SICE Annual Conference in Sapporo, August 4-6, 2004
Hokkaido Institute of Tecnology, Japan

# Tool-type interface system supporting for an expansion of body image toward a remote place

## - Development of virtual shadow interface system -

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**Abstract:** There is considered a problem of disembodiment in computer-mediated communication technology supporting a communication between remote partners. Therefore, whole sense of bodily interaction should be considered and supported. We have studied a design framework and developed communication systems to support embodied interaction so far. In this paper, we pay attention on a shadow non-separable from a real object, and devise a virtual shadow interface system that bridges between a tool and own body , and between a physical place and a virtual remote place by casting a virtual shadow. Our system is promising to support a sense as if a tool in hand and body image expanded toward a virtual remote place continuously.

**Keywords:** tool, shadow, body image, embodied interaction, computer-mediated communication

## 1. Introduction

There have been several studies in the research field computer-mediated communication (CMC) to support embodied interaction among remote communication partners. There is considered a problem of disembodiment in CMC [1].Most previous communication systems have put in a lot of work on representing a bodily action called as non-verbal mode such as gaze, facial expression, and gesture, based on a design framework braking the interaction into communication channels in a context-independent way [2]. However, as it is considered that a context is generated through mutual bodily interaction among communication partner, place, and myself [3][4], whole sense of bodily interaction should be considered and supported in CMC not only representing bodily action [1]. Therefore we focus on a function of embodied interaction by referring to a Shimizu's principle "Co-creation of Ba" [3][5] (Ba means a co-existing space in Japanese). We consider, in face-to-face situation a co-existing space is created by means that embodied interaction serves for a "spatial relation" between the other communication partner and myself, where the other communication partner and myself exist, and a "bodily involvement" between the other communication partner and myself, to what extent do they engage with each other. We devised a "dual" embodied interaction design approach to support these two functions of embodied interaction between remote places so far [6].

In this paper on the basis of supporting embodied interaction, we propose our novel design approach to employ a "shadow" non-separable from a physical object as a media that bridges between a tool and own body , and between a physically real place and a virtual remote place by casting a virtual shadow. We implement an interface system that casts a virtual shadow over a real shadow of a tool in hand in an accurate position, and represents the virtual shadow toward a virtual place continuously. We explain this idea and its implementation.

## 2. Tool and shadow

We devised an idea that we change an appearance of a tool by projecting a virtual tool onto a physical tool, and implemented a video projection system casting a virtual long stick onto a short stick in hand as shown in Fig. 1. Fig. 2(a) shows that when the system projected a wooden texture over the stick on a table, the texture is put on the stick and on the table continuously. However, when a user picks up the stick above the table, the texture is projected separately between on the stick and on the table as shown in Fig. 2(b). This separated texture from the real stick brings about a feeling that the tool is still short and doesn't look getting longer. Therefore, we project a black figure instead of a wooden texture over a real shadow of the stick consistently as shown in Fig. 2(c,d). Consequently, a virtual shadow of the long stick is cast on the table. Users reported that they felt as if they had a long stick in hand. This result brings us a novel idea that using a tool and projecting a virtual shadow can enhance a continuous engagement

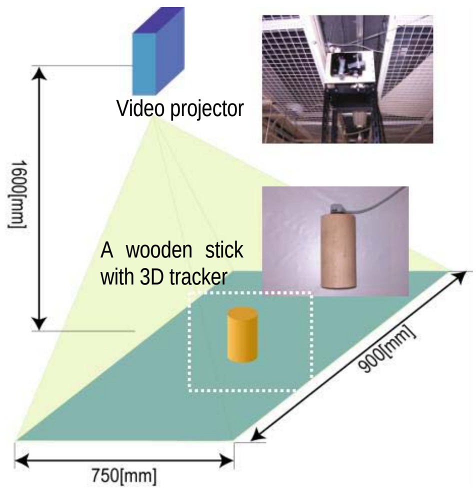
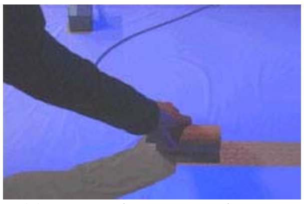
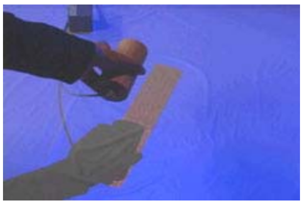


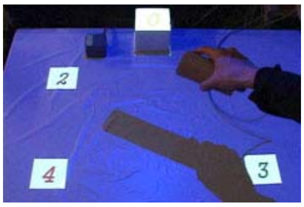

**Fig. 1.** A virtual image projection system



(a) A wooden texture is cast on the stick and the table.



