Remote Collaboration Based on Portable Object in Mixed Reality

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Abstract

In this paper, we propose a remote collaboration system based on portable object in Mixed Reality. We put the replica that is the target of the work in the remote workspaces and set up the coordinate system based on it. The process of the manipulation to the replica and its effects are displayed with the virtual objects by using a technology of Mixed Reality, and they are shared based on the replica between remote places. These make the interaction with the replica shared between the remote workspaces. By sharing the state of the virtual objects based on the object coordinate system, users can collaborate with sense of touch naturally in remote places. We implement the system that actuates our concept and find it effective by evaluating it.

1. Introduction

Earlier it was also popularly practiced as remote collaboration system, remote users collaborated with sharing electronic data through a network[1]. In these systems, users could not treat information of real world and objects. Later MR(Mixed Reality) made it possible, that they took in information of the real world in a virtual world. And then MR was applied to collaboration ways, in that users work with sharing virtual information in remote places.

However, when users treat real objects, there were asymmetric remote collaboration systems, such as only worker manipulates his or her own real object and the other user (he is a director or a supporter) directs him watching a view of worker, but it was impossible, that both users, who had their own real objects in remote places, treated their own real object each other and collaborated through them (it's symmetric remote collaboration system). Different manipulations of each remote user make discrepancy between states of each real object, so it's too difficult to make the same state in remote place. In this paper, the change in thinking makes it possible, remote users have own real object and collaborate naturally, without discrepancy between stats of real objects. We treat work spaces not as based on world coordinate system, but as based on real object, that is a target of the collaborated work.

In this research, remote users have the same replicas of the target real object in each work space, and then each replicas have coordinate system based on itself (It's called object coordinate system in this paper). A process of the manipulation to the replicas and its effect are showed with virtual object with Mixed-Reality and shared based on the replicas between remote places. This will enable work through the replicas to be shared in remote places. Sharing and coinciding the state of virtual objects based on object coordinate system between remote places allow remote users to work naturally each other with touching real object.

Virtual objects based on object coordinate system rotate and translate keeping relative position and orientation to the replica, when user rotate and translate the replica by his or her hand. Process of user's manipulation and its effect are showed with virtual objects, and these virtual objects are also showed in remote place keeping relative position to the replica and coincid between remote work spaces.

In this research, we implemented a system, that actualize the proposal, and evaluated its performance. We also implemented a prototype of the system.

In this paper, chapter 2 describe background of this research and problem of current systems. Then remote collaboration based on portable real object in Mixed Reality is proposed in chapter 3. Chapter 4 shows implements of the system, and performance of the system

is evaluated in chapter 5. Chapter 6 is the implement of prototype system and we state a conclusion and future works in chapter 7.

2. Background and Problem

2.1. Remote Collaboration with Real Object

There are some examples of remote collaboraion or communication with real object.

Tangible interface provides interaction with digital world through real object to us. By applying tangible interface to remote environment, "PsyBench" [2] that Ishii and the others developed realized remote collaboration based on interaction with real object. In "PsyBench" system, XY-stage is built by putting electric magnet under a table in each remote places and magnets are set under bottom of objects on the table. It makes physical state on the table coincide between remote places.

Sekiguchi and others developed "RobotPHONE"[3] that realized remote communication by sharing motion of teddy bear-shaped robot through Internet and making it coincide.

These systems that use tangible interface offer a sense of touch and make manipulation intuitive, however, there are some problems. One is that, there are physical restrictions on motion of objects, as effects of manipulation to real objects are realized through magnetic or mechanic actuator. Another problem is unnatural behaviors such as a real object moves suddenly. Cause of it is that, there is no information of awareness where the other user is going to manipulate.

2.2. Remote Collaboration in Mixed Reality

Feeling of Mixed Reality :MR that is technology to do excellence of electronic data such as CG or a letter to reality space is applied currently in various fields such as work support in the field of industry [4], entertainment [5] or medical care technology [6].

MR let users communicate or collaborate with treating information of the real world.

Simon and others developed "3-D Live"[7] that observer can watch a real-time 3D image of whole body of remote user from all angles he or she want in real space.

Dieter and others developed a system that's 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 face-to-face users work in the same real space, but in remote places they collaborate by sharing 3D window.

There is an example that user treat directly the real object in remote collaboration. Suzuki and others proposed a remote support system[9]. In this system they assume relation as a worker and a director and the director direct by pointing with watching a immersive worker's view. From a remote place the director can watch a stereo image of worker's view through a HMD (Head-Mounted Display) and manipulate a virtual pointer displayed in the worker's real space instead of his or her finger. The worker feels like the remote director is pointing in his or her work space. In this system, one user as the worker can treat real objects directly, but the other user as the director can treat only virtual objects.

