"Lazy Susan" Communication System for Remote, Spatial and Physical Collaborative Works

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Abstract

Various communication systems in shared space technology have been proposed to support remote spatial collaborative works with physical objects. The authors have focused on sharing bodily interactions with physical objects between remote places, and have developed "Lazy Susan" communication systems. We have applied our unique communication system to support remote collaborative works and proved that our communication system is useful to change spatial and positional relation between a remote physical object and local self. Moreover, in order to exploit the feature of "Lazy Susan" communication system, we have proposed three modes; Rotation, Magnifying and Personal mode, and implement visual tag interface as additional functions for a collaborative work. We discussed also uniqueness of our system in comparison to conventional communication systems and indicated its possibility.

Keywords

Remote collaborative work, Bodily interaction, Lazy Susan, Spatial and positional relation, Visual tag

1. Introduction

Recently, remote people who separate physically from each other can exchange their messages and information by virtue of a rapid development of mobile phone and e-mail means. A remote communication is becoming a part of daily lifestyle. It is anticipated that a communication service utilizing a high quality video and sound devices will be further developed and employed more frequently. Within such a communication environment, numerous technologies which are so-called, in general, "shared space technology"[1] have been proposed; such technology can express bodily actions such as eye gazes during conversation[2], teaching a remote machine operation[3] and operating a remote object in three dimensions with tele-operated robot[4].

In contrast, people are bodily present at the same place in face-to-face situations. This full-bodied presence is crucial to everyday human encounters[5]. People can attune themselves to mood, when they are bodily present in a situation. We believe that such a bodily present situation is fundamental before interpersonal communication takes place[6]. However, conventional communication systems are characterized by supporting remote people through only a portion of bodily interactions, and have supported capability of bodily presence insufficiently. Therefore, we have investigated method to create a sense "as if remote people were present at the same place" by particularly focusing on capability of whole sense of bodily interactions. We have proposed a method to share bodily actions between remote people, and have developed "Lazy Susan" communication system which enables users to operate remote disk by their own hands and see interactions with remote people visually. Experiments demonstrated that the communication system can create a sense of presence of a remote partner and a sense of co-existence between remote people[7].

In this paper, we describe a remote spatial collaborative work with physical objects supported by employing our "Lazy Susan" communication system. Additionally, we propose the advanced "Lazy Susan" communication system to add several functions for collaborative works by applying visual tag interface.

2. "Lazy Susan" communication system

2.1. Overview of "Lazy Susan" communication system

In this chapter, we describe an overview of our "Lazy Susan" communication system. Figure 1 shows a conceptual image of this communication system to represent two expressions; movements of physical disk operated by remote people and visual representations of bodily actions. We have applied this communication system to three situations; (1) integrating both bodily interactions at each physical place into interactions in a shared virtual space [8], (2) integrating interactions at one local site into interactions at another remote place (one-way tele-presence) [7], and (3) integrating interactions at each site into interactions at each physical place (two-way tele-presence) [9]. In this instance, we explain the communication system according to the above second situation. Figure 2 shows the schematic diagram of the "Lazy Susan" communication system. A participant at one site (PlaceA in Figure 2(a)) can communicate with a remote participant at another site (PlaceB in Figure 2(b)) by viewing a synthesized video including a reflection of a remote partner and self. On the other hand, the participant at PlaceB can communicate with the remote participant at PlaceA, whose reflection is projected on a local tabletop and on a screen across a table directly. Concurrently, both participants can communicate with each other through interacting with physical disk, rotations of which are synchronized with those of remote corresponding disk. If there is a conflict such that, for example, one participant attempts to rotate the disk clockwise while the other participant attempts to rotate counterclockwise, each participant will feel torque in the opposite directions.