(b) A wooden texture is cast over the table.



(c) A virtual shadow is cast over the table.

(d) A virtual shadow is cast over the table.

**Fig. 2.** Virtual image is cast over the wooden stick

between a physical space and a virtual space. Therefore, in order to consider a seamless connection between a physical local space and a virtual remote space, we investigate a concept of embodied interaction in terms of body image concerning to a tool and a shadow hereafter.

Even when we close our eyes, we know and feel position and posture of our own body. This model of own body in mind is called as body image [7]. The body image isn't fixed but changed dynamically. Some interesting results of experiments on body image have been reported in cognitive science and brain science these days.

Generally, a tool is absolutely imperative for us to live a daily life, and produces a new function when we use a tool. It might say that a tool can enhance a body function. As a phenomenon that a tool is a part of own body, a dynamic change of body image with a tool and without a tool is reported [7].

In terms of shadow, a shadow has several unique properties, expressing a movement of the physical object, non-separable from the physical object even when it moves fast, and arousing a sense of existence of the physical object. Our research group has focused on such uniqueness of a shadow, and has studied employing a shadow as an avatar of representing an existence of a remote communication partner [8]. Moreover, it is reported that own body image can expands toward a point of shadow of our own body [9]. Then, a technique of interaction with shadow in a virtual space has been proposed [10] so far; however, we intend to employ a shadow as a media connecting between a real tool and a virtual one, and between a physical space and a virtual space continuously.

## 3. Design

On the basis of above-mentioned knowledge, we consider a design framework to support embodied interaction toward a remote place by using a tool and casting a virtual shadow on the tool. We devise an idea of integrating a virtual shadow with a real shadow, and of stretching the virtual shadow toward a virtual remote place as shown in Fig. 3.

Our concept has two features; connecting a virtual shadow with a real shadow consistently, and connecting the virtual shadow into a virtual space seamlessly. Therefore our system should accord positions of three light sources with each other virtually; a real light source for casting a real shadow, a virtual light source for casting a virtual shadow at a local place, and another virtual light source for casting a virtual shadow at a virtual remote place. Therefore, requirements as follows should be satisfied to implement our system.

- Measure in real time position and posture of a physical tool generating a real shadow.
- Cast a virtual shadow that connects consistently with a real shadow of a tool.
- Connect a physical local place with a virtual remote place consistently.
- Cast a virtual shadow at a local place to connect with its virtual shadow in a virtual remote place seamlessly.

Additionally, we devise a representation that a virtual shadow changes dynamically according to bodily action, such that a virtual shadow stretches out when we shake a stick fast and investigate various representations of virtual shadow.

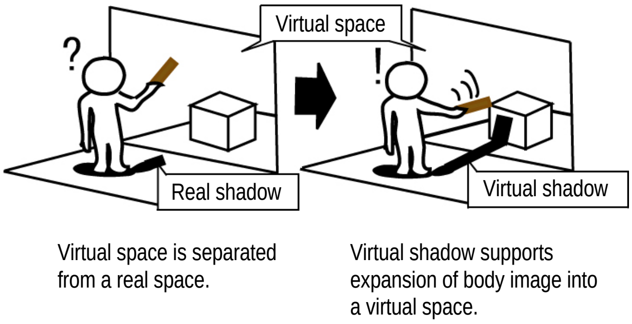



**Fig. 3.** Design of virtual shadow interface system

## 4. Implementation

Fig. 4 shows the system configuration. A face-to-face situation is set up that a remote partner and a local participant stand across a table. A face-to-face screen (screen size: 1100x1000[mm]), onto which a video of remote table and a remote communication partner is projected, fixes at a horizontal screen as a local table (height: 900[mm], screen size: 840x1000[mm]) at an angle for a smooth connection. A video projector2, which serves as a light source casting a real shadow and as a virtual light source casting virtual shadow, is installed over the horizontal screen. A video projector1, which projects a video of remote table, is installed behind a face-to-face screen. 3D tracker transmitter is installed in one corner on the table (horizontal screen), and a user can handle in hand a physical stick (20x20x190 [mm]) with 3D tracker-receiver over the table. The position and posture data of the stick can be transmitted to a host computer in real time. The host computer generates a virtual shadow according to the 3D data of the stick, and the video projector2 cast the virtual shadow over the real shadow consistently. At the same time the data of virtual shadow is transmitted to a remote host computer, and then the virtual shadow is cast on the remote table. Consequently, the user can see a long virtual shadow from a local table toward a remote table. We