There is "lazy Susan"[10] by Uesugi et al. as an example of trying collaboration both remote users have own real object in Mixed Reality. In "lazy Susan" effects of interaction with real objects passed on to remote place by shooting a video of manipulation to real objects and projecting it onto a table in remote work space. There is a disc it can rotate on the table, and a motion of it coincide between remote places. It makes user aware the other user, the collaboration alive and the sense of share workspace enhance. However there is a problem that it causes some trouble in manipulation if the view is changed by rotation by remote user without local user's willingness. And it is a tabletop system so that workspace is fixed essentially.

Iso and others proposed to adapt to the differences in room structure. In "ComAdapter", they tried to describe user's posture, physical relationship and so on in different rooms. There are some discontinuous scenes when they describe dynamic situation in the rooms or the process of the user's motion. This system aims natural living-room communication when room's structures are different. On the other hand, we set out a remote collaboration system with manipulating one target object.

3. Proposal

3.1. Remote Collaboration Based on Portable Object in Mixed Reality

A technology of Mixed Reality extends real world and increase a possibility of collaboration. In Mixed Reality they can collaborate with the real object face-to-face or only one user treats the real object in remote collaboration, however it is not impossible that both users in remote places have the real object and manipulate it because discrepancy turn up between each real object in remote places. We therefore set up a coordinate system on the portable-real object (object coordinate system) and display the virtual objects based on the real object so that users can help his or herself to treat the real object by hands and collaborate between remote places.

First, users who are participants of the collaboration have a replica of real object of the same shape and size each other as a target of the work. Each user can help his or herself to move the replicas because a

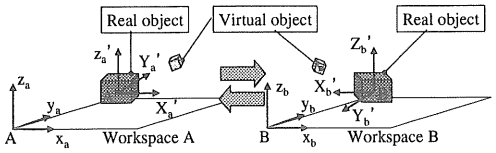

Figure 1. Transformation

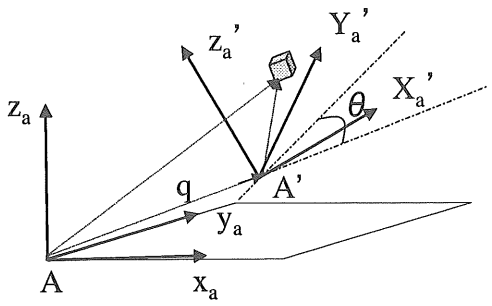

Figure 2. Transformation of the coordinate system

motion of replica by one user's manipulation does not influence the other replica in remote workspace. Second, the process of interaction with the replica and its effects are displayed as the virtual objects in remote place and shared between both workspace. The various virtual objects displayed around the replica that is a target of manipulation are put on the object coordinate system. This gives that the virtual objects get rotation and translation with keeping a relative position and orientation to the replica when user rotate and translate the replica. These virtual objects are also displayed around the replica in remote place and a scene of them coincide between both workspaces, so users can collaborate through the replicas.

3.2. Object Coordinate System

The virtual objects displayed based on the replica are also displayed in remote place by keeping the relative position and rotation to the replica. There are two coordinate systems in this concept, one is world coordinate system and the other is object coordinate system. These coordinate systems are set up in addition in remote workspaces and coordinate transformation is needed to share the virtual scene between remote places.

First, ${}^{A}T_{A'}$ is a transformation matrix from object coordinate system into world coordinate system. If the position and the orientation of the virtual object based on world coordinate system is ${}^{A}V$, we use a inverse matrix ${}^{A'}T_{A}$ of the transformation matrix ${}^{A}T_{A'}$.

$$ {}^{A'}V = {}^{A'}T_{A}\,{}^{A}V $$

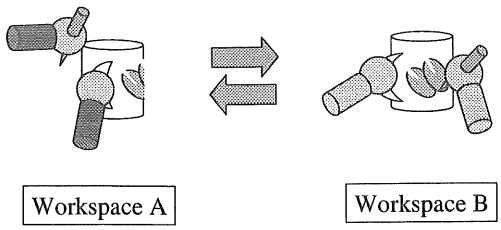

Figure 3. Image if painting on the mug

It transform ${}^{A}V$ into ${}^{A'}V$ the position and the orientation based on the object coordinate system in the workspace A. And then it is shared with the workspace B. It is the same as the position and the orientation based on the object coordinate system in the workspace B.

$$ {}^{A'}V = {}^{B'}V $$

Then we find ${}^{B}V$ the position and the orientation of the virtual object based on world coordinate system in the workspace B. With ${}^{B}T_{B'}$ homogeneous transformation matrix from object coordinate system into world coordinate system in the workspace B,

$$ {}^{B}V = {}^{B}T_{B'}\,{}^{B'}V $$

the position and the orientation: ${}^{B}V$ is found. In this way the virtual objects based on the replicas are shared between the remote workspace A and B.

