PROVIDE "OUT TOGETHER FEELING" BY SHARING PANORAMA LIVE IMAGE BETWEEN OUTDOOR AND INDOOR USERS

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Abstract. We have previously described the Out Together Feeling as when two people, one indoors and the other outdoors, share an experience as though they were both outdoors together. Here, we describe a video-based communication system called WithYou2, which was developed to provide the Out Together Feeling equally to both indoor and outdoor users. Using WithYou2, the indoor user wears a head-mounted display (HMD) and watches live video captured by a 360º panoramic camera mounted on the outdoor user's shoulder. Thus, the indoor user can look around by simply turning his or her head. The outdoor user wears a partially transparent HMD and can see the image that the indoor user sees. We describe the results of field tests to evaluate the WithYou2 system, which showed that both users experienced the Out Together Feeling to a greater extent than with the WithYou system.

1. Introduction

We have previously reported a system called WithYou (Chang *et al.*) intended to provide the *Out Together Feeling* to an indoor user and an outdoor user. We have described the Out Together Feeling as the experience of two people at different locations feeling as though they were together. In other words, it makes a pair of users, one outdoors and the other indoors, experience a sense of doing something together, which entails a telepresence technology for use in outdoor environments.

In our previous work, we defined three basic elements that are necessary for the Out Together Feeling:

1. The indoor user must be able to freely and naturally peruse the surroundings of the outdoor user.
2. Each user must be able to perceive where the other user is looking without vocal cues.
3. Communication via gestures must be supported.

The WithYou system has functions corresponding to these three basic elements. First, the indoor user wears a head-mounted display (HMD) and watches live video from a pan/tilt/zoom (PTZ) camera mounted on the outdoor user's chest. The indoor user can look around by simply turning his or her head. Second, the indoor user can know where the outdoor user is looking by checking the orientation of the outdoor user's face, which is displayed on the HMD. The outdoor user can also determine where the indoor user is looking by checking the direction of the PTZ camera.

Using WithYou system, we observed that the outdoor user did not experience the same level of Out Together Feeling as the indoor user. We attributed this to the following factors:

1. Less information is sent from the indoor user to the outdoor user. For example, the outdoor user cannot see images and gestures of the indoor user. Additionally, in our early evaluation, many subjects claimed that adding a "face-to-face" feature may enhance the Out Together Feeling.
2. The outdoor user can roughly determine the direction in which the indoor user is facing by checking the camera mounted on his/her chest. However, the outdoor user found it difficult to accurately determine where the indoor user was looking.

The purpose of the present work was to design and implement new methods of interaction that may provide an enhanced and more equal level of the Out Together Feeling.

2. Related work

There have been a number of reports of communication via wearable robots. For example, Tsumaki *et al*. proposed and developed a wearable robotic system called Telecommunicator that allowed a local-site user to communicate with others at a remote site. Telecommunicator is a wearable robotic device mounted on the user's shoulder that consists of a pan-and-tilt video camera and a simple arm. The local-site user wears an HMD and controls a camera mounted on the remote site user by turning his or her head. Live images are displayed on the HMD at the local site. In our work, we focus on the direction in which both users are facing to allow enhanced

communication between them. Additionally, with our system, users may look at each other using the video cameras.

3. The WithYou2 System

To address the shortcoming of WithYou, we designed and implemented a system called WithYou2. It provides the following functionality for interaction between the indoor and outdoor users. These functions correspond to the three basic elements of the Out Together Feeling.

3.1. FREE VIEWING FOR BOTH INDOOR AND OUTDOOR USER

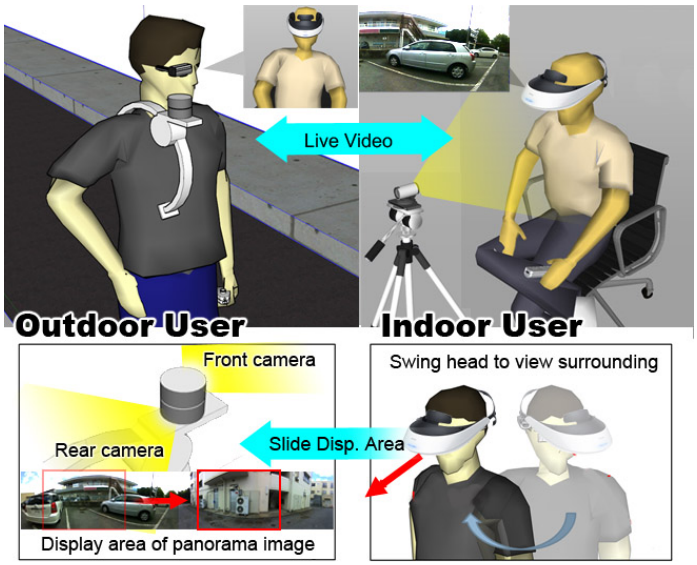

Figure 1. System Overview.

