Mobility Link XR: Interspace Interaction System in Electric Wheelchair

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Abstract. This research proposes a communication system called Mobility Link XR that connects physical space and cyberspace with mobility. Mobility Link XR is a system that enables remote users to view panoramic video from a 360-degree camera attached to a mobility vehicle in different space by wearing a VR device, and mobility users to view the remote user as an avatar by wearing an MR device. In this way, sharing space in three dimensions using XR enables a higher level of human communication. In this paper, we apply Mobility Link XR to an electric wheelchair and design two types of scenarios: an assistance mode that reproduces the positional relationship of communication in a conventional wheelchair, and a passenger mode that reproduces the positional relationship inside a vehicle, which is said to be a suitable distance for conversation. We also evaluated the reproducibility of communication in the wheelchair and the effectiveness of communication using the avatar. The results showed that the reproducibility of voice and emotion was highly evaluated and that the side-by-side positional relationship enabled higher quality communication as the avatar was more easily seen and felt present.

Keywords: Virtual Reality · Mixwd Reality · Interspace Communication · Wheelchair · Remote Control.

1 Introduction

Information technology extends our living space into cyberspace, virtual reality, or the so-called metaverse. Also, as a digital counterpart of physical space, the concept of digital twins has attracted many researchers, both in academia and industry, in the context of smart cities. Thus, methods to connect and integrate various spaces are becoming increasingly important to improve communication and services between spaces. We present Mobility Link XR, a communication

system that connects physical and cyber spaces. Mobility Link XR provides a unified user experience for remote users and mobility users through mobility. Remote users can view panoramic video from a 360-degree camera attached to the mobility vehicle with a VR device, and mobility users can see the remote user as an avatar by wearing an MR device. In this study, Mobility Link XR is applied to an electric wheelchair to provide a communication method for two scenarios: assistance mode and passenger mode. The contributions of this paper are as follows

1. Proposal of Mobility Link, a new communication system that connects different spaces
2. Introduction of a scenario in a wheelchair using Mobility Link XR
3. User survey and discussion to evaluate the effectiveness of Mobility Link XR

2 Related Research

2.1 Interspace Communication

Bai et al.[1] proposed an MR remote collaboration system that shares a panoramic image of the user's surroundings with the remote user and elucidate that both users can provide a sense of co-presence by communicating not only verbally but also visually and gesturally through MR.

Cai et al.[2] proposed a mixed reality-based mobile communication system to connect two users in separate environments. Evaluations were conducted to investigate the system's usability and user performance, showing that both users can effectively communicate instructions related to the physical world and enable smooth remote collaboration.

Yonezawa et al.[6] proposed Metapo, a mobile robot equipped with a spherical display, a 360° camera image, and a robot hand, etc. Metapo functions as a portal to physical space, cyberspace, etc., and allows multiple remote users to communicate with each other through Metapo.

2.2 Teleoperation System

Ostanin et al.[4] proposed a framework to interactively control multiple robots using mixed reality interface technology. They experimentally demonstrated that the proposed framework can connect to and interactively control heterogeneous robots using multiple robots such as robotic arms, small mobility, and UAVs.

Hashizume et al.[3] proposed "Telewheelchair," an electric wheelchair with HMD-based teleoperation and operation assistance functions to reduce the caregiver's burden in wheelchairs. They investigate the user study of wheelchairs and the work time for each four tasks, the results showed that the operation mode using the HMD was superior to the other operation modes

