Consistent Desktop Sharing Based on Document Coordinate System for Face-to-face Online Meeting

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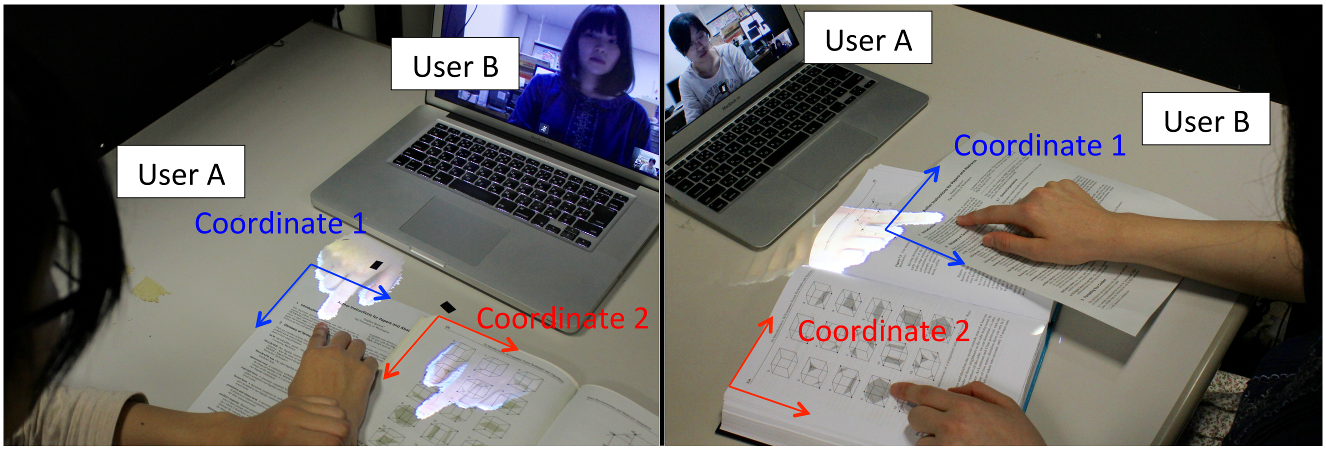

Figure 1: *The appearance of documents are transferred to the counterparts while the placement of the documents are not consistent.*

1 Introduction

Remote physical desktop sharing system has been widely studied in interactive surface research field to support distant collaborative works [Ishii 1990; Junuzovic et al. 2012; Higuchi et al. 2015]. Basically, the appearance of a work space on one site is captured by an overhead camera, and overlaid with that on the other site, and vice versa. Consequently, the users in the both sites share the same graphical information on their desktops. For example, in a remote education system, an educator writes an annotation on a projected document image to provide an instruction to a remote student, which is visually overlaid on the physical counterpart on the student site. One of the significant advantages of such systems is that users can visually share not only their documents or books but also context or non-verbal information such as the gestures of their hands and pens. Sharing the gestures enhances social telepresence, which is an important sense to resemble face-to-face interaction[Finn 1997]. Enhancing social telepresence psychologically makes the physical distance between remote people shorter[Tanaka et al. 2014], and mutual awareness higher[Garrison et al. 1999].

Several graphical overlaying methods have been explored so far. For example, desktop appearances are overlaid each other in computer monitors [Ishii 1990], or projected onto the physical desktops [Junuzovic et al. 2012]. The previous techniques basically assume that the appearances of physical desktop surfaces are directly overlaid without any modifications. That is to say, desktops are shared based on the desktop coordinate systems. This implicitly assumes that same documents or books are placed at the same positions and orientations on the both sites. Therefore, once a document is even slightly moved, the desktops are no longer correctly shared, which makes the collaborative works harder (Fig. 2, left).

Compared to these physical desktop sharing systems, virtual document sharing systems such as Google Docs are generally based on the browser (or window) coordinate system, such that users can consistently share a document while they place their windows at different locations in their desktops which are shown on monitors of even different resolutions. In this research, we propose to introduce this concept to a physical desktop sharing environment, such that a document appearance on one site is geometrically aligned and projected onto the same document surface on the other site as shown in Fig. 1. In other words, the appearances of documents/books on the desktops are shared based on each document coordinate system as shown in the right figure of Fig. 2. This paper shows the technical details of the system such as computer vision-based document matching, thermo vision-based hand detection, and spatially consistent graphical representation of projected body image transition between documents. We also introduce a prototype system and some results from our proof-of-concept experiment.

