Empathic Mixed Reality

Sharing What You Feel and Interacting with What You See

Thammathip Piumsomboon[1], Youngho Lee[1,2], Gun A. Lee[1], Arindam Dey[1], Mark Billinghurst[1]
[1]University of South Australia, Mawson Lakes, Australia
[2]Mokpo National University, Jeonnam, South Korea
Thammathip.Piumsomboon@unisa.edu.au, Youngho@ce.mokpo.ac.kr,
Gun.Lee@unisa.edu.au, Arindam.Dey@unisa.edu.au, Mark.Billinghurst@unisa.edu.au

***Abstract*—Empathic Computing is a research field that aims to use technology to create deeper shared understanding or empathy between people. At the same time, Mixed Reality (MR) technology provides an immersive experience that can make an ideal interface for collaboration. In this paper, we present some of our research into how MR technology can be applied to creating Empathic Computing experiences. This includes exploring how to share gaze in a remote collaboration between Augmented Reality (AR) and Virtual Reality (VR) environments, using physiological signals to enhance collaborative VR, and supporting interaction through eye-gaze in VR. Early outcomes indicate that as we design collaborative interfaces to enhance empathy between people, this could also benefit the personal experience of the individual interacting with the interface.**

Keywords—empathic computing; mixed reality; collaboration

I. Introduction

Today, we are witnessing technology trends where machines are beginning to realize people's emotions and thoughts, a rapid growth in communication infrastructure with increasing bandwidth and pervasiveness, and advances in hardware that can capture people and their environment. An emerging field that stands at the center of this convergence is Empathic Computing. Empathy, as described by Alfred Adler [3], is "seeing with the eyes of another, listening with the ears of another, and feeling with the heart of another". So, Empathic Computing is a research field that explores how technology can create deeper understanding or empathy between people. Empathic Computing systems are enabled by a combination of natural collaboration, capturing of user experience and their surroundings, and the capability for implicit understanding of user emotion and context, as illustrated in Figure 1.

Mixed Reality (MR) as introduced by Milgram and Kishino [2], blends real and virtual worlds along the reality-virtuality continuum, shown in Figure 2. Both MR and Virtual Reality (VR) can provide an immersive experience in either real or virtual environments. Being in a 3D environment means that a person can make use of their natural ability for spatial interaction. Well-designed interfaces could potentially make interaction and collaboration inside such systems more natural, effective, and engaging.

The affordances of MR and VR interfaces align well with the requirements necessary for Empathic Computing. Firstly,

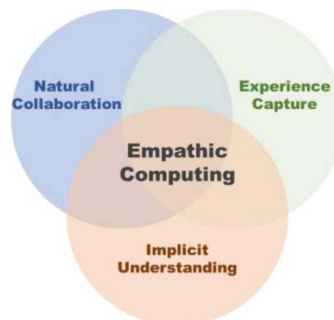

Fig. 1. Empathic Computing combines Natural Collaboration, Experience Capture, and Implicit Understanding [1].

MR and VR naturally support collaboration in three-dimensional real or virtual environments. Secondly, MR and VR are highly personalized platforms which make it easier to capture personal data such as user's gaze, movement, and physiological data. The user's environment can also be captured using spatial mapping and imaging technology, providing the context. With all this information combined, a system could be developed that could potentially identify a user's thoughts and state of mind. Lastly, the variety of data captured could also be shared and reproduced with a remote person, enabling them to feel as if they are there with the local user.

In our research, we have begun exploring the applications of MR and VR to Empathic Computing. In this paper, we present a summary of findings from selected studies. The sections that follow include research in collaborative interfaces that share where you gaze (section 2), interfaces that share how you feel (section 3), and those that support an interaction with what you see (section 4). Finally, in section 5, we conclude and share our thoughts on future research.

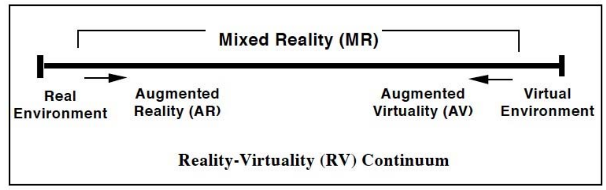

Fig. 2. Milgram and Kishino's Mixed Reality on the Reality-Virtuality Continuum [2]

978-1-5386-3091-4/17 $31.00 © 2017 IEEE
DOI 10.1109/ISUVR.2017.20

II. SHARING WHERE YOU GAZE

In a face-to-face collaboration, collaborators can determine each other's focus of attention through their face direction and eye gaze. In case of remote collaboration, we have been studying the effect of sharing gaze and other cues for communication.