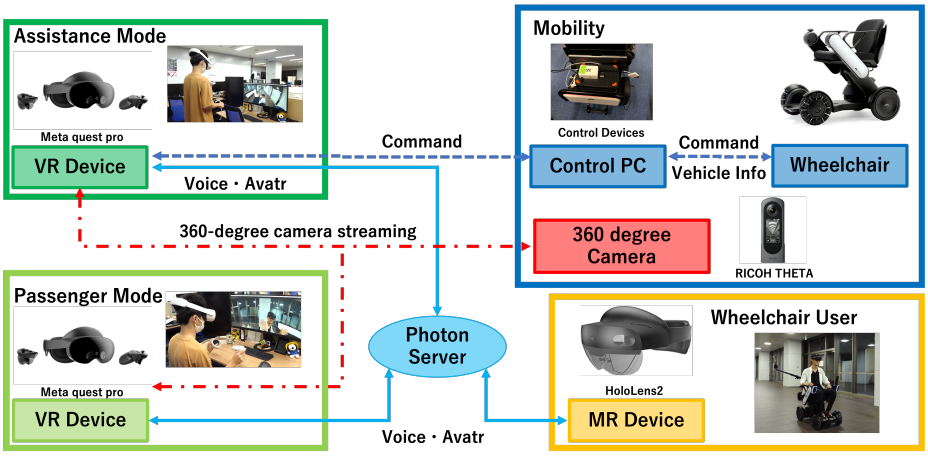

Fig. 1. System Design

3 Methodology

This section describes an overview of the Mobility Link XR system, which enables communication with remote persons through mobility, and two types of communication scenarios in an electric wheelchair using this system.

3.1 Mobility Link XR

Mobility Link XR is a system that enables users in different spaces to communicate with each other in mobility, a place where conversations are easily generated. In this system, a remote user can virtually ride in a mobility vehicle in a different space by wearing a VR device. The mobility vehicle is attached with a 360-degree camera, and the remote user can view the panoramic video to understand the surrounding conditions of the mobility vehicle. The mobility user can also see the remote user as an avatar by wearing an MR device. This enables the user to express not only language through speech, but also facial expressions, emotions, and three-dimensional physical expressions, making it possible for the user to communicate at a higher level.

3.2 System Design and Scenarios in wheelchair

As described in the Stinzer effect[5], the positional relationship between people is one of the major factors in the quality and content of communication. In this paper, Mobility Link XR is applied to a wheelchair, which is a front/rear positional relationship and a special kind of communication, such as letting the person in the back drive, and two scenarios are designed as shown in Figure 1.

Scenario 1: Assistance mode The first scenario is communication performed by the remote user as a caregiver. Wheelchairs are essentially an indispensable means of transportation for the elderly and physically disabled, and basically require the presence of a caregiver. On the other hand, the presence of a caregiver also creates opportunities for communication. To reproduce this communication, a remote caregiver can operate the wheelchair, and the wheelchair user can talk with the caregiver while leaving the wheelchair in the caregiver's hands. The positioning of the wheelchair user is not commonly seen in general communication, and we believe that this type of communication can be created.

Scenario 2: Passenger mode The second scenario is communication in which the remote user acts as a passenger. The interior of a car is said to be a suitable distance for conversation. Therefore, by reproducing the positional relationship between the wheelchair user in the driver's seat and the remote passenger in the passenger seat, we have created a place where communication can occur. In this scenario, the wheelchair user moves using a joystick attached to the wheelchair.

4 Evaluation

In this paper, two user surveys were conducted to evaluate the effectiveness of Mobility Link XR. This chapter describes the details of each survey and its results. Six students and staff members of the laboratory (four males and two females, average age of 25) participated in the user surveys. The survey was conducted in a 15-m straight corridor in the laboratory, as shown in the figure 2.

4.1 User Study1

The first user study compares a conversation while actually pushing a wheelchair with a conversation using the proposed system in order to investigate how well the Assistance mode described in section 3.2.1 reproduces communication in an actual wheelchair.

Procedure Subjects were first given a lecture on how to remotely operate the wheelchair and practiced for about 10 minutes to become familiar with the wheelchair. After that, the subjects were asked to talk with the facilitator while riding or pushing the wheelchair along the path shown in the figure 2. On the outward journey, the subject rode in the wheelchair and the facilitator pushed the wheelchair from behind as a caregiver. On the return trip, the subject pushed the wheelchair and the facilitator rode the wheelchair. On the outward journey, the subject rode in the wheelchair wearing the MR device. The facilitator remotely controlled the wheelchair with a VR device. On the return trip, the subject used the VR device to remotely control the subject's chair, and the facilitator talked with the subject while the subject was in the wheelchair. After the completion of all tasks, a 6-question questionnaire with a 5-point Likert scale and an open-ended questionnaire was administered.

