Spatiotemporal Teleport Experience in Mixed Reality using Live and Recorded Omni-Camera Views

Atsuro Yamamoto
Shibaura Institute of Technology
Tokyo, Japan

Takashi Ijiri
Shibaura Institute of Technology
Tokyo, Japan

ABSTRACT

This study proposes a method for realizing a spatiotemporal teleportation experience in a real-world environment using mixed reality (MR) technology and an omnidirectional (omni-) camera. In an environment where an omni-camera is placed, the user wears a head-mounted display (HMD) to enter the MR space. This MR space provides a marker at the omni-camera, allowing the user to select it and teleport their viewpoint to the camera. During teleportation, the user can also revisit past scenes by reviewing omni-videos recorded earlier. To illustrate the feasibility of the method, we present three example application scenarios: landscape viewing, sports viewing, and surveillance. The results of our user study suggest that the method is easy for novice users to operate, and participants particularly enjoyed the time-shift function, which allowed them to review past moments.

ACM Reference Format:
Atsuro Yamamoto and Takashi Ijiri. 2025. Spatiotemporal Teleport Experience in Mixed Reality using Live and Recorded Omni-Camera Views. In *31st ACM Symposium on Virtual Reality Software and Technology (VRST '25), November 12–14, 2025, Montreal, QC, Canada.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3756884.3768388

Figure 1: Three example applications of the proposed method: (a) landscape viewing, (b) sports viewing, and (c) surveillance.

1 INTRODUCTION

Mixed reality (MR) is a technology that overlays virtual objects onto the real world using a camera or an optical pass-through head-mounted display (HMD). However, in an MR environment, it is challenging to support the teleport-based navigation commonly used in virtual reality (VR), as VR covers the entire field of view with a virtual environment, whereas MR overlays virtual objects onto the user's real-world view. Moreover, in the real world, there are many situations in which one may want to revisit past scenes, such as reviewing a play performed a few seconds earlier during a sports game. Enabling such teleportation into the past would enhance entertainment experiences such as sports viewing and sightseeing.

Researchers have presented various methods for providing telepresence, in which users feel as if they are in remote locations, using VR techniques. For instance, methods such as sharing the field of view of others in remote locations [1], utilizing omnidirectional (omni-) cameras placed at remote sites [2], and employing cameras mounted on drones [3] have been proposed. These methods enable users to view remote locations; however, they do not aim to provide teleportation interaction in the real world, nor do they allow revisiting past scenes.

This study aims to realize a spatiotemporal teleportation experience in the real world. For this, we propose a method that combines an omni-camera and a camera pass-through HMD (Figure 1). In an environment where an omni-camera is placed, the user wears an HMD to enter the MR space. This MR space provides a marker at the omni-camera, allowing the user to select it with a controller and teleport their viewpoint to the camera. After teleportation, the user can also revisit past scenes by reviewing omni-videos recorded 10 seconds earlier or further back. To illustrate the feasibility of the proposed method, we present three example applications: landscape viewing, sports viewing, and surveillance.

2 METHOD

Fig. 2a presents an overview of the proposed method. The system consists of an omni-camera (RICHO THETA V) placed at the teleport destination, a VR tracker located near the camera, an HMD with a camera pass-through function (VALVE INDEX), and a PC. When the user enters the MR space, a spherical marker is displayed at the camera position within the user's field of view (Fig. 2b). By selecting this marker using a ray projected from the controller, the user's viewpoint is teleported to the selected camera, and real-time omni-video without parallax is displayed on the HMD (Fig. 2c).

VRST '25, November 12–14, 2025, Montreal, QC, Canada

ACM ISBN 979-8-4007-2118-2/2025/11
https://doi.org/10.1145/3756884.3768388

This teleportation enables the user to observe the real world from viewpoints that are otherwise physically inaccessible. When teleported to the camera, the user can look back toward their original position, where a marker is displayed. The user can teleport back by selecting this marker.

During teleportation to the camera, the user can also switch between *Live & Time-shift* or *Recordings* modes by selecting the buttons shown in Fig. 2d. In Live & Time-shift mode, real-time video is displayed on the HMD. In this mode, the user can manipulate a slider to shift the video playback by up to 10 seconds into the past. In other words, the user can revisit the real world as it was a few seconds earlier. This mode is particularly useful for applications such as sports viewing, where users often want to review plays that occurred moments before. In Recordings mode, omni-videos previously recorded by the camera placed at the same position are listed in a UI panel (Fig. 2e), and the user can select one to play. This mode is useful for applications such as tourist observation decks, where users can experience sunny daytime views even on a rainy day.

