XR Communication System for Remote Control Wheelchairs

HIRONORI SHIMOSATO
Graduate School of Engineering,
Nagoya University
JAPAN

NOZOMI HAYASHIDA
Graduate School of Engineering,
Nagoya University
JAPAN

KENTA URANO
Graduate School of Engineering,
Nagoya University
JAPAN

TAKURO YONEZAWA
Graduate School of Engineering,
Nagoya University
JAPAN

NOBUO KAWAGUCHI
Graduate School of Engineering,
Nagoya University Institutes of
Innovation for Future Society, Nagoya
University
JAPAN

ABSTRACT

With the introduction of the IoT, communication is becoming more diverse. While IoT is becoming more and more widespread, there are some forms of human communication are being lost. The development of self-propelled robots has progressed, and electric and automated wheelchairs are also being utilized. A caregiver wasoriginally required to operate a wheelchair. However, with the advent of IoT wheelchairs, wheelchairs can be operated by wheelchair users only, increasing convenience. On the other hand, wheelchairs have been used as a kind of communication between caregivers and wheelchair users, and the development of IoT wheelchairs has reduced the opportunities for communication between caregivers and wheelchair users. In this paper, we propose a method to reproduce communication scenarios in the following two scenarios using an IoT wheelchair and present the design and implementation of the prototype created.

CCS CONCEPTS

• **Human-centered computing → Interface design prototyping**; **Scenario-based design**.

KEYWORDS

XR, Communication System, IoT Wheelchair

ACM Reference Format:
HIRONORI SHIMOSATO, NOZOMI HAYASHIDA, KENTA URANO, TAKURO YONEZAWA, and NOBUO KAWAGUCHI. 2022. XR Communication System for Remote Control Wheelchairs. In *Proceedings of the 12th International Conference on the Internet of Things (IoT '22), November 7–10, 2022, Delft, Netherlands.* ACM, New York, NY, USA, 5 pages. https://doi.org/10.1145/3567445.3571111

IoT '22, November 7–10, 2022, Delft, Netherlands

ACM ISBN 978-1-4503-9665-3/22/11…$15.00
https://doi.org/10.1145/3567445.3571111

1 INTRODUCTION

The IoT has enabled a wide variety of communication methods. The advent of cell phones has made it possible to communicate remotely, but now that cell phones and the Internet connection to the PC, there are many ways to communicate face-to-face without having to meet in person. There are also many other metaverse technologies that enable people to gather and communicate in a virtual space, just as they do in a physical space, by using VR devices and other technologies to convert human vision into the IoT.

While such communication is possible despite physical distance, there are some forms of human communication that are being lost. The development of self-propelled robots has progressed, and electric and automatic wheelchairs are also being utilized. A caregiver was originally required to operate a wheelchair, but with the advent of IoT wheelchairs, wheelchairs can now be used by a single person, increasing convenience. On the other hand, wheelchairs have been used as a kind of human communication between caregivers and wheelchair users, and the development of IoT wheelchairs has reduced the opportunities for communication between caregivers and wheelchair users.

Positional relationships have a great influence on human communication [9]. It is also said that the type of human communication that occurs there depends on the method of operation, such as manual or automatic[11]. We would like to explore the positive effect on human communication that a special positional relationship such as a wheelchair, where people are not facing each other, and also we would like to reproduce it. This research aims to recreate human communication between IoT wheelchair users and remote assistants using XR technology and to clarify how the new human communication varies depending on the form of human communication.

In this paper, we propose a method to reproduce communication scenarios in the remote control scenario and passenger scenario using an IoT wheelchair and present the design and implementation of the prototype created. The contributions of our research are as follows

- We propose one of human communication that connects physical and virtual space
- We propose to reproduce the existing wheelchair-based human communication and to communicate in a new position

- We create a prototype using a wheelchair and XR.

2 RELATED WORK

As XR is becoming a familiar device, coupled with the corona disaster environment, research on communication using XR is being actively conducted. There have also been many attempts to unify the interfaces of robots that have various uses and to visualize and control the information of these robots using XR.