The indoor user wears an HMD and can view 360º panoramic live video images from two cameras placed on the outdoor user's shoulder. By turning his/her head, the indoor user can look at the remote user's surroundings, as shown in the bottom part of Figure 1. The outdoor user's face and an image of what s/he sees are displayed on indoor user's HMD.

The outdoor user wears a partially transparent HMD and can see an image of the indoor user, which is captured from a camera placed in front of the indoor user. There are two viewing modes for the outdoor user:

1. Indoor user view mode. This mode shows the image that the indoor user is currently viewing via his/her HMD. In this mode, the outdoor user can clearly see what the indoor user is looking at.
2. Indoor user face mode. This mode shows the face and gestures of the indoor user, which enables gestural communication between users.

3.2. GRAPHICAL USER INTERFACE (GUI) ON THE HMD

The indoor/outdoor user's HMD screens also display some graphical information of the remote user. Figure 2 is the indoor user's HMD screen, which displays the following information:

1. The direction in which the indoor user is facing (the dark red pie in the white circle).
2. The direction in which the outdoor user is facing (the white point on the red arc).
3. The outdoor user's image(left-top) and his/her view(left-bottom).
4. Other information such as which user is controlling the camera, the focus status of each user, and system messages.

Figure 2. GUI on the indoor user's HMD screen.

3.3. INTERACTION METHODS IMPROVED FROM WITHYOU

In WithYou2, both users can see the face and gestures of the other user. WithYou provided several "gesture" functions that enabled both users to transmit sound messages to the remote user by pressing a button. However, in field trials, these functions were not found to be as helpful as was anticipated. The outdoor user commonly performed hand gestures that could be viewed remotely by the indoor user. In WithYou2, the outdoor user can also view the indoor user's gestures and face. Thus, bi-directional gestural interaction can be achieved using WithYou2.

It is also important for both users to know where the other user is facing. Using WithYou, the outdoor user guessed where the indoor user was looking by looking at the PTZ camera mounted on his or her own chest, which was not very accurate. Using WithYou2, the outdoor user can select the view mode that shows the current video image from the 360º panoramic camera that is shown on the indoor user’s HMD. This enables the outdoor user to know exactly where the indoor user is looking.

Another important function of our system is recognition of joint attention. Here, joint attention means that both users focus on the same object or location. Thus, before recognizing joint attention, the system must recognize whether each user is focusing on something. We recalibrated the threshold of the focusing state and the rules defining join attention. In WithYou, we assumed a user was in "focusing" mode if his or her gaze remained static for more than 2 seconds. When one user entered focusing mode, the system sent a notification to the other user and played a sound. This provided a hint of the partner’s actions. In WithYou2, when one user is in focusing mode and the other is facing the same direction (even without entering focusing mode), the system recognizes this situation as joint attention and sends a notification to both users.

4. Implementation

The WithYou2 system consists of two parts, the outdoor user's device and the indoor user's device, and they communicate via a network (e.g., the Internet).

4.1. WEARABLE DEVICE OF THE OUTDOOR USER

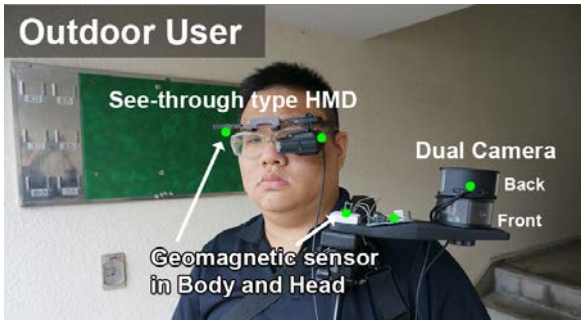

Figure 3. Wearable device of the outdoor user.

The outdoor user wears a partially transparent HMD, as shown in Figure 3. Two geomagnetic sensors are used (one for the body, the other for the head),

and two 180º wide-angle cameras are mounted on the outdoor user's shoulder. He also carries a laptop computer on his back. The outdoor user holds a wireless hand controller to operate the system, allowing him or her to implement functions, including changing the view mode.

4.2. WEARABLE DEVICE OF THE INDOOR USER

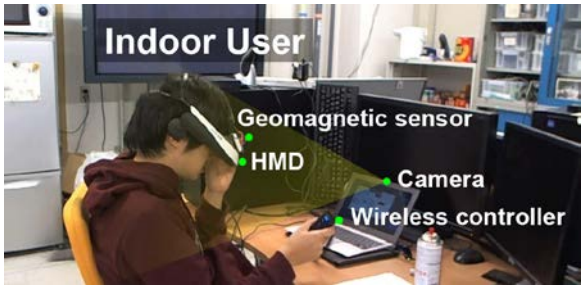

Figure 4. Wearable device of the indoor user.