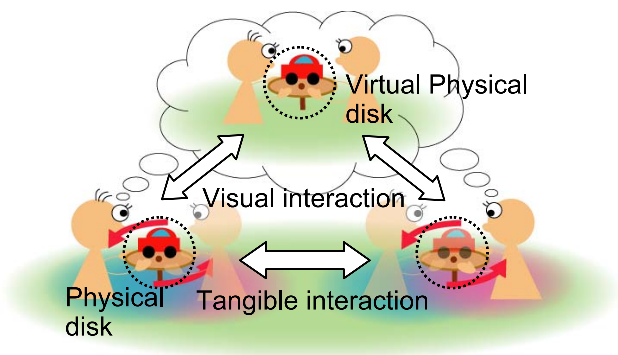


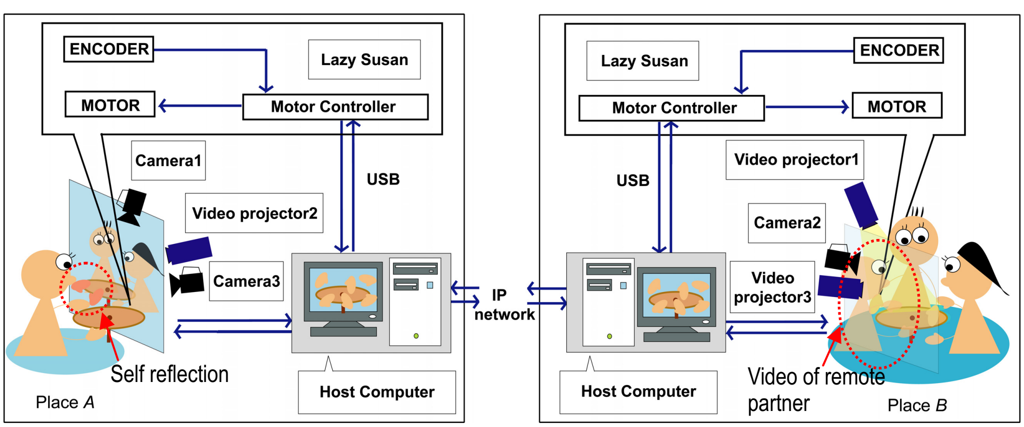
Figure 1. A conceptual image of "Lazy Susan" communication system to create a sense of co-existence

Communication experiments demonstrated that our system could support to create a sense "as if own body expanded toward remote space" at PlaceA and "as if remote people were present at own local place" at PlaceB[7]. However, we have neither applied our communication system to support remote spatial collaborative works with physical objects nor investigated its possibility of contribution yet.

2.2. Remote collaborative work on "Lazy Susan" communication system

We can see and experience interactions with revolving disk or "Lazy Susan" in daily life. For example, at Chinese restaurant people sit around the circle table. They can talk to communication partners over the table, and pass an object toward people at opposite side and take an object out of reach toward self by using a rotating disk. We have applied our aforementioned communication system to support a remote collaborative work, and investigated how people can utilize the "Lazy Susan" communication system in a remote collaborative work, and what the communication system can or cannot support during such a collaborative work.

We have conducted experiments on a collaborative modeling work with wooden building bricks on a table and on a collaborative drawing on a whiteboard attached on a rotatable disk. Two couples of four participants experienced each task for approximately 15 minutes. After the experiments, we had brief interviews with participants on the usability of this system, and we observed recorded video during interactions. We describe



(a) Displaying a video space of remote place including self reflection across a table

(b) Projecting a reflection of a remote partner on a local tabletop and on a screen across the table

Figure 2. Schematic diagram of "Lazy Susan" communication system (One-way tele-presence)

how they conducted collaborative works on "Lazy Susan" as below.