2.1 XR Communication System

Theophilus et al. [10], and Huidong et al. [1] have developed systems that share a 360-degree video of a worker's viewpoint and a 3D model of the surroundings with remote supporters, who work with each other using AR and VR devices. Thammathip et al[7] also developed Mini-me, which provides remote work support using an AR device with an avatar of the remote supporter using a VR device. Geonsun et al.[5] evaluated three viewpoint-sharing methods: 2D video, 360-degree video, and 3D models in a one-to-many environment where multiple workers wearing AR devices can be monitored by remote supporters wearing VR devices. Jan et al. [2] proposed a method that uses floor projection and mobile displays in combination with positional tracking to visualize a virtual world and interact with Head-Mounted-Display(HMD) non-users and HMD wearers to share VR experiences.

In addition, there has been a lot of research and development on the metaverse, starting with games, and it has been used in research on social phenomena, marketing simulations, education, and museum tours.

2.2 Teleoperation System

Roldán et al.[8] developed a Unity-based VR interface for operating robotic arms and mobile robots. The robot's position in the real world is projected into the virtual space based on target markers. The manipulation method is to specify the position of each robot object, and the robot in the real world can move to the specified position.NASA-TLX[3] showed that the VR interface reduced the operator's workload by 22%.

Ostain et al. [6] proposed a framework to interactively control various robots using Hololens, an MR device being developed by Microsoft. The MR device is a virtual space on top of the real space, which enables intuitive manipulation of the actual robot, thereby reducing the number of manipulation errors and other errors in robot control. This reduces errors in robot control. Ostain et al. calculated the positions of the MR device and the mobile robot by matching the point cloud obtained from the MR device with the point cloud obtained from the LiDAR attached to the mobile robot.

Hashizume et al. [4] have developed the Telewheelchair, an electric wheelchair with a VR teleoperation function, to reduce the burden on wheelchair caregivers. A 360-degree camera is mounted on the wheelchair, and the caregiver can operate the wheelchair with the attached VR controller while viewing the real world through the 360-degree camera from the VR device. The results showed that the operation mode using the HMD was superior to the other operation modes.

As described above, some research has been conducted on communication using XR and remote control of wheelchairs, but not enough research has been conducted on the effect on communication when a wheelchair is operated remotely. Based on these studies, the purpose of this research is to create a platform to generate communication using XR in situations that are being lost or that were not originally envisioned and to investigate how teleoperation using XR affects communication. In this paper, we focus on communication in wheelchairs and discuss its application and impact.

(a) Scenario1: Assistance **(b) Scenario2: Passenger**

Figure 1: Scenario for wheelchair XR communication

3 PROPOSED SYSTEM

3.1 Scenario

As mentioned in the Stinzer effect[9], positional relationships are one of the major factors in the quality and content of human communication. In this paper, we design two scenarios in human communication between a wheelchair user and a remote person, as shown in Fig 1 in order to examine how the quality and content of communication change depending on the trust and positional relationship between the wheelchair user and the caregiver.

3.1.1 Scenario 1: Assistance.

The first scenario is communication performed by a remote person as a caregiver (Fig. 1a). A wheelchair is essentially an indispensable means of transportation for the elderly and physically disabled and basically requires a caregiver to accompany the wheelchair user. On the other hand, the presence of a caregiver also creates an opportunity for communication. To reproduce this communication, a remote caregiver operates the wheelchair, and the wheelchair user can talk with the caregiver while leaving the wheelchair to the caregiver. The positional relationship of the wheelchair user is not often seen in general communication, and we believe that this type of communication can be generated.

3.1.2 Scenario 2: Passenger.

The second scenario is a communication in which the remote party acts as a seatmate (Fig. 1b). It is said that the inside of a car is an appropriate distance for conversation. Therefore, we created a place where communication can occur by recreating the positional relationship between the wheelchair user in the driver's seat and

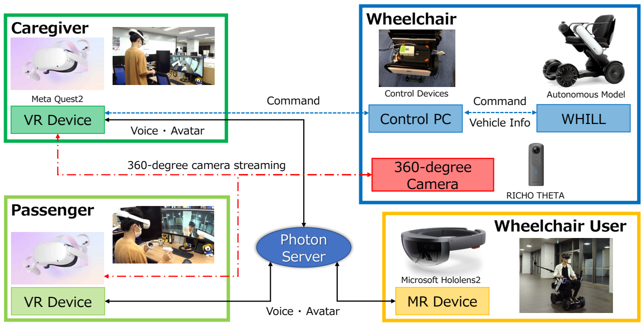


Figure 2: System Design

the remote passenger in the passenger seat. In this scenario, the wheelchair user moves using a joystick attached to the wheelchair.