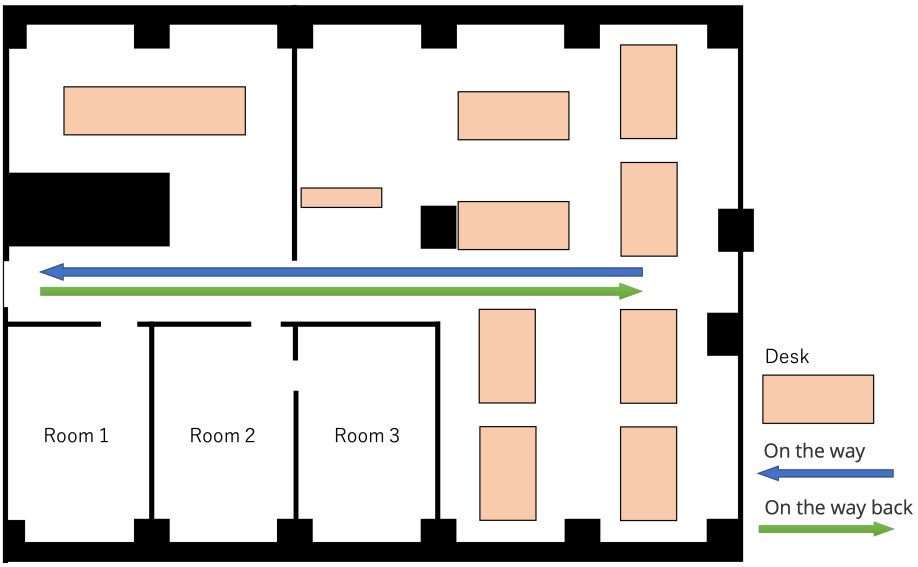

Fig. 2. Passage where the experiment was conducted

Result The figure 4 shows the mean and standard deviation of the 5-point Likert scale for each evaluation index in User Survey 1. As shown in the figure 4, the five items except for operation were reproduced to some extent. The results were especially high for Talk and Emotions. The relatively low values for Gesture and Face despite the use of an avatar may be due to the fact that the wheelchair user rarely communicated non-verbally with the avatar since it was behind the user. In addition, the users in wheelchairs said that it was difficult to operate the device despite the practice. In this study, we used a joystick to remotely control the VR device, but we believe that a more intuitive method of remote control is needed.

4.2 User Study2

The second user study will investigate the effectiveness of using avatars by comparing video calls and this system (Scenarios 1 and 2) while both users are remote from each other.

Procedure As in User Study 1, the subject was the wheelchair user and the facilitator was the remote user for the outward trip, and the subject was the remote user and the facilitator was the wheelchair user for the return trip. First, the subject held a tablet connected to the remote user via video call and engaged in conversation. Second, the conversation was conducted in the assistance mode, and finally, the conversation was conducted in the passenger mode. In all cases, the wheelchair was operated with a joystick attached to the wheelchair.