The indoor user wears an HMD, as shown in Figure 4, and holds a wireless hand controller. A geomagnetic sensor is mounted on the HMD to measure the horizontal direction of the indoor user's face. This direction is linked to the viewing area of the panoramic live images sent from the cameras on the outdoor user's shoulder. Additionally, a camera is placed in front of the indoor user to capture his or her face and gestures.

5. Evaluation

The aim of this experiment was to determine the effectiveness of interaction methods in our system, and also to assess users' experience of the Out Together Feeling compared with our previous work.

We evaluated the system in the electrical shopping district in Akihabara. During the experiment, subjects were asked to buy something by conversing with the remote user, and they were told to use the system freely to achieve their goals.

5.1. METHOD AND CONDITIONS

Seven subjects (six pairs by two examinees reversed their roles) participated in this experiment. One user in each pair (the outdoor user) went outside and walked around while the other user (the indoor user) remained indoors. Prior to commencing the task, the subjects practiced using the system for 10 minutes. The task in this experiment was to buy something interesting, and the subjects had 20 minutes to achieve the task. The indoor user could ask

the outdoor user to enter to a store, pick something up, and then show it to the camera.

The indoor user's system was connected to a wired LAN, and the outdoor user's system was connected to a long-term evolution (LTE) wireless network in the street. The outdoor user used a cell phone to communicate verbally with the indoor user, and the indoor user used Skype to communicate with the outdoor user's cell phone.

5.2. RESULTS

TABLE 1. Selected Questionnaire and responses. Scores were on a scale from 1 to 5, where 5 indicates strong agreement and 1 indicates strong disagreement. The mean scores are shown.

Question		Indoor user	Outdoor User
Q1	I felt a sense of Out Together Feeling with my remote partner.	4.2	3.75
Q2	I was able to see the face of remote user	4.6	4.25
Q3	Do you think that looking the face of remote user improves the Out Together Feeling with remote user?	3.8	3.25
Q4	Do you think that notification of focus status and joint attention improves the Out Together Feeling with remote user?	3.6	3.25
Q5	I was able to determine the direction in which the remote user was facing.	4.4	3.0
Q6	Did you notice the gestures performed by remote user?	3.4	3.5
Q7	Did you understand the information displayed on the GUI?	4.6	3.75
Q8	Did you feel the field of view was sufficiently wide?	4.8	N/A
Q9	Were you able to determine what the indoor user was looking at?	N/A	4.7

Table 1 shows the results of the questionnaire. The answers to Q1 showed that both users felt a sense of Out Together Feeling to a greater extent than with the WithYou system. However, the results also showed that indoor users experienced the Out Together Feeling to a greater extent than the outdoor users did.

The scores for Q2 indicated that both users were able to see the face of the other. The scores for Q3 indicate that the indoor users felt that it was useful to be able to see the direction in which the other user was facing. However, the outdoor users gave this function a lower score. One reason for this is that the outdoor user could not see the indoor user's facial expressions because the indoor user was wearing a HMD.

The scores for Q9 indicated that the outdoor user was able to effectively determine what the indoor user was looking at. Furthermore, the scores for

Q7 showed that the graphical information (i.e., GUI) displayed by WithYou2 was easy to understand. The scores for Q8 suggested that the panoramic video images helped the indoor users to experience the remote environment of the outdoor user.

We provided view modes that allow the indoor and outdoor users to see each other. Selected detailed user feedback from Q3 is shown in Table 2. Both the indoor and outdoor users felt that the "see each other's face" mode provided only a limited enhancement of the Out Together Feeling. This may be because the outdoor user sees an image of the other person wearing an HMD, and he or she cannot see the facial expressions of the indoor user.

TABLE 2. Selected user feedback (related to Q3).

Participant	Answer
Indoor user	I could see the image of outdoor user by checking the top-left area of the GUI; however, my attention was focussed on the main image, and I did not have time to look at the outdoor user.
Outdoor user	I felt the indoor user's presence when I first saw the image; however, I cannot see the expressions of indoor user clearly, and it felt no different from a static image.

Conclusions

We have described the design and implementation of a system called WithYou2, which provides an enhanced and more equal level of the Out Together Feeling compared with our previous system, WithYou, both for the indoor and outdoor users. We carried out a field test of our system, which was evaluated positively by the participants, and were able to overcome many of the shortcomings of the previous system.

References

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