On a collaborative modeling work, we asked *ParticipantA* (as which we call participants at PlaceA illustrated in Figure 2(a)) to direct *ParticipantB* (as which we call participants at PlaceB illustrated in Figure 2(b)) how to model with brick on a table at PlaceB. We observed that a remote *ParticipantA* could point to a brick at PlaceB and instruct *ParticipantB* which brick to choose and how to move a brick by using video hands of *ParticipantA*. Then, we observed that *ParticipantA* instructed *ParticipantB* to model a building by showing own brick projected on a tabletop at PlaceB as well as own video hands. Furthermore, *ParticipantA* could change position of the building on the remote disk by rotating the disk in order to view backside of the models and so that it was easy for *ParticipantB* to understand instructions of *ParticipantA*.

We also observed an interesting phenomenon that *ParticipantA* almost stretched out his video hands toward a falling brick on a remote disk when they rotated the disk by themselves or when they touched the disk that a remote *ParticipantB* rotated. Figure 3 shows that *ParticipantA* reached out to such a falling brick at once. At the interview, they reported that "they felt as if their hands expanded to the remote place when they rotated the disk."

Meanwhile, we observed that *ParticipantB* modeled a building with bricks and moved a brick by following an instruction of *ParticipantA*. Most of them at PlaceB reported that when a remote *ParticipantA* rotated the disk, a sense was enhanced as if they rotated the same disk with a remote participant, and as if they worked together in face-to-face situation. A few of them also reported that they could read eye gaze of video of *ParticipantA* for instruction of modeling. However, they also reported that they could hardly understand instructions of *ParticipantA* on building up bricks heightwise in three dimensions on the table.

During the collaborative drawing as shown in Figure 4, we observed that they adjusted a timing of drawing by alternately rotating the disk after they drew something or after a remote one drew. Moreover, we also observed that they rotated the disk and showed what they drew to a remote partner for easy viewing and understanding. Most of them reported that our communication system supported a situation as if participants were around the same table and worked together while moving around the table. However, some of participants at PlaceA reported that they had a difficulty in drawing on the board because the board they were drawing on was different from the screen on which they saw a combined image of a local board and a remote board. Such an inappropriate interaction occurred occasionally because of an

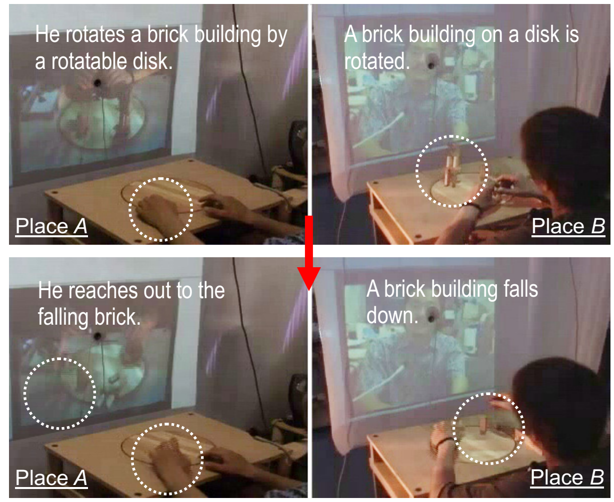
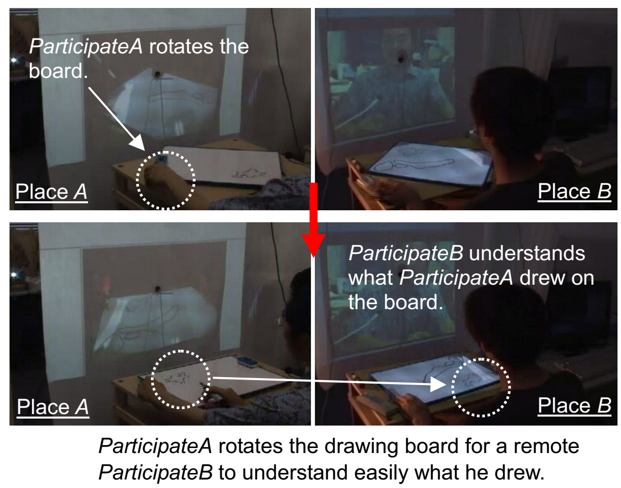


Figure 3. A scene of a remote collaborative modeling work that a local user rotated a remote model on the disk.