A. Gaze and Pointer in Asymmetric Collaboration

To explore if sharing gaze could improve asymmetric collaboration, we created a wearable Augmented Reality (AR) system combining eye tracking, a head-mounted display (HMD), and a head-worn camera (HWC) [4]. A local worker wore this AR system, while a remote helper watched the video feed from the HWC on a desktop computer and interacted with the local worker using speech and pointing cues. We conducted a user study comparing four conditions; (1) sharing the helper's pointer, (2) sharing the worker's gaze, (3) sharing both pointer and gaze, and (4) sharing none of these cues. A block assembly task was used in the study, where the local worker assembled physical building blocks with an assistance of the remote helper who gave instructions. It was found that sharing both the eye-gaze from the worker and pointer cues from the helper improved co-presence and collaborative performance.

B. Gazes, FoV, and Gestures in Symmetric Collaboration

Most collaborative AR and VR systems focus on collaboration between users in either only AR or VR situations. We are interested in the collaboration between AR and VR users where they can experience a single shared space and collaborate on real-world tasks. There are many possible applications of this type of system such as emergency response, remote maintenance, education and others. For this reason, we created CoVAR, one of the first systems to combine Augmented and Virtual Reality technologies for room-scale collaboration (see Figure 3). CoVAR explores the use of several different awareness cues to inform users of what their collaborators are doing and where they are looking. These include showing head gaze, eye gaze, field-of-view (*fov*), and head and hand gestures.

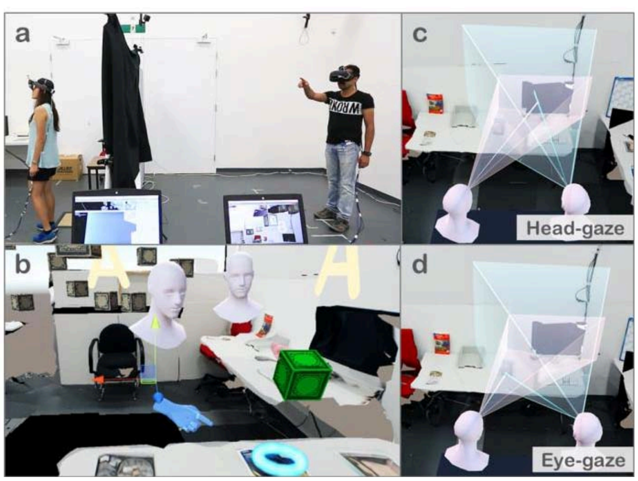

Fig. 3. a) CoVAR setup with AR user on the left and VR user on the right, b) third person view from within the simulation showing avatar's bust and hands rendered in a reconstructed environment, c) head-gaze and *fov* cues, d) eye-gaze and *fov* cues.

Fig. 4. a) Real-world space on the AR user side, b) reconstructed space on the VR user side.

In CoVAR, a person wearing an AR HMD can see a virtual representation of their remote partner in the real world beside them. Similarly, the remote partner uses a VR display to see a virtual copy of their partner. We conducted a study to compare three cues: *fov*, eye-gaze, and head-gaze against a baseline condition showing only virtual representations of each collaborator's head and hands. The study uses a collaborative object finding and placing task, called "Gaze and Place", where users had to search for tagged virtual blocks in an AR or VR interface and try to look at and move the same block. Our results show that awareness cues significantly improved user performance, usability, and subjective preferences, with the head-gaze cue being most beneficial. We also found that with a *fov* cue, VR users could empathize with the AR user, who had limited vision of the virtual workspace. This work establishes the feasibility of room-scale cross-platform collaboration and identifies the utility of providing collaboration cues in such systems.

C. Capturing and Sharing What You See

The key advantage of a mixed platform collaboration between AR and VR, is being able to share the real-world environment in 3D from the local AR user to a remote VR user. A crucial component of the CoVAR system, is to be able to share a reconstruction of the AR user's environment to the VR user. In the study described in subsection 2C, a 3D reconstruction of the AR user's space was completed offline using the Microsoft HoloLens depth sensing capability. The result comparing the real world and virtual reconstruction is shown in Figure 4. By capturing and sharing the workspace reconstruction to the VR side, the VR user could understand and use the spatial information to better collaborate with the local AR user as if s/he was there. For example, we found that with a wide *fov* VR display, the VR user also possessed a greater peripheral vision of the virtual workspace than the AR user who have limited vision due to a smaller *fov* of HoloLens optical see-through display used. At the time of this writing, we are adding support to CoVAR for real-time reconstruction and data sharing with the remote user. This would benefit the remote user greatly in a dynamic environment where constant changes of the surroundings are to be expected.

III. SHARING WHAT YOU FEEL

Beyond gaze and gesture cues, that enhance the performance and feeling of presence in remote collaboration, Empathic Computing also seeks to share a user's state of mind

Fig. 5. A local worker wearing Empathic Glasses and a remote helper using a desktop computer [6].

to improve empathy among collaborators. In this section, we present early research that look into sharing emotions and physiological cues in AR and VR.

