Robot Control Support System Using a MR Device

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***Abstract*—At the Fukushima Daiichi Nuclear Power Station, various robots are currently being developed and operated for decommissioning [1]. However, as the number of robot arms and cameras increases, the number of displays and buttons increases, and the operation tends to be complicated. The maneuverability is reduced because the operator must maneuver the robot while viewing many displays and buttons. Therefore, in this research, as a system to support the vision of the pilot by utilizing the MR device, we developed a system that can project the image obtained by the web camera using the MR device and check both the image and the controller. We confirmed that low-latency, smooth images can be transferred, and we confirmed that there was no problem with maneuvering even if actually operated on a robot. As a result, a simple remote control system using a MR device and a web camera could be realized, and the basis of an operation system using a MR device in the future could be formed. At the beginning of this paper, we will explain about MR device and in the middle, we will explain about the development environment and the prototype system, and finally an application example and evaluation method.**

***Index Terms*—MR, robot, control system**

I. Introduction

At Fukushima Daiichi Nuclear Power Station, etc., work for decommissioning is currently being carried out at a rapid pace, and various robots are being developed and operated. For example, there are “Quince” [2] developed as a robot for indoor space exploration and “a robot for surveying high places” [3] developed as a robot for high places investigation. Besides the research robots, “Sakura ichi go” and “Sakura ni go” [4] are working and transportation robots newly developed according to the needs in the nuclear power plant. All of these robots have been developed on the premise that they should be operated by remote control, and the technology of remote control is regarded as very important [5]. In our laboratory, we are also developing a decommissioning robot [6] called the U-bo series (Fig. 1). This robot designed for the decommissioning robot contest [7], which is a robot designed to transport goods to a destination. At present, we are operating by using a display and a controller from a remote location and maneuvering on the basis of camera images mounted on the aircraft. We were examining the method of using VR (virtual reality) so that we could maneuver with a feeling closer to reality. By using the VR technology, you can get the sense of realism as if you are working in the field, and you can expect accurate and advanced work. However, the control technology using VR has the disadvantage that it can’t be controlled while looking at the controller. The control controller will become more complicated if it comes to mount an arm etc. from now on. In order to prevent incorrect operation, it is necessary to simultaneously view the image sent from the robot while viewing the controller at hand.

Therefore, in this paper, by using MR (Mixed Reality) device and projecting the image from the robot's camera on the real space, it is possible to confirm the image without disturbing the visual information of the controller. And develop a new system to make smooth maneuvering possible. First, we assumed a robot connected with a Web camera to a personal computer, and realized a system that can project an image obtained from it to a MR device through a wireless LAN. Second, by actually mounting the MR device and confirming the image actually sent, it was confirmed that there was no problem even if it was applied to the operation of the robot. Finally, we examined and examined the application of this system and the evaluation method of feeling in use.

II. METHODS

A. MR Devise

First of all, MR stands for (Mixed Reality), which is a combined existence of AR (Augmented Reality) and VR.

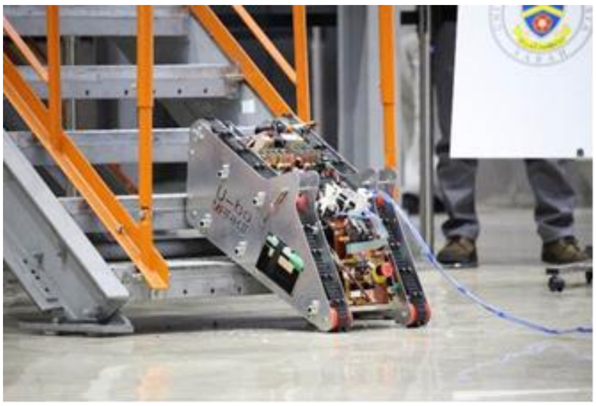

Figure 1. U-bo Mark2.