ParticipateA rotates the drawing board for a remote *ParticipateB* to understand easily what he drew.

Figure 4. A scene of a remote collaborative drawing work that a remote user drew a map on a whiteboard attached on the disk.

inconsistency between a local workspace and a shared workspace. For instance, *ParticipantA* tried pointing directly to a remote object on the screen by their own physical hands not by using video hands. However, the above results indicate our system can support a remote collaborative work including operating physical objects and drawing on a shared board with a sense as if they were around the same table.

We summarize the feature of this communication system to support remote collaborative works.

- Changing an orientation of a remote object for ease of viewing and comprehension by rotating a disk
- Changing an orientation of a local object and a remote object for easy instruction to remote people by rotating a disk

- Adjusting a timing of collaborative work process by rotating a disk alternately
- Enhancing a sense as if they were present at the same place
- Not supporting a collaborative modeling heightwise in three dimensions

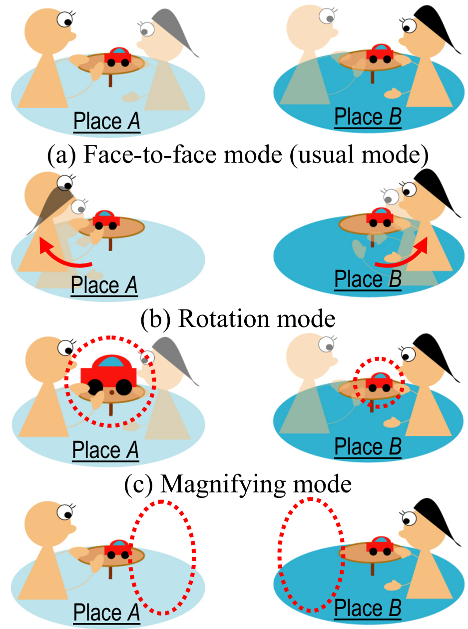
3. "Lazy Susan" communication system with visual tag interface

3.1. Collaborative work with physical objects

We advance the "Lazy Susan" communication system toward supporting a remote spatial collaborative work with physical objects in consideration of conventional communication systems for collaborative works on tabletop. It has been pointed out that usual video conference system representing remote people in a display cannot support gesture such as pointing to a remote document, because people cannot understand what the gesture of remote partner points to and there are misunderstandings between them[10]. Therefore, an appropriate spatial relationship among remote partner, remote object and self should be required in order to support for a user to point to a remote object[11]. Then, in regard to representing bodily actions, a user is required to be able to understand how own body appears in a remote place, and its appearance should reflect fidelity of bodily action[12]. Moreover, Kruger et al. have investigated spatial relationship among another partner, objects and self during spatial and physical collaborative work on tabletop in face-to-face setting, and demonstrated that orientation on tables is significant for comprehension as to ease of reading and task, coordination as to differentiating own and the other object and space, and communication as to conveying intentions[13].

When we consider remote collaborative works utilizing our "Lazy Susan" communication system based on above-referenced features of spatial collaborative works, it is demonstrated that our communication system has features supporting ease of viewing and task for remote partner and self by operating remote object on a rotating disk and conveying intentions by rotating disk. In order to exploit the feature of interactions with "Lazy Susan", we focus on bodily interactions around a table during a spatial collaborative work in face-to-face setting based on Kruger's report[13], and we consider following interactions.

People can see a large drawing on a table from various viewpoints of other communication partners after moving around the table, when they cannot rotate the drawing easily by own hand on the table. When it is hard for people to understand details of a model and a drawing because those objects are complicated, they can bend



(a) Face-to-face mode (usual mode)

(b) Rotation mode

(c) Magnifying mode

(d) Personal mode

Figure 5. Three modes for a collaborative work on "Lazy Susan"

over toward the object, or they can move the object toward own face. Those actions are for comprehension as to easy viewing and understanding. Then when we have a collaborative work on the same table, we often separate personal workspace from group work space on the table[13]. Those actions are for coordination as to differentiating own and the other object and space.

