[DC] Improving Multi-User Interaction for Mixed Reality Telecollaboration

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Abstract

Mixed reality (MR) approaches offer merging of real and virtual worlds to create new environments and visualizations for real-time interaction. Existing MR systems, however, do not utilise user real environment, lack detail in dynamic environments, and often lack multi-user capabilities. This research focuses on exploring multi-user aspects of immersive collaboration, where an arbitrary number of co-located and remotely located users can collaborate in a single or merged collaborative MR space. The aim is to enable users to experience VR/AR together, irrespective of the type of HMD, and facilitate users with their collaborative tasks. The main goal is to develop an immersive collaboration platform in which users can utilize the space around them and at the same time collaborate and switch between different perspectives of other co-located and remote users.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Mixed / augmented reality;

1 Introduction & Motivation

In the wake of the recent pandemic, Zoom-oriented lifestyles where the work meeting, teaching and socialisation without leaving your desk have become the new normal [6]. The tools in the same time/different place quadrant of time-space matrix used in CSCW show advantages such as working together in different places at the same time without face-to-face meetings. However, some of the shortcomings of existing systems include the lack of interaction with people and the sense of the presence of others, frustrate users [2]. This provides an excellent opportunity for mixed reality collaboration (MRC). Mixed reality (MR) approaches blend real-world elements with virtual content, unlocking natural and intuitive interactions between humans, computers and the environment, and gives users a sense of immersion in their virtual experience. In this way, users do not just convey information, they feel that they are "really there" in a remote environment [4], and they are sharing the space together [7].

Suppose S_A and S_B are two different spaces. The immersion relationship between these two spaces can be denoted $S_A \supset S_B$, which arises when S_A can be used to create a space in which the participant will experience a simulation of that space as if they were in S_B. Therefore, we want to create a collaborative space S_A which is at a higher immersion level than S_B, where $S_A \supset S_B$ but $S_B \not\supset S_A$. Existing collaboration applications lack the immersive telepresence challenge of "sense of presence." In such a system, often the only source of information for remote viewers is a single-viewpoint video stream, making it difficult for users to understand or navigate the remote location. VR applications that offer navigation mostly use a virtual environment or pre-scanned environment, but these solutions are often cumbersome, lack detail in dynamic environments, and often lack multi-user capabilities. In many remote collaboration scenarios, the task space (S_A) can be divided into different areas. For

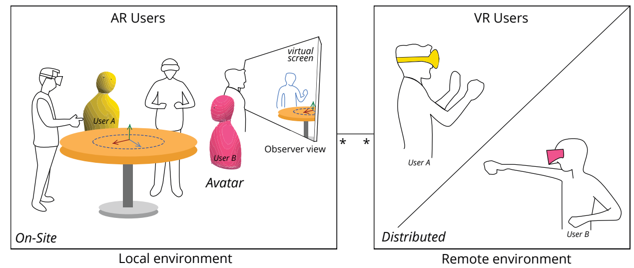

Figure 1: Multi-user collaboration in Mixed Reality space.

instance, in the construction industry, there are often multiple areas on a machine that a technician has to repair along with a remote assistant, and sometimes work done in one area is dependent on work being done in another area. Such tasks often require the use of multiple views, each of which corresponds to a different point of view and different subtasks [3].

This PhD project sets to address these challenges by allowing multiple users to immerse themselves in a real-world environment where remote users interact with local users, creating a seamless experience across a continuum of real and virtual reality. To enable multiple areas of the task space to be shared with a remote worker, a multi-camera collaboration system will be developed to cover each area of the workspace. Most commodity 360° cameras are capable of capturing the real environment and stream it live to the local user. This research will utilise this to expand the collaboration space with multiple spaces to achieve large-scale collaboration by combining multiple workspaces. It aims to create an underlying basis for both AR and VR users and provides capabilities that better adapt to user needs and overcome the isolating digital and physical barriers posed by HMDs for face-to-face communication. Thus, the proposed work aims to identify these components and conduct user evaluation in various task settings to assess spatial presence, social presence, and user productivity while effectively completing a collaborative task.

2 Research Goals

The main research problem of the thesis can be formulated in the following question: "How can multiple remote VR users effectively connect and collaborate with local users in one or more MRC spaces?" In order to elaborate on the main research question, there are additional sub-research questions:

RQ1 *Teleportation*: How do multiple remote users have spatial awareness and presence in MRC spaces?

RQ2 *Representation*: How to represent co-presence of multiple remote VR users in the MRC spaces?

RQ3 *Interaction*: How to support multiple VR users interact effectively in MRC spaces?