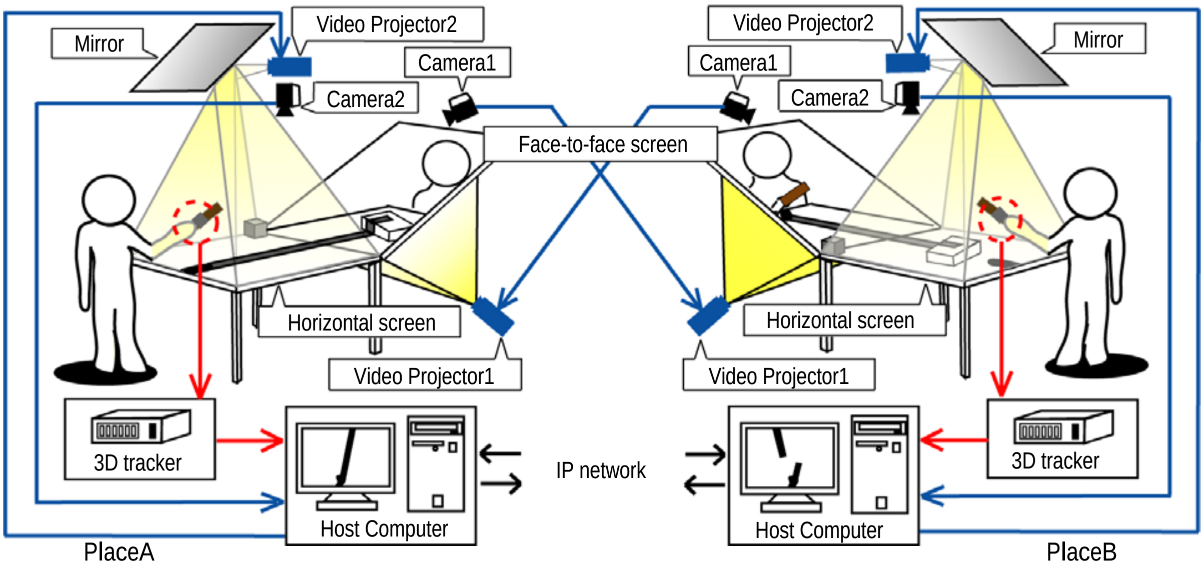



**Fig. 4.** Schematic diagram of virtual shadow interface system

explain how to generate a virtual shadow connecting to a real shadow of a tool consistently.

Fig. 5 shows a coordination system of the optical system. A video is projected in the area (660x880[mm]) on the horizontal screen. When one position of a stick is ($X_R$, $Y_R$, $Z_R$), the shadow of the point of the stick is ($X_S$, $Y_S$), the length of horizontal screen: H, the distance between the point shortest from the center of the projector lens and bottom of the screen: h, and the shortest distance between the projector lens and screen: $L_S$, the shadow of the stick ($X_S$, $Y_S$) can be calculated as equation (1),(2). The host computer generates a black figure within such a region, and the projector can cast the black figure over the real shadow consistently. Fig. 6 shows a modified coordination system in order to connect a local coordination system with a remote coordination system continuously. In this coordination system, two coordination systems can be used at the same time. That means, when a virtual shadow stretches at PlaceA toward remote PlaceB, the virtual shadow stretching from PlaceA can be in the coordination system A at PlaceB. While, when a virtual shadow stretches from PlaceB toward PlaceA, the virtual shadow can be in the coordination system B at PlaceA. In this way, a virtual shadow is cast consistently over a real shadow on the table at each site.