In order to support the aforementioned interactions on a table between remote places, we propose to support the following three modes in our "Lazy Susan" communication system. Figure 5 shows conceptual image of usual mode (Figure 5(a)) and these three modes.

1. Rotation mode: changing spatial and positional relation between remote communication partner and self by operating disk (Figure 5(b))
2. Magnifying mode: scaling up representation of remote object on a disk by operating disk (Figure 5(c))
3. Personal mode: separating workspace on a table into personal workspace and group work space (Figure 5(d))

3.2. Design of advanced "Lazy Susan" communication system

Firstly, we should consider how users can change each mode during a collaborative work. It is required that users can change each mode easily on the table during a collaborative work, and they can understand which mode

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is chosen at the present moment at each place. Additionally, these three modes should be incorporated compatibly in our communication system. Therefore, we focus attention on visual tag interface as a method of changing each mode. Visual tag interface proposes a method to identify a printed icon by capturing video of the icon and by image processing. For instance, a bar-code printed on a commercial product is one of visual tag. Several interface systems using visual tag have been proposed so far. BrightBoard [14] have proposed a method to recognize a command button drawn on a whiteboard by hand. Matrix code[15] can recognize three-dimensional location of a visual tag as well as ID of the tag, and can display visual information on the tag. Real World Teleconferencing[16] has also proposed displaying video of remote communication partner on the visual tag.

As visual tag interface system can be constructed based on image processing, we consider visual tag interface can be implemented compatibly without any new hardware in our "Lazy Susan" communication system including video camera over the table.

3.3. Implementation of advanced "Lazy Susan" communication system

We implement visual tag interface system into another "Lazy Susan" communication system (two-way tele-presence) according to the third situation described in Section 2.1. The system can project a video of remote tabletop onto a local tabletop each to each by implementing filtering software for removing video feedback, project video of remote partner onto the screen across a table, and share movements of physical disk.

We explain how the visual tag can work and the mode can be changed in our system as below. Figure 6 shows an overview and Figure 7 illustrates how to recognize the tag. An icon on visual tag means a function corresponding to one of aforementioned three modes as shown in Figure 6. The icon is printed in black and white because the tag can be recognized robustly and independently from light environment comparatively, and users can also easily view and understand the icon on the tag. The user should put only one tag within the specific region on the table as shown in Figure 6, where a light intensity is constant. A CCD camera captures whole region of tabletop, and only specific region including visual tag can be clipped from the whole tabletop image. And, rectangle region of visual tag can be detected after threshold processing and noise reduction operations. When the rectangle region can be recognized, the area of icon within the rectangle region can be calculated and compared to the area stored on ahead in the computer. At last, the icon is recognized as one of three tags because the area of icon on the tag is different from each other. This method of calculating icon area can be available because the light intensity and the distance between camera and tag are approximately constant. After the icon is recognized, the mode of visual tag and rotational angle of disk can be transmitted to a remote computer via IP network with each other. And then, each mode can be conducted at each place.

When the icon is recognized, the green outline appears around the specific region for users to understand the tag is identified or not as shown in Figure 7. At remote place, the red marker appears in the specific region for users not to put the tag there.

At the present system, the only one mode can be conducted at each place. When a user puts on two visual tags within the region, those tags cannot be recognized. When both remote users put a different tag with each other at each place, only one tag can be recognized and the mode can be conducted.