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As compared with AR displaying a virtual object in real space using a smartphone or the like, and VR displaying a virtual space using HMD (Head Mounted Display), MR has the feature project a virtual object in real space using HMD. As an application example of the MR device, there are visualization of the magnetic field that should not usually be visible [8] and application to navigation during surgery [9]. In this research, we decided to use this device as a visual aid for remote control of a robot. Fig. 2 shows the main body of the MR device. Unlike VR devices, goggles can be seen through. Therefore, the wearer can do various tasks while looking at own hand. Fig. 3 shows the operator wearing the MR device and looking at the projected object.

An example of a MR device is Microsoft's Hololens [10]. The wearable computer released in March 2016 has a built-in CPU and GPU, and can be operated it alone. There is no need for a dedicated controller to operate the device itself, and it can be operated by the movement of the finger, so the operator can keep holding the robot controller at all times. It is designed for developers, and a lot of development materials are available, so we decided to use it in this research. Table I shows the details of the Hololens specification. Fig. 4 shows the image seen from the actually worn viewpoint.

Figure 2. Main body of MR device.

TABLE I. HOLOLENS SPEC.

Wireless LAN	Wi-Fi 802.11ac
Bluetooth	Bluetooth 4.0 LE
CPU	Intel 32bit architecture
GPU	Custom built Microsoft Holographic Processing Unit（HPU 1.0）
Memory	2GB RAM
OS	Windows 10
Battery	2 to 3 hours continuous operation
Weight	579g
Resolution	About 47 pixels per degree

TABLE II. DEVELOPING EQUIPMENT AND ENVIRONMENT.

MR device	Microsoft Hololens
Web camera	logicool C920
Development environment	Unity, Visual Studio
Streaming software	webcamXP 5

B. System Configuration

Fig. 5 shows the system configuration. Think of a PC as a robot and connect a web camera. The purpose is to send the image obtained from the web camera to the MR device. The PC and the MR device are connected by a wireless LAN, and can see the image from the web camera in real time. The development equipment and environment are as shown in Table II.

The development environment is Unity [11]. The actual development screen looks like Fig. 6. Hololens’s OS is Windows 10, so development with Universal Windows Platform (UWP) is effective. UWP is an execution platform for Windows applications that is designed to run on all devices (PC, tablet, Iot devices) that have windows 10 as the OS. Developer can use Visual Studio to develop in various languages such as VisualBasic, C++, C#, Java Script, etc. Once built, it is compiled into CPU-specific binaries (x86, x64, ARM) using a technology called ".NET native". Therefore, the dependency between devices can be eliminated. In addition, the Hololens emulator is also supported, so it is possible to confirm the operation even when there is no actual device, so development is easy. The application created in this research is built for UWP using Unity, and it works by installing it in Hololens as a UWP application from Visual Studio.

We use webcam XP 5 [12] to stream video from webcams. This software can use a webcam as an IP camera. This software can be used to deliver video to the Internet, but it is also possible to easily deliver webcam images to devices in the same LAN environment, so we will use this software in this research. Fig. 7 shows how video from a webcam is delivered.

Webcam XP 5 can compress and deliver video using Motion JPEG codec. By receiving and decoding these in

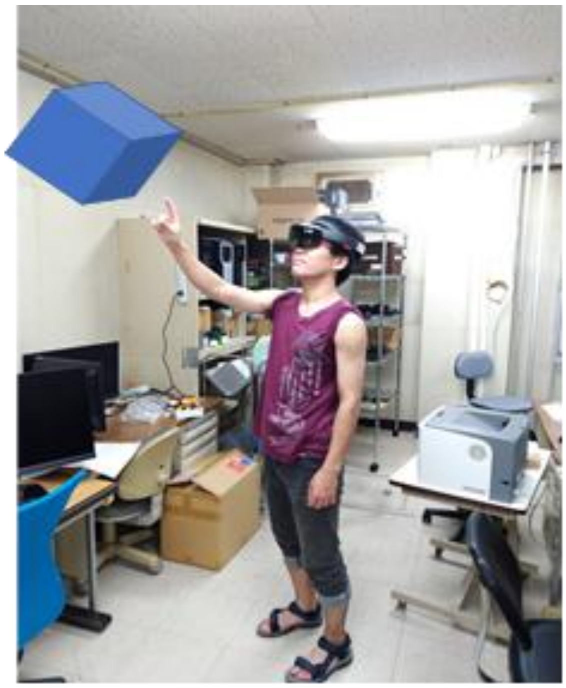

Figure 3. Wearing a MR device.