3.2 Design and Implementation

In order to realize the scenario described in the section, we created a prototype with a space-sharing system between VR and MR and a teleoperation system for the wheelchair. Figure2 shows our system design.

3.2.1 *Space Sharing System.*

The application for the XR device will be developed using Unity. Wheelchair users and remote users will use MR and VR devices, respectively. The location of each device is shared using the photon server [1], which can be used to build a server-side of multiplayer game. The position of the hand is also shared to enable gesture-based communication.

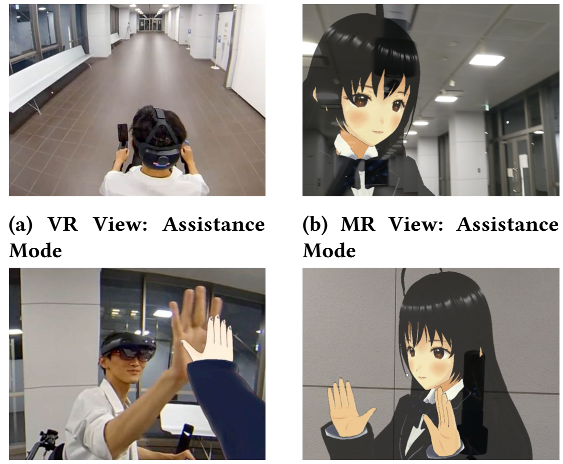
The 360-degree camera attached to the wheelchair delivers the video, and each XR device acquires that video. The remote operator operates the wheelchair and converses with the remote user while viewing this video. The voices of both parties are shared using the microphones and loudspeakers of each XR device. The remote participants operate a wheelchair and talk to each other while viewing these video. The voices of both parties are shared using the microphones and loudspeakers of each XR device.

3.2.2 *Remote Support System.*

A Meta Quest2 controller is used for the teleoperation of the wheelchair. The caregiver performs a spatial pushing action on the controller or tilts the stick attached to the controller in any direction. The amount of change in movement is calculated from the amount of spatial pushing or the tilt of the stick. To calculate the amount of change in a movement when pushing spatially, the user presses any button on the controller immediately before pushing the wheelchair and records the starting position of the button. The difference from the recorded position is used as the amount of change in movement.

Using a messaging protocol called MQTT (Message Queuing Telemetry Transport), the calculated change in movement is sent to the Raspberry Pi attached to the wheelchair. The Raspberry Pi converts the received movement change amount into a Joy message with a ROS topic, and the wheelchair moves based on the ROS topic. In addition to movement commands, information such as emergency stop and destination can also be sent to the wheelchair via

[1]https://www.photonengine.com/ja/server



(a) VR View: Assistance Mode

(b) MR View: Assistance Mode

(c) VR View: Passenger Mode

(d) MR View: Passenger Mode

Figure 3: Each user’s point of view (VR: remote person, MR: wheelchair user)

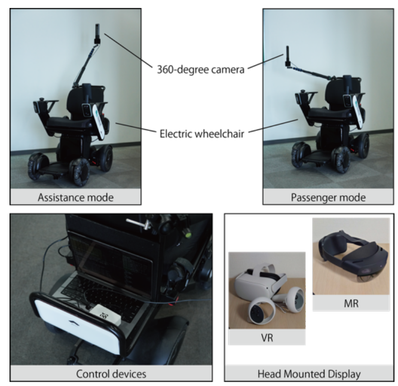


Figure 4: Prototype

MQTT. The wheelchair acquires information from the wheelchair via MQTT, such as the current position, remaining battery capacity, and whether or not a person is seated in the wheelchair, and displays this information on the MR device used by the caregiver and the wheelchair user

3.2.3 *Prototype.*

Figure4 shows the prototype created. This prototype has the following devices.

- VR device: Meta Quest2 [2]
- MR device: Microsoft Hololens2 [3]
- Wheelchair: WHILL Electric Wheelchair [4]
- 360-degree camera: RICOH THETA V [5]

The WHILL electric wheelchair used was designed for automatic operation development, so it can be operated by Robot Operation

[2]https://store.facebook.com/jp/quest/products/quest-2/
[3]https://www.microsoft.com/ja-jp/hololens/hardware
[4]https://whill.inc/jp/maas
[5]https://theta360.com/ja/about/theta/v.html

System(ROS). The wheelchair is equipped with a stereo camera and 2DLiDAR for obstacle detection and automatically stops if there is an obstacle in the direction of movement.