3.3. Image of Use

Two users have a white plain mug of the same shape and size by his or her hand in remote workspace. Each user can move his or her mug portable. They wear HMD and have a stylus mounted magnetic sensor receiver by the other hand. They paint on a surface of the mug with the stylus as a pen. A painted picture is described with the virtual object and shared on the surface of the mug between the remote places. The stylus of one user is displayed around the mug that the other user has as the virtual object that shape a pen by keeping the relative position and orientation. Though they work in remote places, they feel like design together in real time. They can also help his or herself to move the mug to watch a painting of the other user or paint on the surface where he or she likes.

4. Implementation

4.1. Synchronization of the Virtual Information

To share the virtual scene in remote places, a change of the virtual objects must be passed on to the other workspace and coincide when one of the virtual objects changes in the local workspace. First, all virtual objects are registed with ID number. Second, when one of the virtual objects changes,

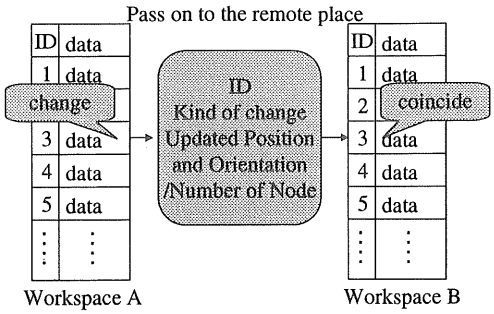

Figure 4. Synchronous of the virtual scene

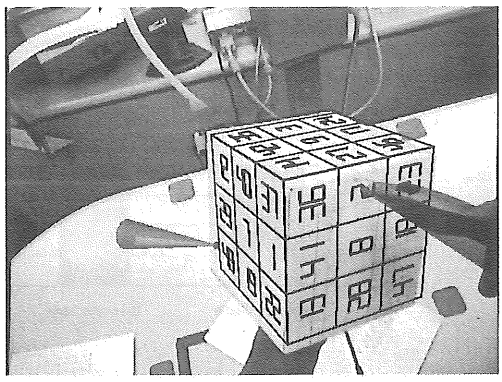

Figure 5. Vision of experiment

the system detects it and passes on the ID number and a kind and degree of the change to the remote workspace. Then the virtual object of the ID number passed on is changed as the same kind and degree. The kinds of changing are the rotation, the translation and the change of displayed virtual object by switching over virtual nodes. If the kind of the change is rotation or translation, an updated position and orientation is passed on to the other workspace and if it is the switching over the nodes, a number of the selected node is also passed on.

4.2. System Architecture

We use the video see-through HMD of CANON. A video camera and a liquid-crystal display are mounted in it. This HMD and the stylus have the receiver of Fastrak that is a magnetic sensor so that a six-degree-of-freedom that is the position and the orientation is taken out. Other sensor receivers are mounted on the replicas that are the target of the work. Alignment of real space and virtual space is done by the hybrid method of magnetic sensor and marker. For display and manipulation of the virtual objects, we use a function of MR Platform Plus[11] of CANON. Two PC are connected through network between remote places.

5. Evaluation

This concept is a collaboration way by sharing the processes of interaction and its effect based on the portable target object between remote places. In this system, pointing is actuated by displaying a pointer of the virtual object to the same position and orientation in remote place. A purpose of this evaluation experiment is to make sure if a pointing that is one of interaction ways is become aware. We also check if the pointing is become aware when two users point one after the other. Twelve subjects participate in this experiment, they include men and women, from twentysomething to fortysomething.

As the figure 5 shows, we use a cube, 12cm on a side and its surface is divided 9 tiles, on that a number is displayed at random with virtual object.

5.1. Experiment 1

Two subjects do tasks at a time. One points a tile as a director and the other answer the number on it as a answerer. The director points tiles of another surface at random 5 times. These ways are done in a two cases, one is that two subjects are in the same place and the director points with a pen. Answerer watches pointing behind the director. We call this task "nearly face-to-face". and the other is that two subjects are in the remote places, both wear the HMD and have the cube by his or her hand and the director points with the stylus. The director begins pointing concurrently with a signal and say "here" when he or she just has pointed the tile. Then the answerer read its number and next pointing starts. The director does not think about the next tile, decide quickly and just pay attention to point the tile of another surface. It is marked if the answers are correct or not in both cases. We clock a time from when the director starts pointing to when the answerer answers the number in both cases. And we clock also a time from when the director finishes pointing to when the answerer answers the number as a answer time in second case.