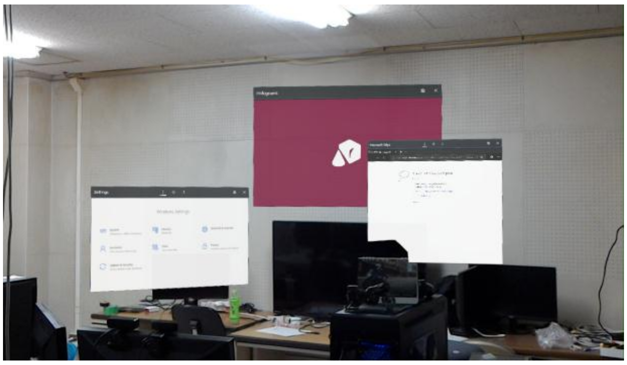

Figure 4. View from device wearer.

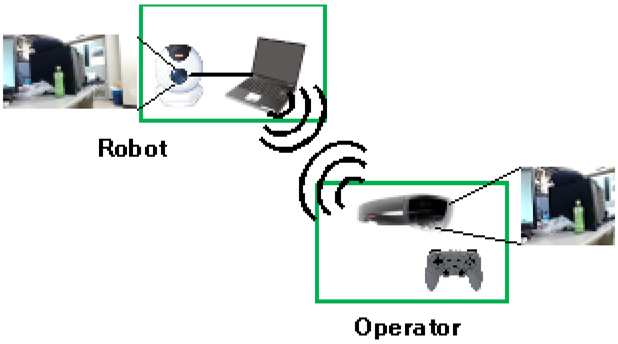

Figure 5. System configuration

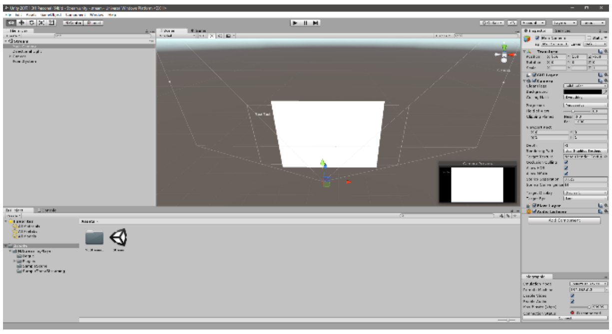

Figure 6. Screenshot of unity.

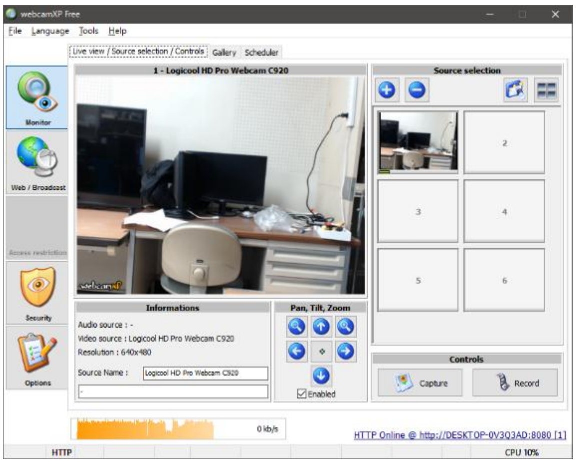

Figure 7. Screenshot of webcam XP 5.

the Unity application, you can check the video on any device. Fig. 8 shows how Unity acquires the video delivered using the webcam and Webcam XP 5. We have developed a system that allows easy access to web camera images by simply entering the IP address of the streaming PC on Unity. Also, it can check the frame rate in real time. The delay is about 0.2 to 0.3 seconds, and the frame rate is about 24 fps. The image size is 640x480 pixels. Although this image size seems to be small, if the image size is increased too much, the delay may become large, which may cause a problem in maneuvering.