Figure 3b, 3d show the viewpoints of the wheelchair user seen through the MR device in each scenario. Figure 3a and 3c show the viewpoints of the remote user seen through the VR device in each scenario.

4 DISCUSSION

4.1 Limications and Practical Issues

The following are the major issues that need to be solved before the prototype device created in this research can be put into practical use.

- Safety of wheelchair operation
- Sensory feedback to the wheelchair operator
- Avatar resolution

It is very important to guarantee safety in practical applications. In the prototype developed in this paper, there is a 2-second delay in the network video distribution. The caregiver checks the images from the 360-degree camera through the VR interface. However, a 2-second delay is dangerous and does not allow for comfortable operation. In this research, the automatic stop function of WHILL is used to avoid collisions caused by operation errors due to this delay. However, real-time delivery with less delay is necessary for future social implementation. In addition, the method of operation may also affect communication. In this paper, the wheelchair was operated in two scenarios, manual operation, and remote control. When the wheelchair is operated automatically, the caregiver and user can focus only on communication. This eliminates the need for both caregivers and users to operate the wheelchair, thereby improving safety. However, because communication may occur through manual operation, it is necessary to switch between manual and automatic operation depending on the situation while ensuring safety to promote communication.

Next, we consider feedback when a caregiver pushes the controller. The caregiver operates the wheelchair by using the joystick on the controller or by pushing the wheelchair, but the only feedback of the caregiver actually pushing the wheelchair is the image projected on the VR interface. Therefore, there is little sensation of pushing, which may have no effect on communication. It is necessary to give the user a sense of control by using a different method when the wheelchair is being operated. As a countermeasure, the controller could vibrate when the wheelchair is being operated, providing pseudo-weighted feedback.

Another issue is the resolution of the avatar used for space sharing. For the prototype in this paper, we used an avatar made of an object that imitates a head and an object that imitates a hand for simplicity of implementation. This alone is sufficient for communication using gestures and conversation, but it is not enough. In order to reproduce more realistic communication, avatars with more realistic facial expressions and eye contact are needed.

4.2 Implication for further applications

This paper focuses on real-time communication between an elderly or physically disabled person who needs a wheelchair and a caregiver using a wheelchair. Therefore, this section describes the following applications and their concrete examples.

- asynchronous communication
- personal mobility

4.2.1 Asynchronous Communication.

Asynchronous communication is the act of communicating with the past or the future. Assuming a service like Bottle Mail, where users can listen to pre-recorded messages, they can share time with the past. For example, a wheelchair can be used as a time capsule, recording messages to oneself in advance so that years later, when one needs a wheelchair, one can receive care while listening to one's own messages from the past.

4.2.2 Personal Mobility.

Wheelchairs were originally used as a means of transportation for physically disabled people, but they can also be used as a means of personal mobility for able-bodied people. For example, wheelchairs can be used for school and factory tours, aquariums, zoos, etc., while communicating with remote guide staff. Another possible application is geocaching, in which messages are displayed when the wheelchair reaches a specific location. In addition, due to the recent coronavirus, it is not easy to visit patients in hospitals. Under such circumstances, this system can be used to provide a place for communication anywhere within the wheelchair's reach, allowing patients to walk outside the hospital while virtually seeing each other.

5 CONCLUSION

Opportunities and methods of communication have changed in response to the changing times caused by the new coronavirus and mobility revolution. In this study, we focused on communication in a wheelchair and developed a prototype of a wheelchair XR communication system using a 360-degree camera and HMD. The system was developed to enable a caregiver to operate the wheelchair through the VR device.

Future challenges include reducing the latency of the 360-degree camera and investigating communication by avatar resolution. In addition, there is a possibility of influencing people's communication depending on the operation methods and situations. Therefore, it is necessary to have the prototypes used under various conditions to investigate changes in their potential effects on communication.

ACKNOWLEDGEMENT

This research is partially supported by NICT BG5 project, NICT DDT project and JST, CREST Grant Number JPMJCR22M4, Japan.

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