	Cylindrical surface	Box
8	Extended elevation	3D figure
9	3D figure	Extended elevation

5.3 Conclusion and Discussion of the Evaluation

Figure 7 shows the conclusion of the accuracy rates regarding the combinations of flat virtual stickers. The accuracy rates of the pointing motion and the tile number were higher than 98%.

The only mistake with respect to the tile number (the combination corresponding to the motion from the large square to the small square) was that, the subject answered the number of the adjacent tile. The reason for this mistake is attributed to the fact that although the area of the small square tile was small (quarter of that of the other tiles), the size of the pointer was the same as the others, or that the display resolution was not sufficiently high. Also, the accuracy rate regarding the pointing motion was lower than in the other cases since the pointer movement was limited to a direction parallel to the virtual sticker. This generated unnatural movement of the pointer. In any case, all accuracy rates were higher than 96%.

Furthermore, Fig. 8 shows the conclusion regarding the accuracy rates, where one participant had a 3D model of the real object.

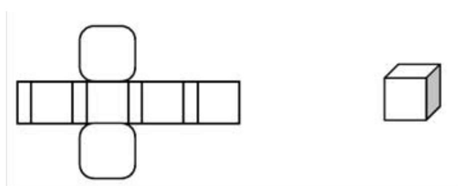

Figure 6: Extended elevation and 3D figure

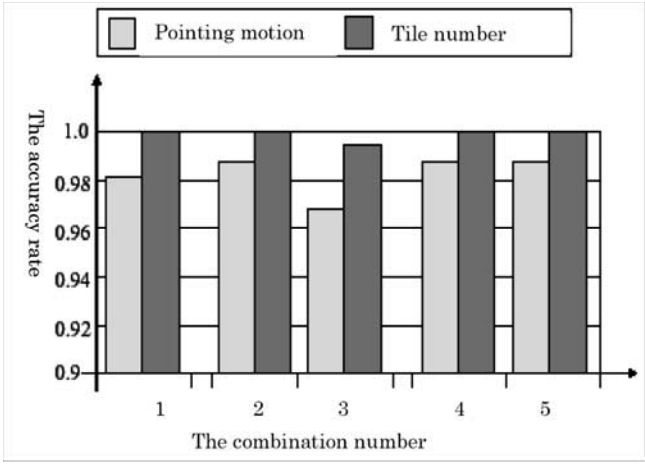

Figure 7: Result 1

As the figure 8 shows, all accuracy rates regarding tile numbers were 100.

The accuracy rates regarding the pointing motion in the combination of motion "from flat square to cylindrical surface" and the combination "from extend elevation to 3D figure" were lower than the others. The similarity between these two combinations is that the subjects moved the 3D object at varying angles in order to observe the pointing motion. At the same time, the experimenter performed the pointing easily on 2D flat areas. This additional load to the subjects caused the decrease in the accuracy rates.

However, even in this case, the rate in each case was higher than 92%.

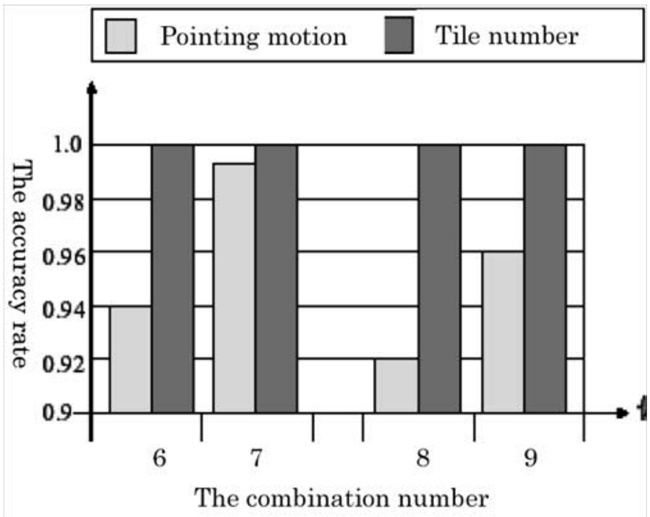

Figure 8: Result 2

The conclusion is that the information regarding the interaction can be shared through "MR Shared Surface" when at least one user utilizes the flat virtual sticker.