A. Capturing Gaze and Emotions with Empathic Glasses

We developed the Empathy Glasses [5-7] which combined wearable facial expression capture hardware, eye tracking, a HWC, and a HMD, to enable a user to see, hear and feel from another person's perspective (see Figure 5). This system allows a user to share their point of view, gaze information and facial expressions with a remote collaborator (See Figure 6). A local worker wears the Empathy Glasses and streams live video, gaze information and face expression to a remote user on a desktop computer. The remote user can use mouse pointing and speech to communicate back with the remote user.

A user study was conducted to compare four conditions; (1) video sharing only, (2) video, gaze, and pointer, (3) video and facial expression, and (4) all cues combined. This study also use a block assembly task where the local worker assembled physical blocks with the help from the remote helper. Users rated the combined interface highest in term of preference for communication and ability to understand their partner's feeling. This work indicated that sharing both gaze and emotional cues could significantly enhance shared user experiences and provided early evidence supporting the value of research in Empathic Computing.

Fig. 6. Remote helper's screen view showing local worker's workspace, gaze, emotions (facial expression), heart rate, and GSR in real-time [5].

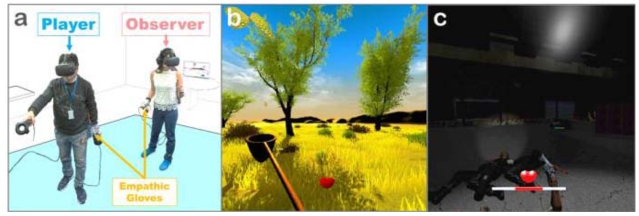

Fig. 7. a) Shared VR study setup showing player and observer co-located in the same space, b) calm butterfly game, c) scary zombie game.

B. Sharing Physiological Cue in Collaborative VR

Apart from sharing emotions, we also explore sharing physiological cues. For this, we created an immersive collaborative VR experience where two players were co-located sharing the same position with an independent head orientation, and an added physiological cue of heart-rate, see Figure 7 [8]. One person was an active participant in the virtual environment (the "player"), while the second participant was an observer watching what the player was doing.

The motivation was to explore how using a shared viewpoint and simple physiological cue, such as heart-rate, can increase the feeling of connectedness and enhance the experience between a player and observer in a collaborative VR. For our exploratory study, we created two games with different contexts, a calm butterfly catching game, and a scary zombie shooting game, as shown in Figure 5b and 5c. We shared the player's heart-rate with the observer through visual and audio cues. We found that the gaming experiences had a strong influence over the heart-rate cue, The shared heart-rate condition was overall preferred subjectively, but the effect was not significant with the current setup and the number of participants that we had. We believe that by combining the information from the physiological interface and the context of the event in the game, the player states of mind could potentially be empathized by the observer.

IV. Interacting with What You See

In the previous sections, we described how sharing gaze, emotions, and physiological cue, can enhance remote collaboration. These inputs were used primarily for enhancing communication experiences between remote collaborators. However, these natural and implicit inputs that we subconsciously use in communication could also improve single user interaction's as well. In this section, we give examples of how eye-gaze can be used for interaction.

A. Collaborative Gaze

An example of using head or eye gaze for interaction in a remote collaboration was demonstrated in CoVAR where both AR and VR users worked together and gazed at the same target object to reveal hidden information. Gaze in this scenario served as a communication cue through a visual representation of a virtual gaze ray to the collaborator and an interaction method for selecting the object that the ray intersected. This coupling of communication and interaction input could potentially reduce the cognitive load of users.

B. *Natural Eye-gaze-based Interaction*

Eye-gaze is typically used for target acquisitions and to solve Midas touch problem of selecting everything seen, dwell time to indicate the user's intention for selection. In our research into designing interfaces around natural eye movements [9], we designed three novel interaction techniques; (1) Duo-Reticles, (2) Radial Pursuit, and (3) Nod and Roll.

Duo-Reticles (DR) is inspired by natural eye saccade movement. This eye-gaze selection method is based on the alignment of the current eye-gaze position and an inertial reticle position that follows but lags the current gaze point. Until the user gazes at the inertial reticle, object selection cannot happen, eliminating the time pressure exerted by using dwell time for selection. Radial Pursuit (RP) is another selection technique used when the scene is cluttered with objects. With RP, as user gazes at a group of cluttered objects, those objects expand outward away from the gaze point so that user could pursue the target object with eye gaze for selection. It takes advantage of smooth pursuit eye movement where our eyes naturally and continuously follow a moving target. Nod and Roll (NR) is a head-gesture-based interaction based on the vestibulo-ocular reflex (VOR). When we fixate our gaze on a target, as we move our head around, the VOR keeps our eyes on the target. We showed that VOR could be used with head gestures such as nodding and rolling for virtual object interaction.