However, we feel a difference in image quality between a real shadow and a virtual shadow such as color, contrast and jaggy. In order to decrease the difference in quality we apply and implement a technique of projecting a virtual real shadow that is a size larger than a real shadow over the real shadow. The host computer generates the virtual real shadow from the video image of local tabletop. This is a different process comparing to generate a virtual shadow of a tool with 3D tracker, because attaching 3D trackers on all objects on the table is difficult and these virtual shadows need not to change dynamically. Fig. 7 shows the process of creating the virtual real shadow. At the first, CCD camera2 in Fig. 4 over the table captures a video of the local tabletop. Then, only physical objects and hands should be detected. However, it's difficult to detect only those physical objects not projected virtual shadow by binarizing the captured image simply. In order to remove

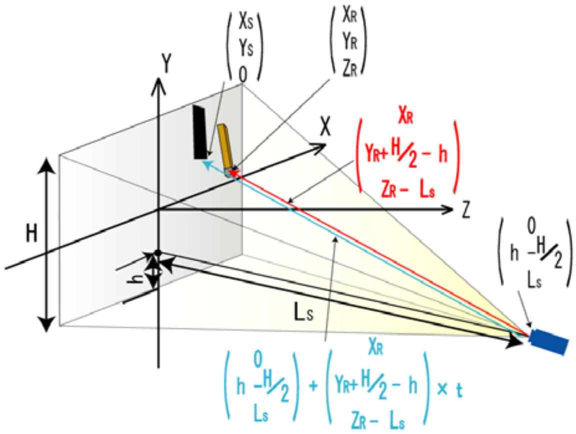



**Fig. 5.** A coordination system of the optical system

$$X_S = X_R \times \left(\frac{L_S}{L_S - Z_R}\right) \qquad \text{---(1)}$$

$$Y_S = \frac{L_S + \left(\frac{H}{2} - h\right) Z_R}{L_S - Z_R} \times Y_R \qquad \text{---(2)}$$

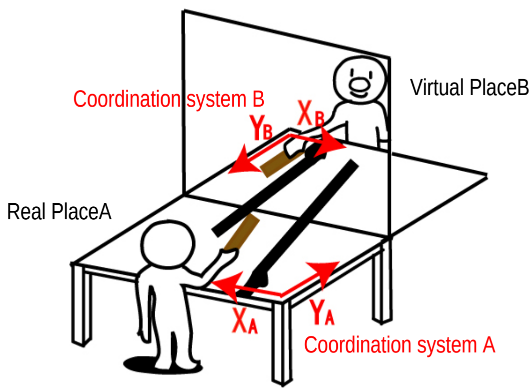



**Fig. 6.** A coordination system between two places

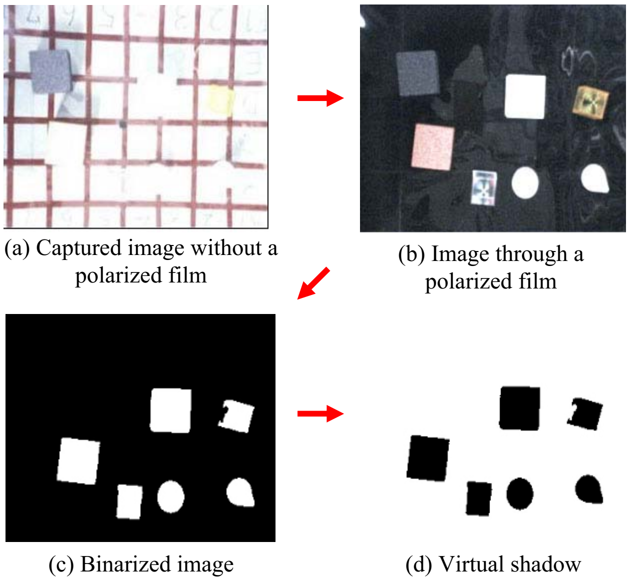

(a) Captured image without a polarized film
(b) Image through a polarized film
(c) Binarized image
(d) Virtual shadow