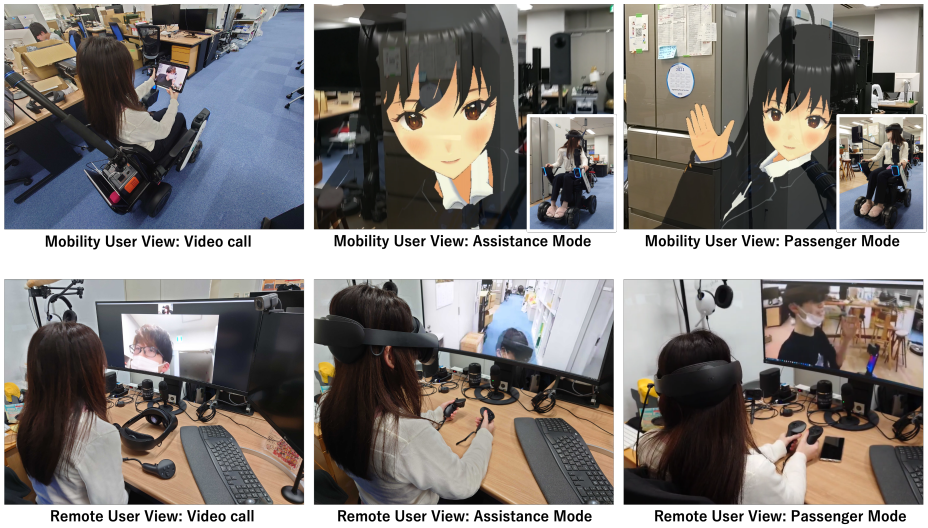

Fig. 3. Each user's view

After all, tasks were completed, a four-question questionnaire and an open-ended questionnaire were administered to determine whether the communication was easier compared to the video call.

Result The figure 5 shows the mean and standard deviation of the 5-point Likert scale for each of the evaluation indicators in User Survey 2. As the figure 5 shows, Talk and Gesture have higher values than the other items. This result indicates that the avatar improves the quality of communication not only through verbal expression but also through nonverbal expression. However, compared to video calls, the 360-degree panoramic image of this system has a low resolution, which makes it difficult to convey facial expressions. In addition, when comparing the Assistance mode and the Passenger mode, it was found that the Passenger mode is easier to see the avatar and feel the presence of the other party nearby, making communication easier.

5 Conclusion

In this study, we proposed the concept of Mobility Link XR, which enables users in different spaces to connect and communicate with each other via mobility, and developed a prototype applied to an electric wheelchair. The evaluation results demonstrated that the system can reproduce communication through special positioning in a wheelchair and improve the quality of communication through avatar gestures. In the future, we will implement more detailed movements of the avatar (facial expressions, lip-sync, eye contact) to achieve higher quality

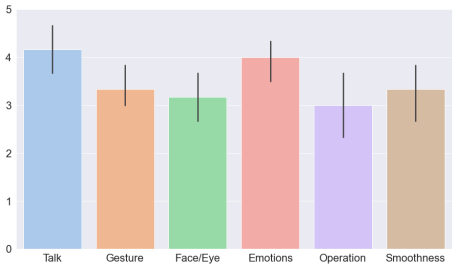

Fig. 4. Results of Likert scale in the User Study1.

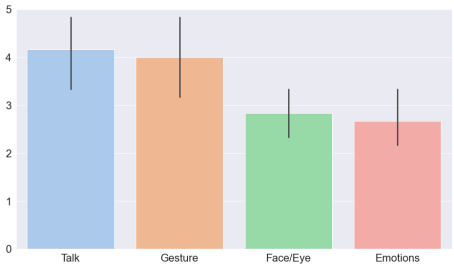

Fig. 5. Results of Likert scale in the User Study2.

communication and clarify its application and potential for various mobility applications.

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References

1. Bai, H., Sasikumar, P., Yang, J., Billinghurst, M.: A user study on mixed reality remote collaboration with eye gaze and hand gesture sharing. In: Proceedings of the 2020 CHI conference on human factors in computing systems. pp. 1–13 (2020)
2. Cai, M., Tanaka, J.: Mixed-reality communication system providing shoulder-to-shoulder collaboration. International Journal on Advances in Software Volume 12, Number 3 & 4, 2019 (2019)
3. Hashizume, S., Suzuki, I., Takazawa, K., Sasaki, R., Ochiai, Y.: Telewheelchair: The remote controllable electric wheelchair system combined human and machine intelligence. In: Proceedings of the 9th Augmented Human International Conference. pp. 1–9 (2018)
4. Ostanin, M., Yagfarov, R., Devitt, D., Akhmetzyanov, A., Klimchik, A.: Multi robots interactive control using mixed reality. International Journal of Production Research **59**(23), 7126–7138 (2021). https://doi.org/10.1080/00207543.2020.1834640
5. Steinzor, B.: The spatial factor in face to face discussion groups. The Journal of Abnormal and Social Psychology **45**, 552–555 (1950)
6. Yonezawa, T., Hayashida, N., Urano, K., Przybilla, J., Kyono, Y., Kawaguchi, N.: Metapo: A robotic meta portal for interspace communication. In: ACM SIGGRAPH 2022 Posters, pp. 1–2 (2022)