We conducted a preliminary user study comparing DR and RP methods to a baseline gaze-dwell technique. We found that user performance was the same for all techniques, but user's subjectively preferred DR over gaze-dwell, and RP was more satisfying and less tiring to use than gaze-dwell. As for NR, users said that it was fun to use but should not to be used for a long period of time. With this outcome, we have shown the potential benefits of using eye-gaze beyond a communication cue and toward an implicit understanding of user's intention.

Empathic Computing increases empathy among people through enhanced communication cues. Using the same input as the communication cue, we also showed that it is possible to design novel interfaces and interaction techniques that can improve user experience. This led us to believe that coupling of communication and interaction inputs would benefit the individual user experience as well as collaboration, as illustrated in Figure 8.

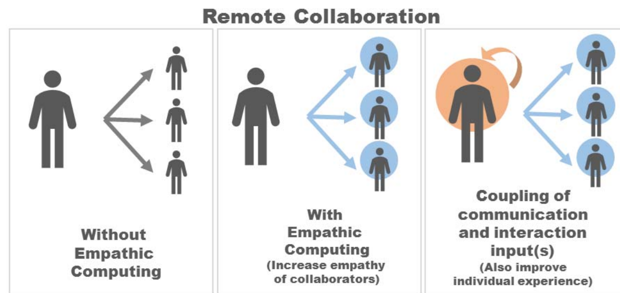

Fig. 8. Benefits of Empathic Computing in remote collaboration; (left) Without Empathic Computing, (middle) Empathic Computing increases empathy, (right) Empathic Computing interface that coupled communication and interaction input(s) can improve individual user experience.

V. Conclusion and Future Works

Empathic Computing aims to create technology that increases empathy between people. At the same time, Mixed Reality and Virtual Reality provide 3D immersive virtual environments for natural collaboration. In our research, we apply Mixed Reality and Virtual Reality techniques to create enhanced Empathic Computing experiences for remote collaboration. Natural collaboration, experience capture, and implicit understanding can be combined to enable Empathic Computing. In this paper, we selected research that progresses toward achieving this goal. We showed how sharing gaze, emotions, and physiological cues can enhance remote collaboration. We also showed that communication cues such as eye gaze, can be used as individual interaction techniques, which also benefit from the implicitness of these natural inputs.

Empathic Computing is a new field and so there are many directions for future research. This includes exploring how key indicators of emotion can be captured and shared, how to represent emotion to other users, and how to evaluate empathic systems. There is also more work that can be done on real time experience capture and how to represent remote collaborators.

References

[1] M. Billinghurst, "The Coming Age of Empathic Computing", https://medium.com/@marknb00/the-coming-age-of-empathic-computing-617caefc7016, Retrieved on 14/5/2017.

[2] P. Milgram and F. Kishino, "A taxonomy of mixed reality visual displays," IEICE TRANSACTIONS on Information and Systems, vol. 77, pp. 1321-1329, 1994.

[3] A. J. Clark, "Empathy and Alfred Adler: An Integral Perspective," The Journal of Individual Psychology, vol. 72, pp. 237-253, 2016.

[4] K. Gupta, G. A. Lee, and M. Billinghurst, "Do You See What I See? The Effect of Gaze Tracking on Task Space Remote Collaboration," IEEE Transactions on Visualization and Computer Graphics, vol. 22, pp. 2413-2422, 2016.

[5] K. Masai, K. Kunze, M. sugimoto, and M. Billinghurst, "Empathy Glasses," presented at the Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems, Santa Clara, California, USA, 2016.

[6] Y. Lee, K. Masai, K. Kunze, M. Sugimoto and M. Billinghurst, "A Remote Collaboration System with Empathy Glasses," 2016 IEEE International Symposium on Mixed and Augmented Reality (ISMAR-Adjunct), Merida, Yucatan, Mexico, 2016, pp. 342-343.

[7] M. Billinghurst, K.Gupta, M.Katsutoshi, Y.Lee, G.Lee, K.Kunze, M. Sugimoto, "Is It in Your Eyes? Explorations in Using Gaze Cues for Remote Collaboration," Collaboration Meets Interactive Spaces, pp.177-199, 2016.

[8] A. Dey, T. Piumsomboon, Y. Lee, and M. Billinghurst, "Effects of Sharing Physiological States of Players in a Collaborative Virtual Reality Gameplay," presented at the Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems, Denver, Colorado, USA, 2017.

[9] T. Piumsomboon, G. Lee, R. W. Lindeman, and M. Billinghurst, "Exploring natural eye-gaze-based interaction for immersive virtual reality," in *2017 IEEE Symposium on 3D User Interfaces (3DUI)*, 2017, pp. 36-39.