As to rotation mode, video of remote tabletop is rotated around the center of the disk and projected onto

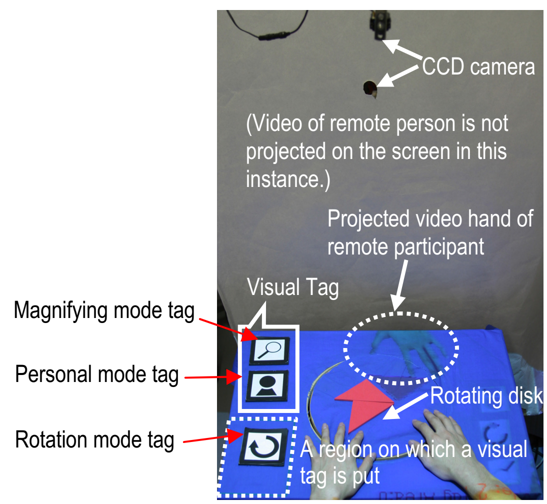

Figure 6. "Lazy Susan" communication system with visual tag interface

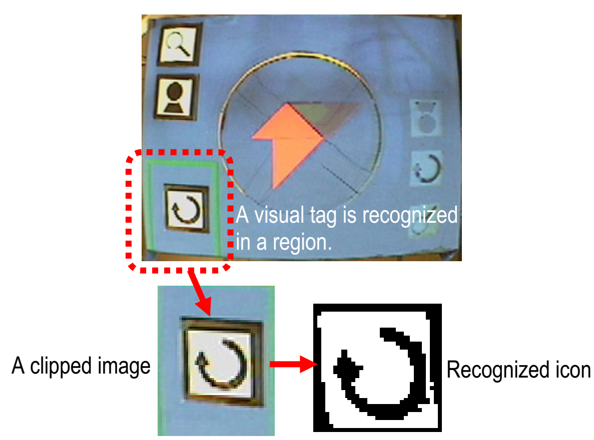

Figure 7. Recognition method of tag

the each local tabletop corresponding to direction and amount of disk rotation from the point when the tag is recognized.

As to magnifying mode, video of remote tabletop is scaled up in the center of the disk from 100 to 800 % and projected onto the local tabletop corresponding to direction and amount of disk rotation from the point when the tag is recognized. At the other remote place, normal video is projected.

As to personal mode, video of remote tabletop cannot be projected onto the tabletop and the rotation of disk cannot be synchronized with each other. They can only see their own tabletop and rotate their own disk.

3.4. Remote collaborative work on advanced "Lazy Susan" with visual tag interface

We describe a remote collaborative modeling work with physical objects when users employ "Lazy Susan" communication system with the visual tag interface.

First we explain rotation mode as shown in Figure 8. They can change the spatial and positional relation between remote partner and self from across the table to across the corner by rotating the disk. In the physical situation, spatial and positional relation between local physical tabletop and self is constant as well as before putting the rotation mode tag. However, such a relation between remote tabletop and local tabletop can be changed visually and relatively. Even when they sit at the table, they can move to the standpoint of remote partner and view the same situation just by rotating the disk without moving around the table.

Second, we explain magnifying mode as shown in Figure 9. They can see the scaled-up representation of the remote tabletop by rotating the disk, and observe the details of scaled-up appearance of remote physical object. It can be useful to direct the remote communication partner in detail.

Third, we show personal mode in Figure 10. In this mode, they cannot see remote tabletop and operate the remote disk with each other. They can do personal work at each place.

At the present system, work process cannot continue from one mode to another mode. For example, when they finish the rotation mode, the normal, or face-to-face across the table, video of remote tabletop is projected onto the local tabletop at once. This means that a relationship among local objects and remote objects is altered before and after each mode. Such a continuity of work process is one of issues to be investigated in the next step. Additionally, video of remote partner doesn't appear or always appears on the screen across the table even in the rotation mode. In order to solve this problem, the system will be able to project video of remote partner onto several screens around the local table by choosing one of multiple projectors corresponding to the spatial and positional relation between the remote partner and self.

Although the above are preliminary results of collaborative works, it was indicated that our system is promising to support remote, spatial and physical collaborative works.