6 Conclusion and Future Work

In this paper, we focused on a sticker or a sheet which could be attached to the surface of a physical object. As a method which is based on MR technology, we proposed a method for sharing real objects with different syntax through the use of virtual stickers between distant mixed reality spaces. We defined a method for sharing of semantics, in which each remote user interacts with a real object, by using virtual sheets which can be attached to the surface of any real object, where the sheet can absorb the differences in syntax between the real objects. Then, we implemented a prototype system referred to as "MR Shared Surface", which featured a pointing function, and conducted experiments. As a result, it was proven that it is possible to share the information regarding the interactions without losing the meaningful relations between the real objects which differ in syntax.

In the future, we intend to implement the function of various interactions and to share those interactions between remote workspaces. Also, we will attempt to improve the adaptation to various 3D objects.

REFERENCES

[1] Kentaro Fukui, Misuzu Kitano and Ken-ichi Okada, Multiparty Conference System Enhanced By Virtual Space: e-MulCS, IPSJ Transactions, Vol. 43, No. 11, pp. 3375–3384 (2002).

[2] Scott Brave, Hiroshi Ishii and Andrew Dahley, Tangible Interfaces For Remote Collaboration And Communication ACM CSCW'98, pp. 616–630 (1998).

[3] Dairoku Sekiguchi, Masahiko Inami, Naoki Kamakami and Susumu Tachi, The Design of Internet-Based RobotPHONE, ICAT2004, pp. 223–228 (2004).

[4] Toshikazu Ohshima, Kiyohide Satoh, Hiroyuki Yamamoto and Hideyuki Tamura, RVBorder Guards: A Multi-player Mixed Reality Entertainment, TVRSJ Vol. 4, No. 4, pp. 699–706 (1999).

[5] Regenbrecht et al., A Tangible AR desktop Environment, Elsevier Computer Graphics, Vol.25, No. 5, pp. 755–763 (2001).

[6] Kiyoshi Kiyokawa, Haruo Takemura, Hidehiko Iwasa and Naokazu Yokoya, Modeling in a Shared Augmented Environment with an Immersive Modeler VLEGO II, TVRSJ Vol.2, pp 73–74 (1997).

[7] Simon Prince, Adrian David Cheok, Fazam Farbiz, Todd Williamson, Nikolas Johnson, Mark Billiaghurst and Hirokazu Kato, 3-D live: Real Time Interaction For Mixed Reality, ACM CSCW'02, pp 364–371(2002).

[8] Dieter Schmalstieg, Anton Fuhrmann and Gerd Hesina, Bridging Multiple User Interface Dimensions With Augmented Reality, IEEE/ACM ISMAR2000, pp 20–29 (2000).

[9] Yuji Suzuki, Yuichi Bannai, Hidekazu Tamaki, Hiroshi Shigeno and Ken-ichi Okada, A 3D Pointing Method for Remote Collaboration Using Mixed Reality Tech-

nology Between Asymmetric Users, CSVC2006, pp 17–22 (2006).
[10] Shigeru Wesugi and Yoshiyuki Miwa, Facilitating interconnectedness between body and space for fullbodied presence - Utilization of Video projection "Lazy Susan" communication system -, Int. Workshop on Presence (Presence2004), pp 208–215 (2004).
[11] Hidekazu Tamaki, Yuichi Bannai, Yuji Suzuki, Hiroshi Shigeno and Ken-ichi Okada, Remote Collaboration Based on Portable Object in Mixed Reality, CollabTech2006, pp 84–89 (2006).
[12] Shinji Uchiyama, Kazuki Takemoto, Kiyohide Satoh, Hiroyuki Yamamoto and Hideyuki Tamura, MR Platform: A Basic Body on Which Mixed Reality Applications Are Built, Proc. IEEE and ACM Int. Symposium on Mixed and Augmented Reality (ISMAR2002), pp. 246–253 (2002).

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