RQ4 *Viewpoint perspective*: How to effectively manage users' viewpoints to support various types of collaborative tasks in MRC spaces?

To answer the above research questions, I have the following objectives to investigate:

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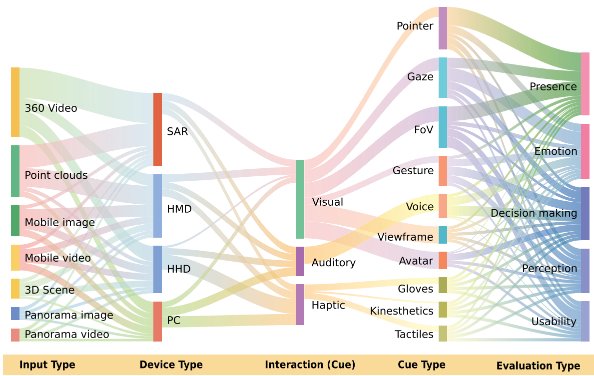

Figure 2: A total of 556 papers that employed MRC technology between 2000-2021 classified by (left-to-right): input type, device type, interaction, cue type and evaluation type in user studies.

1. To conduct a systematic review of the literature to assess the effectiveness of collaboration in MR.
2. To design, implement, and usability test of a multi-user mixed reality remote collaboration system.
3. To design, implement, and evaluate an immersive visualization system that allows exploratory data analysis in multi-user mixed reality collaboration system.

3 Current Results

First, relevant studies were investigated and a systematic literature review were conducted as part of this PhD research. Apart from listing existing work in this field, this review investigated topics, types of publications, as well as recent trends and upcoming advances that will contribute in this area. Overall, 556 collaborative mixed reality papers published between 2000 – 2021 were analyzed and classified according to input type, device type, interaction type, and evaluation criteria used (see Figure 2). The review shows that interest in MRC is growing but has not yet become widespread, and during our review, not many papers on many-to-many collaboration were found. Research also shown that there is a need to develop both functional and engaging visual content, as well as to put more effort into bringing different disciplines together. Real-time performance, high accuracy and low latency are some of the prerequisites for successful MRC applications [1]. Accurate and specific data modelling is also required to provide spatial detailed information. Majority of research shows offline high-fidelity image capture and 3D reconstruction can provide specific data that needed for augmentation, but real-time high-fidelity online model reconstruction is also needed. Due to the capability of mobile graphics, a move towards wearable wireless devices, is to be indispensable to the future of MR in collaboration. It takes limited computing power, memory storage and energy consumption, however, will continue to be bottlenecks for real time 3D mobile graphics even with the advanced GPUs and hardware in current mobile devices.

Thus, to address this issue, a prototype system is being developed that uses a 360° live video streams of a real location for remote collaboration. The system allows multiple remote users to understand and have spatial awareness and presence, and have the co-presence of multiple remote VR users in the MRC space. It provides multiple views of the task area to suit different points of view and different sub-tasks zones of the collaboration area. The user's viewport consists of the video stream from the camera to which they are connected, as well as the viewport of other users who have connected to other cameras at that time.

To validate this approach, a user evaluation will be conducted in which the collaborative task is performed in various numbers of VR-AR settings and also compared to an existing video conferencing application. In each iteration, several analysis will be recorded, such as time spent on tasks, number of errors, qualitative (semi-structured interviews), and quantitative data (SUS, NASA-TLX, SSQ questionnaires), similar to existing remote collaboration studies [5]. Participants will be recruited from university students as well as people from different fields of application. This will give us insight into how a multi-view perspective assists the user in performing collaborative tasks and how it affects communication between co-located and remotely located users, as well as help illustrate and measure the tangible impact on people's ability to complete tasks and their sense of presence.

4 Discussion

Mixed reality research is advancing rapidly, but best practices and applications have yet to emerge in the development in terms of interfaces for multi-user tasks. This research aims to contribute to the MRC space by designing and developing a multi-user mixed reality collaboration system and developing new approach to collaboration and interaction in a multi-user mixed reality collaboration system.

In the remainder of this PhD, further investigation will be carried out to gain a broader understanding of MRC technologies, user interaction techniques, and user evaluation. The prototype developed in this study, offers many potential opportunities to improve some technical issues and user experience. User evaluation, which will be carried out later part of this research, will help illustrate and measure the tangible impact on people's ability to complete tasks and their sense of presence.

Future work will primarily focus on extending the methodology of the evaluation, but there are some considerations what would be valuable to discuss before undertaking further actions:

1. Is there a need to narrow down the topic or focus on something specific that is missing?
2. Are the planned experiments setup adequate or need to be revised?

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