**Fig. 7.** The process of creating the virtual real shadow

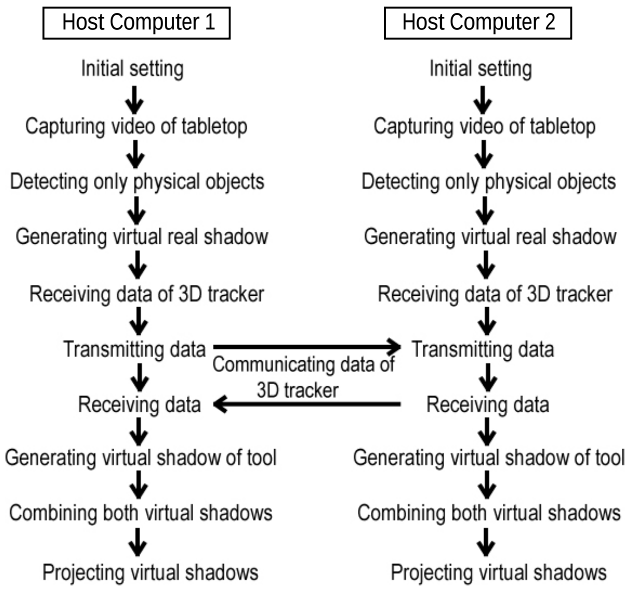



**Fig. 8.** The process of generating virtual shadow

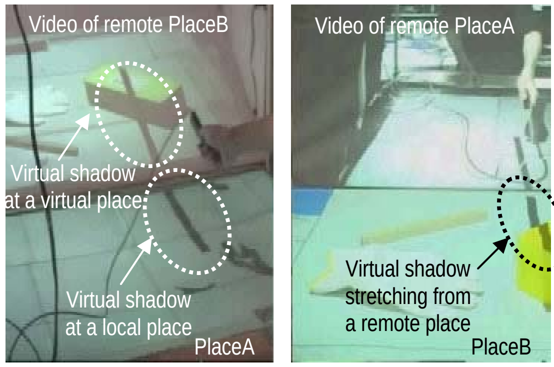



**Fig. 9.** Virtual shadow stretching toward a virtual place

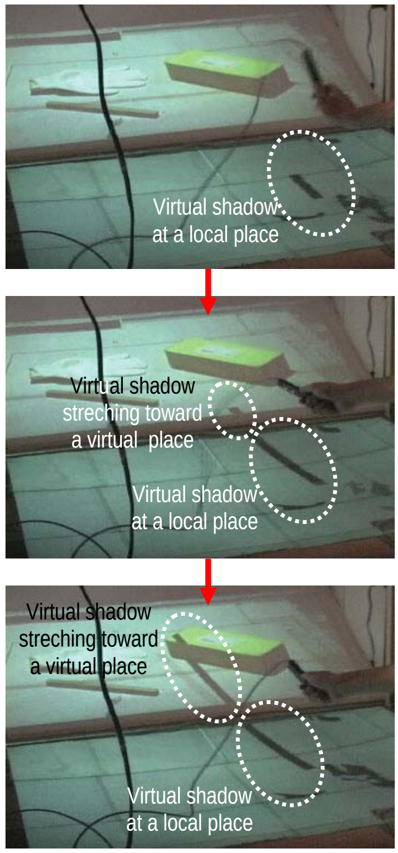



**Fig. 10.** Virtual shadow stretching according to shaking a stick

the projected virtual shadow, we put a polarized film in front of the CCD camera2 and on the table respectively. Therefore we can easily remove the projected image when just capturing as shown in Fig. 7(b). Consequently the virtual shadow is generated from the binarized image as shown in Fig. 7(c,d).

Additionally, a virtual shadow can change its size, color and can stretch according to an angular velocity when a user shakes a stick fast.

At the last, Fig. 8 shows a procedure of generating a virtual shadow at a local and at a remote site. At the beginning, CCD camera2 over the table captures a video of tabletop at each site. The image through a polarized filter is binarized to detect only physical objects. Then a virtual real shadow is generated from the image. At the same time, a virtual shadow of a stick is generated from position and posture of the tool with 3D tracker. At this time, angular velocity of the tool is calculated from the position data and the timer of host computer. When a mode that virtual shadow changes dynamically is chosen, the length of virtual shadow vibrates according to simple harmonic oscillation. Then, two remote host computers transmit the position data of the virtual shadow at each coordination system with each other. Consequently, local and remote virtual shadows, and local virtual real shadows are combined into one image, and then virtual shadows are cast over the each table. Fig. 9 shows a scene that the virtual shadow, connecting with a real shadow at local site and stretching toward a remote place, is projected. Then Fig. 10 shows a scene that the virtual shadow can change its length according to shaking a stick.

# 5. Various representations of virtual shadow

We had performance test on our two systems connecting with each other via LAN (100Mbytes/s). As a result, delay time when transmitting the position data of virtual shadow shows less than 1 [msec], and frame rate generating virtual shadow results 15-25 [fps]. Then the difference between virtual shadow and real shadow of a tool in hand is in error less than 2[cm].