5.2. Experiment 2

Two subjects do tasks at a time. The subjects wear the HMD and have the cube and stylus by his or her hand and point and answer one after the other in remote places. We mark if the answers are correct or not and clock a time from when subject A starts pointing to when A answers the number of the tile that subject B has pointed.

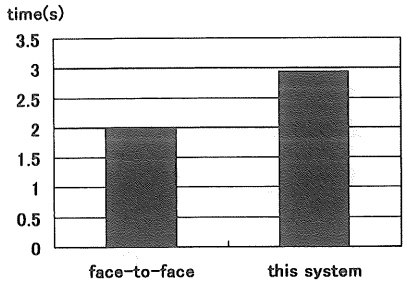

Figure 6. Time from when the director started pointing to when the answerer answered

5.3. Conclusion and Discussion of the Experiment

In the experiment 1, it took 1.99s to do the "nearly face-to-face" task and 2.94s to do the task with our system in remote places. It took also 0.53s to answer the number with our system in remote places (answer time). The answers are 100 % correct in the both cases. It shows that pointing takes 2.94s and is become aware correctly in our system. A difference between the two cases is 0.96s. It includes a delay caused by a load of HMD, its narrow vision and low resolution and a delay of the network.

In the experiment 2, it took 7.26s from when subject A starts pointing to when A answers the number of the tile that subject B has pointed. And the answers are 100 % correct too. It shows that as if pointing is done one after the other, it is become aware correctly by displaying the relative position and orientation of the director's stylus.

6. Prototype system

Then we implement a prototype system. Users have a replica of beige cylinder by his or her hand and the stylus by the other hand. Knives, holes and dole are displayed as the virtual objects around the cylinder. They are shared between the remote places. The virtual object shaped the knife is displayed on the stylus and it is also displayed by keeping the relative position and orientation to the cylinder in the remote place. In figure 7 a blue virtual knife of user A is displayed on the stylus and in figure 8 it's also displayed by keeping relationship to the cylinder.

A role of the game is that, users stab the knives into the holes one after the other. If any user stabs into a losing hole that is set at random, the dole on top of the cylinder pops up and this user lose the game. Users can play with sense of touch and high realistic sensation.

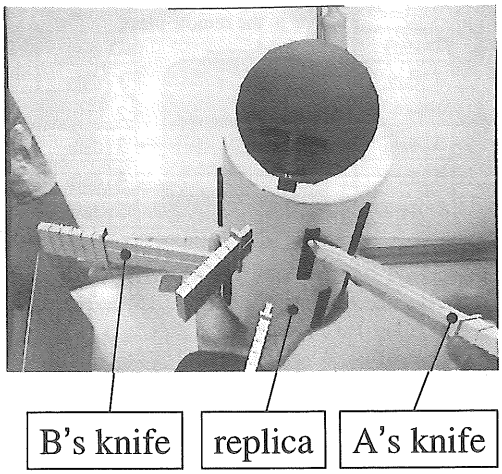

Figure 7. Vision of user A

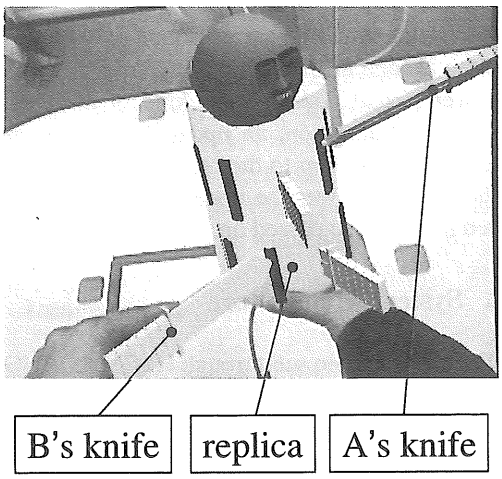

Figure 8. Vision of user B

7. Conclusion and Future Work

In this paper, we put the replica that is the target of the work in the remote workspaces and set up the coordinate system based on it. The process of the manipulation to the replica and its effects are displayed with the virtual objects by using a technology of Mixed Reality, and they are shared based on the replica between remote places. These make the interaction with the replica shared between the remote workspaces. By sharing the state of the virtual objects based on the object coordinate system, users can collaborate with sense of touch naturally in remote places.

We implemented the system and evaluated it so that we find the pointing is become aware correctly as if it is done one after the other in our system. Finally we implement the prototype system.

In the future, we will implement an aplication of the collaboration like a real-time painting system and evaluate if real-time collaboration is possible with our sys-

tem.

In this system, we use the same shape and size of the replica between the remote places. We will treat different size of the replica such as a car and a miniature of it. A work support system will be actualized as a worker builds the car and a director directs with the miniature of it with his or her hand in remote place.

Acknowledgements

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