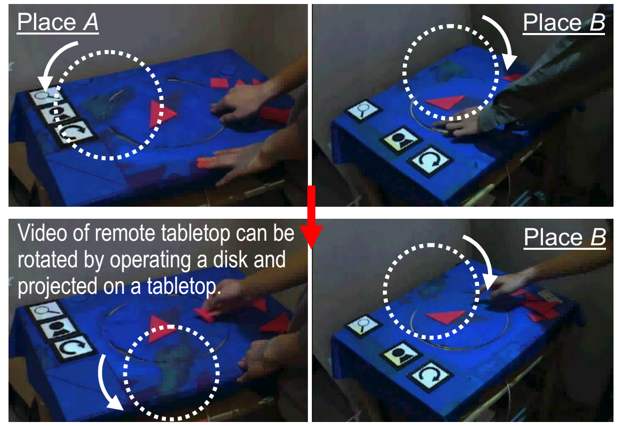

Figure 8. A scene in use on Rotation mode

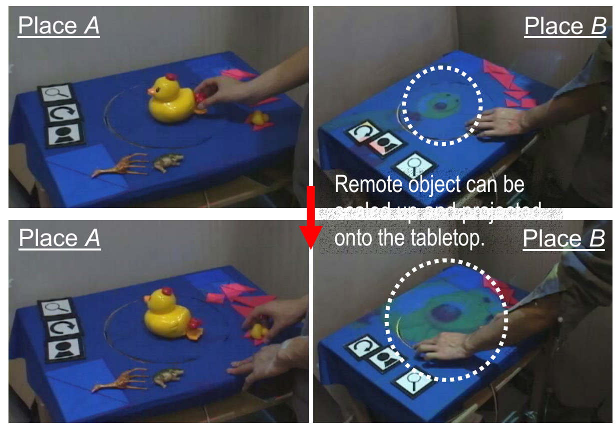

Figure 9. A scene in use on Magnifying mode

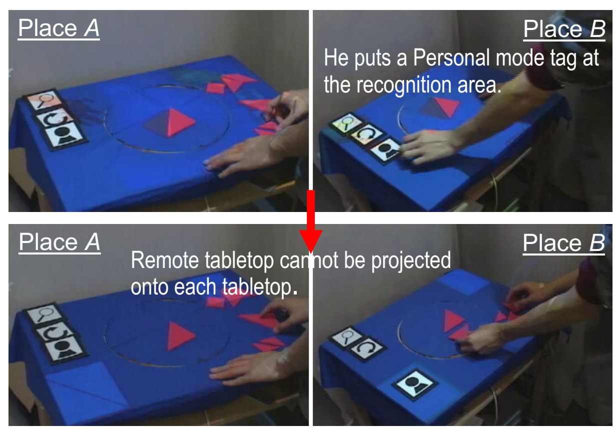

Figure 10. A scene in use on Personal mode

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4. Discussion

Several interface systems employing metaphor of rotating disk have been proposed so far. In a co-located situation, DiamondSpin[17] has been proposed with a tabletop display, around which people can sit and view several pictures. They can pass a picture toward another person and draw an out-of-reach picture toward self as if they rotated the transparent round table. MagicMeeting[18] provided AR conferencing system, in which they can put a virtual model such as automobile and parts virtually on the physical cake platter. They can view the backside of the virtual model by rotating the physical cake platter, and another person at the same place can also rotate the model for her/his easy viewing and comprehension. These interface systems are just only utilized in face-to-face situation, and are not supposed for a remote collaborative work.

In contrast, several communication systems have also been proposed to support a remote collaborative work with physical objects. In communication systems based on sharing movements of physical objects between remote places, PsyBench[19] and ActuatedWorkBench[20] have been proposed. These systems can synchronize two-dimensional movements of local object with those of corresponding remote object by controlling magnet under those objects. Those communication systems can support to operate only specific object with magnet, but can support bodily interactions insufficiently because those systems cannot represent bodily actions of remote partner visually. In comparison to these systems, users can only share rotations of a physical disk in our communication system, although they cannot operate each remote object. Consequently, they can rotate directly by hand any physical objects just on a remote physical disk for ease of viewing and comprehension.