We asked 6 adult students to experience various representations of virtual shadow. At the first, we focus on a relationship between a real shadow of our own hand and a virtual shadow of a tool. Then our system casts only a virtual shadow of the stick not the real shadow of own hand by installing a video projector under the horizontal screen instead of above. A mirror reflecting projected image is installed on the floor in order to make a distance between a screen and a projector. Fig. 11 shows a scene of removed real shadow. Participants reported, “they felt a sense of discomfort without own hand shadow”, “they felt own hand was separated from the virtual shadow”, and “they felt they handled a tool such as a laser pointer”. Although this is just a pilot study, these comments indicate that this representation without own hand’s shadow is insufficient to support a connectedness between real hand and a virtual tool. The shadow of own hand is required to connect between own hand and a virtual shadow continuously.

At the next step, only shadow including a real shadow of own hand and virtual shadow of a stick appears on the screen without seeing own real hand and a real stick. Then, participants handle the stick under the screen, and their shadows are cast on the screen from underneath. Fig. 12 shows a scene of this representation. Participants reported, “they felt that they hold such as a long stick as virtual shadow indicated”, and “they felt that the stick stretched toward a virtual space”. These comments indicate representation of shadow can support embodied interaction without seeing their real objects.

Then, in order to investigate an effect of virtual shadow on continuity of embodied interaction between a local place and a remote place, three virtual representations are cast over the stick on the table. Fig. 13 shows these three representations. Although each virtual image is projected beside a stick, it is intentional for easily viewable figure at this time. Fig .13(a) shows a long black figure. Fig. 13(b) shows a frame of a stick and Fig. 13(c) shows a pointer separated from a real shadow of a tool. At each condition, one participant uses the virtual shadow tool to instruct another remote participant on how to move an object on the table. When a black figure was projected over the tool, participants reported “they felt that they stretched toward a remote place”, “they felt it's easy to direct to an object and to indicate the location.”, and “they felt that a long shadow was projected as if they had a long stick”. When a frame was projected over the stick, participants reported “they felt it's easy to direct to an object and to indicate the location”, and “they felt that they easily looked at the virtual tool”. When the pointer is projected, participants reported, “they didn't feel that they connected toward a remote place”, and “they had difficulty to indicate to a remote participant”. From these comments, we can find a sense ,as if own tool stretched out toward a remote place, is enhanced by representing a continuous image connecting with a real tool rather than by representing a pointer image separated from a real shadow. Especially, some of participants reported such a sense of expansion of a tool was enhanced when projecting a black figure comparing to when projecting a frame image. We assume that it is influenced by that they felt the “shadow” not just a black figure was cast on the table.

Additionally, participants experienced another

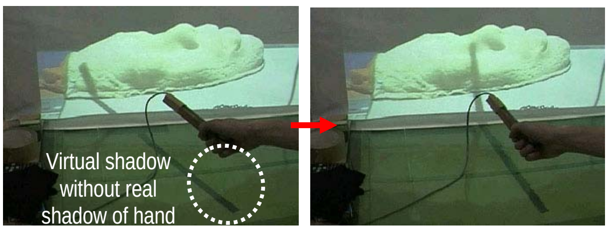



**Fig. 11.** Projecting only a virtual shadow of the tool not the real shadow of own hand

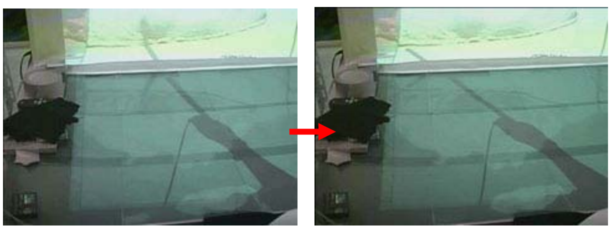
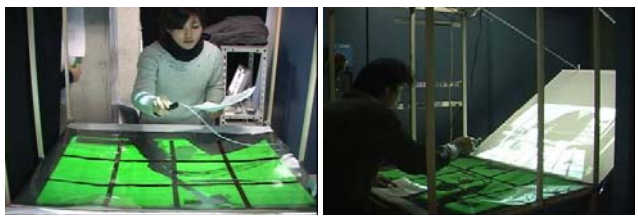


**Fig. 12.** Projecting only a shadow without seeing real hands and a tool

(a) Black figure (b) Frame (c) Pointer

**Fig. 13.** Three representations casting over the stick

(a) A participant sees a streching virtual shadow of a remote stick.