With MR devices, you can place objects in real space and make them appear as if it is there. However, when the operator turns the viewpoint in the other direction such as the controller, if the image from the robot camera disappears, a situation where safety can't be checked may occur, leading to an accident. So, this time, we made the image move by following the direction in which the viewpoint is turned. In this way, the operator can check the controller etc. without taking his eyes off the image.

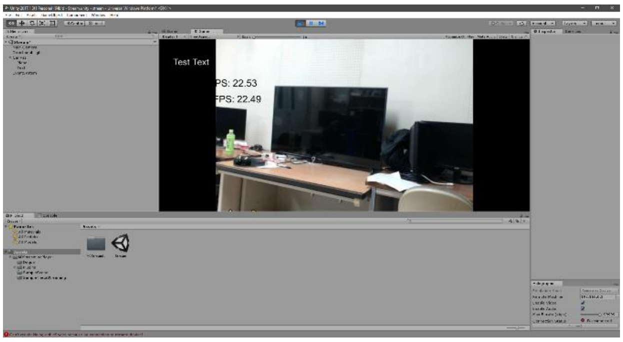

Figure 8. Screenshot of unity streaming from webcam XP 5.

Figure 9. Operator

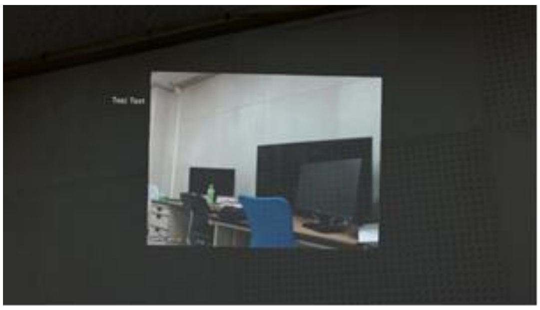

Figure 10. Hololens's view from web camera.

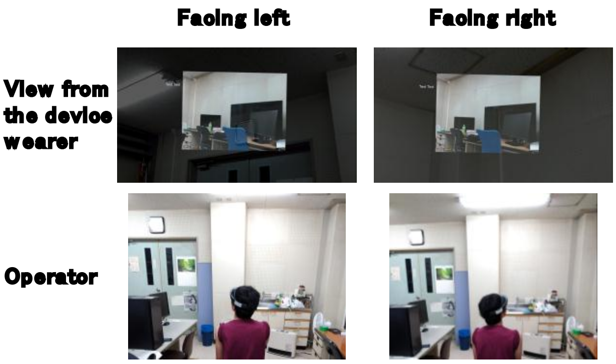

Figure 11. View differences by viewpoint change

III. Result

Fig. 9 and 10 show how an image from a Web camera is checked through Hololens in a created system. The operator can check the image while looking at the controller for robot control.

The delay is relatively low, about 0.2 to 0.4 seconds, and it can be said that there is no significant impact on maneuvering. The frame rate is also kept around 20 fps, which is not anxious. In this research, we could realize a simple remote control system using MR device and Web camera, and could form the basis of the remote control system using MR device in the future. Fig. 11 shows how the image moves following the movement of the head. This allows the robot operator to see the controller at hand superimposed on the image sent from the robot.

IV. Discussion

In this research, we succeeded in projecting the image obtained from the web camera on the MR device. However, it can't be said that the function alone can fully support the operator. For example, if the robot is equipped with multiple cameras, a function to switch the viewpoint is required. As future prospects, it is important to add new functions to the basic system conducted in this research. Therefore, example of the new functions and the evaluation method of the system are shown below.

A. Enhance User Interface

At the present stage, as shown in Fig. 12, a sample text was displayed together with the image of the web camera. However, when actually operating a robot, environmental information such as battery information of the robot, temperature, the connection status of radio waves, etc. become important. If such information can be viewed with the video, the operability will be further improved, and visual information will be utilized to the full.