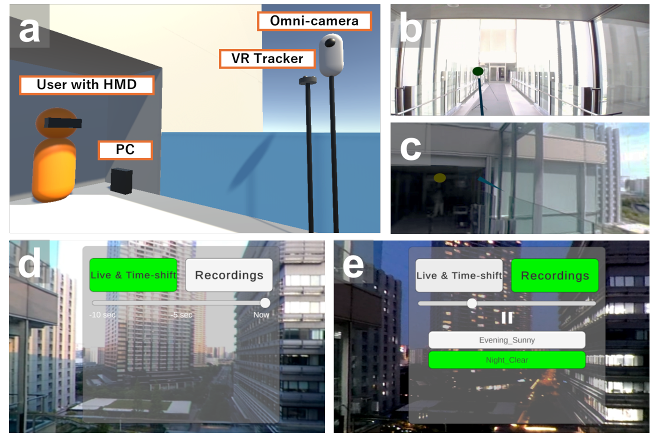

Figure 2: Overview of the proposed method.

3 APPLICATION

To demonstrate the feasibility of the proposed method, we developed three example applications: landscape viewing, sports viewing, and surveillance. In the landscape viewing application (Fig. 1a), the omni-camera is placed outside a high observation deck, allowing the user to safely enjoy views from locations that are physically inaccessible. In addition, we prepared omni-videos recorded on a sunny day during both daytime and nighttime, enabling users to view either sunny landscapes or nightscapes, regardless of the actual weather or time. In the sports viewing application (Fig. 1b), the user can watch a basketball game from multiple viewpoints and replay missed or notable plays using the time-shift function. In the surveillance application (Fig. 1c), the omni-camera is placed outside the user's field of view, allowing them to monitor the surroundings without physically moving.

4 USER STUDY

To evaluate the usability of the proposed method, we conducted a user study using the sports viewing application. Each participant first completed a brief tutorial and practiced spatiotemporal teleportation several times, then observed a basketball game in which two players practiced one-on-one for 5 minutes—the first 3 minutes on a half court and the last 2 minutes on a full court. After the observation, each participant answered the 10 questions of the System Usability Scale (SUS) using a 5-point Likert scale and provided open-ended comments on the proposed method.

Five university students participated in the experiment. Three had prior experience with VR/MR, while the others had none. The average SUS score was 70.5 (see the supporting video for the average score of each question). Questions related to the simplicity and consistency of the system received relatively high scores (Q3 = 3.4, Q5 = 4.2, Q7 = 4.4). In contrast, questions addressing complexity and the need for support received lower scores (Q2 = 1.8, Q4 = 1.8). These results suggest that the proposed spatiotemporal teleportation method is easy to use regardless of prior VR/MR experience. However, responses to the question about whether participants would like to use the system frequently were lower than expected (Q1 = 2.8). We attribute this to the limited performance of the omni-camera (30 fps, 1920×1028) in capturing fast-paced sports such as basketball.

Participants also provided qualitative feedback on the method. For example, some remarked, "It was fun being able to rewind and check the moment of the shot," and "Replaying the shot allowed me to revisit the play related to the score," indicating that the time-shift function was positively received. Conversely, comments such as "The video and actual sound are out of sync in the omni-camera view," and "The frame rate and resolution of the omni-camera were not sufficient," highlighted challenges in improving the quality of the experience. All participants' comments were translated from Japanese to English by the authors.

5 CONCLUSION

In this study, we proposed a method for achieving a spatiotemporal teleportation experience by combining an omnidirectional camera with a camera pass-through HMD. We also presented three example applications—landscape viewing, sports viewing, and surveillance. The results of the user study indicate that the method is easy to use, regardless of prior VR/MR experience, and that participants particularly enjoyed the time-shift function, which enabled them to review past moments. The main limitation of the current system is the transfer speed and resolution of the omni-camera view, as noted by participants in the user study. Future work will focus on adopting omni-cameras with higher frame rates and resolutions and optimizing data transfer to improve experience quality. Another promising direction is to support teleportation to arbitrary positions using cameras mounted on drones.

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