2 Consistent Desktop Sharing Based on Document Coordinate System

Our proposed system on each site consists of an RGB camera, far-infrared (FIR) camera, and a projector which are all installed so that they face down to a desktop surface. In addition, a virtual face-to-face environment is realized by placing a flat panel display and a web-cam. This section describes the technical details of the proposed method.

2.1 Desktop Appearance Transfer

To realize desktop sharing based on document coordinate system, we apply a computer vision technique to recognize the position and orientation of same documents on both sites. In particular, we apply

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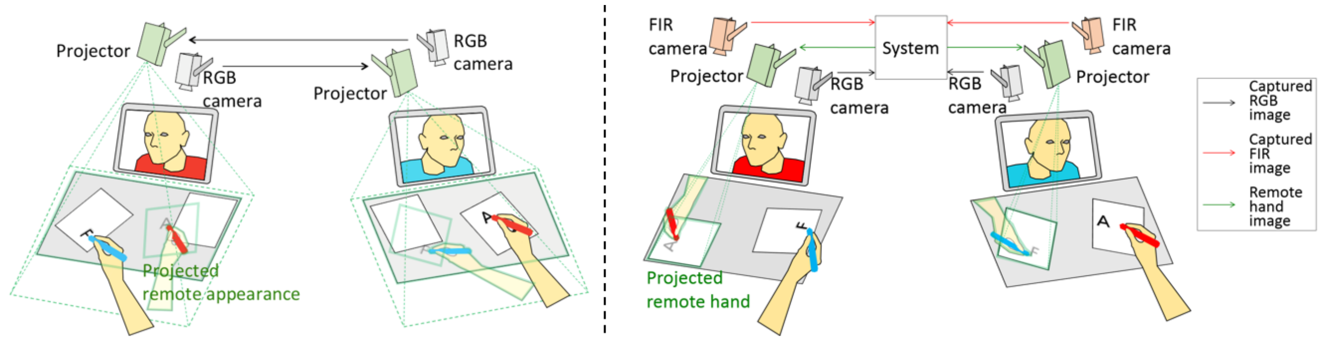

Figure 2: *Previous sharing technique (left) and proposed concept (right).*

SIFT feature descriptor to captured images of desktop surfaces by the RGB camera. Then, the appearance on and above the document in one site is transferred to the other site, and projected onto the corresponding document surface with an accurate geometric alignment using homography transformation. We empirically confirmed that the recognition did not fail even when a certain amount of annotations or drawings is physically written or projected onto a document.

2.2 Hand Region Transfer

Hand gestures are important non-verbal cues in remote collaborations. We extract a hand region from a captured image on one site and transfer it to the other. We apply the FIR camera to extract hand region using heat information [Koike et al. 2001] because the extraction using the RGB camera fails by the interference of projections. We then extract the corresponding region of an image captured by the RGB camera.

We regard the farthest point of the hand region from a user body as a fingertip or pen point position. To increase the sense of face-to-face collaboration, we rotate the transferred hand region 180 degrees around the fingertip or pen point so that the projected hand is extended from a collaborator displayed on the flat panel display.

2.3 Hand Transition Between Documents

In our desktop sharing environment, the places of shared documents are possibly different. For example, document A and B are respectively placed on the left and right areas of the desktop on one site, while the layout is switched on the other site. In such cases, when a user's hand is moved from the document A to B on one site, the projected hand on the other site suddenly jumps between two documents. This would decrease the sense of presence. To solve this issue, we gradually moves the projected hand graphics when it moves between two documents.

3 Demonstration System

Our proof-of-concept demonstration system consists of two sets of a RGB camera (PointGrey FL3-U3-32S2C-CS), a FIR camera (MITSUBISHI IR-SC1H), a projector (Acer X1161P), a flat panel display and a web-cam (Apple MacBook Air (11-inch, Mid 2012), Apple MacBook Pro (15-inch, Early 2011)). A workstation (Intel Core i7-4770K CPU) controls all the components and simulate distant communication on it. As shown in the supplementary video, our concept works well. The appearance of documents are successfully transferred to the counterparts even when the placement of the documents are not consistent. Projected hand images also move smoothly between shared documents. We confirm that the proposed method provides a better collaborative environment where users can freely place their shared documents on their desktops without any constraint.

4 Conclusion

To the best of our knowledge, this is the first work that realizes a physical desktop sharing environment where a document appearance on one site is geometrically aligned and projected onto the same document surface on the other site. The appearance of documents are successfully transferred to the counterparts while the placement of the documents are not consistent. Projected hand images also move smoothly between shared documents. As a result, we confirm that the proposed method provides a better collaborative environment where users can freely place their shared documents on their desktops.

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