According to an idea of operating remote physical objects directly, using master-slave robot system[4] might be also useful. Gestureman[3] can support a spatial indication such as teaching a remote machine operation. These robot communication systems can support physical and spatial interactions such as modeling with physical bricks in three dimensions at only one site. However, those robot systems are hard to support bodily interactions with physical objects at both sites as our communication systems have proposed. Moreover, these systems are hardly available among more than three people and more than three remote places. We apply our "Lazy Susan" communication system between remote two places to among three remote places as shown in Figure 11.

As to sharing a workspace, several video communication systems are also proposed based on a metaphor that people are around one table. AGORA[21] is

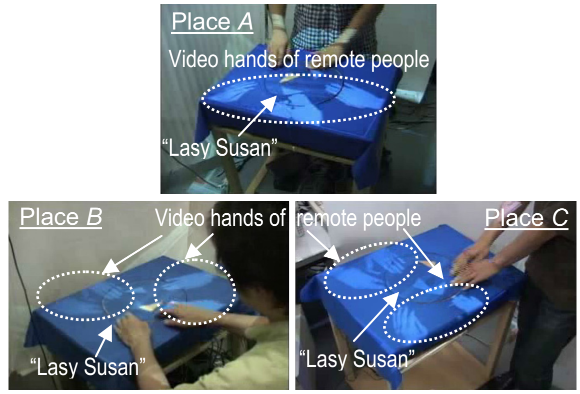

Figure 11. A scene in use of "Lazy Susan" communication system among three places

intended to support a collaborative work between remote two places by projecting the other tabletop onto a local tabletop as well as by projecting participants onto a screen around a table. In this system, people can point to remote object directly by video hand but cannot operate a remote physical object. A situation is fixed that people sit to the table. Consequently, they cannot change various viewpoints of other partners dynamically as our system proposes.

ClearBoard[22] proposes a face-to-face situation across a transparent board and supports mutual gaze awareness while drawing collaboratively between remote two places. Then, HyperMirror[23] can create a visually shared space by combining remote two images in a virtual mirror. These video communication systems can support a dialogue and a visual interaction such as indication and gaze awareness. However, it cannot support to operate a physical object directly.

As stated above, our "Lazy Susan" communication system has a unique feature of changing spatial and positional relation among remote communication partners, remote physical objects and self by rotating disk and by rotating video to support ease of viewing and task, and intentional communication.

As future works, we'll investigate validity of three modes for a remote collaborative work based on empirical study. Moreover, we consider that the resolution of projected video should be improved in Magnifying mode, and add other various modes in consideration of exploiting features of rotating disk for supporting a remote, spatial and physical collaborative work on tabletop.

5. Conclusions

Various communication systems have been proposed to support for a remote collaborative work in the research field of shared space technology. In contrast, the authors have focused on capability of whole sense of bodily interactions in human-human communication and have investigated a method to create a sense “as if remote people were present at the same place between remote people”. Consequently, we have developed “Lazy Susan” communication system which enables users to interact with a remote partner through rotating physical disk. In this research, we apply the unique communication system to support a remote collaborative work, and demonstrate our system is useful to change spatial and positional relation among remote physical objects and local self for ease of task and intentional communication. Moreover, in order to exploit the feature of “Lazy Susan” communication system, we propose three modes of (1) changing positional relation between remote partner and self, (2) scaling up the representation of remote object and (3) differentiating personal workspace and group workspace, and implement those functions based on visual tag interface. The uniqueness of our communication system in comparison to conventional communication systems was demonstrated and it was indicated that our system is promising to support a remote, spatial, and physical collaborative work.

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