(b) A prticipant uses a virtual shadow tool and give an instruction.

**Fig. 14.** A scene of communication employing virtual shadow system

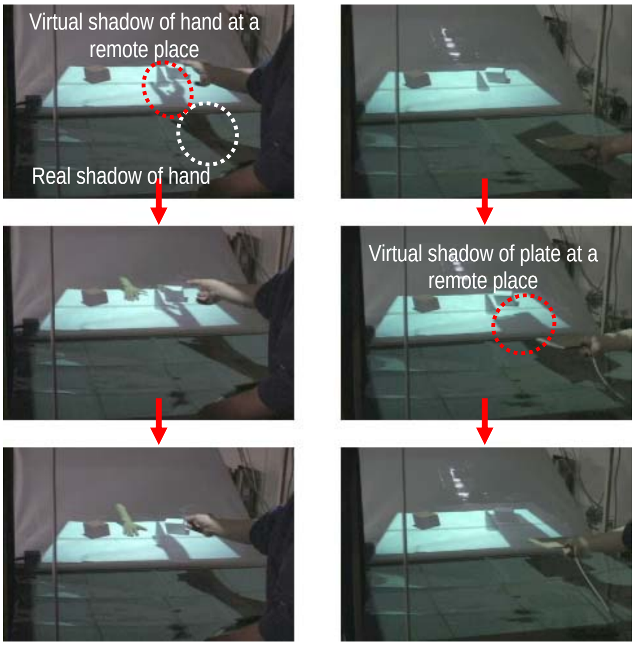
representation that a virtual shadow changes dynamically according to bodily action, such that a virtual shadow stretches out when they shake a stick fast as shown in Fig. 10. The stretching shadow remains the longest for 5[sec], after that the length of shadow goes back to normal. They experienced the same task as described above under two conditions; a stretching shadow and a stretching frame. When the shadow changes according to an angular velocity of shaking the stick, they reported "they felt that a feeling that a tool was stretching was enhanced comparing to representation of virtual shadow the length of which is fixed", and "it's easy to indicate after they get used to use". Then remote participants reported "they could anticipate their indication through the motion of virtual shadow". When the frame image changes according to swinging a stick, some reported "it's easy to indicate after they get used to use", and other reported "it's hard to indicate using this tool". Then remote participants reported "they felt something strange was stretching toward to them, that was not a tool", and "the reality of the image was weak". These results indicate dynamic changing representations according to bodily action influence a sense of expansion of a tool or own body rather than the fixed representation.

At the last, we devise a various representations of virtual shadows in order to investigate the capability of our system. Fig. 15 shows scenes of several representations of virtual shadows. Fig. 15(a) shows that shadow of own hand can stretch toward a virtual remote place. Participants reported "they tried to hold a remote object", and "they felt their hands become larger and longer". Fig. 15(b) shows that shadow of a plate appears on the table. Our system can change a size of the virtual shadow dynamically.

These preliminary results indicate that our system may be capable of supporting an embodied interaction from own local place and a virtual remote place seamlessly by casting virtual shadow. However, as this is a small-scale pilot study, further experimentation is required to validate these observations.

# 5. Conclusion

There is considered a problem of disembodiment in computer-mediated communication technology supporting a communication between remote partners. Therefore, it is required that a design approach to support whole sense of embodied interaction between remote communication partners. However, previous communication systems have not been developed in the view of supporting such embodiment. In this paper, we pay attention on a shadow non-separable from a real object on the basis of expansion of body image, and devise a virtual shadow interface system that casting a virtual shadow over a real shadow of the physical object in an accurate position ,and on the virtual remote place seamlessly from local place. A pilot study of various representations examined the effect of virtual shadow on a sense of connectedness between the virtual tool and own body, and between a local place and a virtual remote place. Preliminary results are encouraging, indicating that our system is promising to bridges between a tool and own body, and between a physical place and a virtual remote place.




(a) Virtual shadow of hand (b) Virtual shadow of plate

**Fig. 15.** Various representations of virtual shadow

# Acknowledgements

This research is supported partially by a Grant-in-Aid for the WABOT-HOUSE Project by Gifu Prefecture. The authors would like to thank Tomofumi Katayama and Takabumi Watanabe for their helps.

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