B. Some Common Mistakes

When using a 360-degree camera, it is possible to view all directions without changing the posture of the robot, so in recent years the usage for robots and drone has increased. If the field of view can be changed according to the movement of the head, the sense of reality will be further enhanced and the operability will be improved. Application technology to robots using VR devices [13] is already present, but application technology to robots using MR devices is novel, as it is unique. Fig. 13 shows an image when a 360-degree camera is actually used.

C. Display Routes Such as Drone

In the case of automatic drone flight, it is necessary to visually check in advance whether there is an obstacle on the route. Robots whose routes are decided in advance as well as drones need to confirm the situation on the site in real time in advance. At that time, as shown in Fig. 14, if the route can be projected to the real space using a MR device, it is possible to confirm the presence of an obstacle visually intelligibly. This method is also effective for operator because it can prevent collisions between robots and obstacles.

D. Pseudo Third Person Viewpoint Using SLAM

If you operate from a first-person viewpoint while checking the image from the camera of the robot, an operator can maneuver with a sense of realism that feels as if you were actually in the field. However, in the case of the first person viewpoint, there is a problem that the sense of distance to the obstacle is difficult to grasp, and the situation in the blind spot is not known. Therefore, in this research, we propose to reproduce the pseudo third person viewpoint using visual SLAM [14] and use it for maneuvering. By mounting a sensor for visual SLAM on a robot, it is possible to create a 3D map of the surrounding environment and reproduce the third person viewpoint in a pseudo manner. Fig. 15 is an image of the view seen by the operator. It is thought that operability can be greatly improved because the operator can easily grasp the positional relationship between the obstacle and the robot if it can be steered from the third person viewpoint. In addition, the driver can use different viewpoints according to the situation by adding the switching function to the first person viewpoint.

E. Evaluation of Operation Feeling

It is very important to evaluate and compare the existing systems, those using displays and VR devices, and those using the proposed MR devices.

Figure 12. The test text is display.

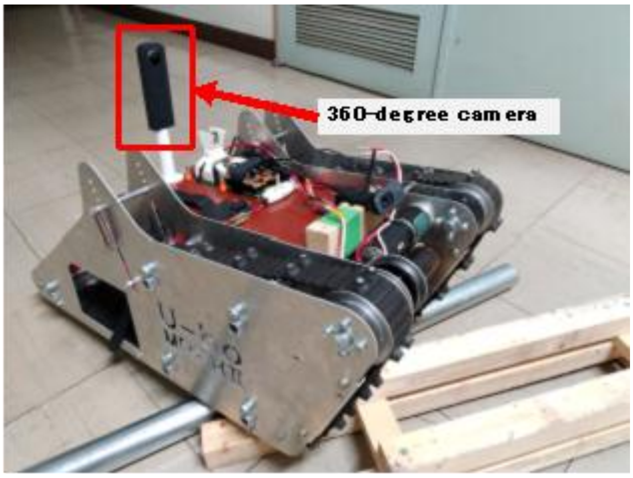

Figure 13. Using 360-degree camera.

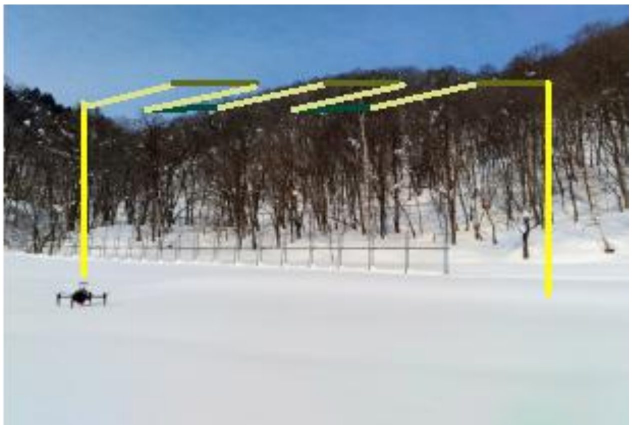

Figure 14. Display drone's automatic flight route.

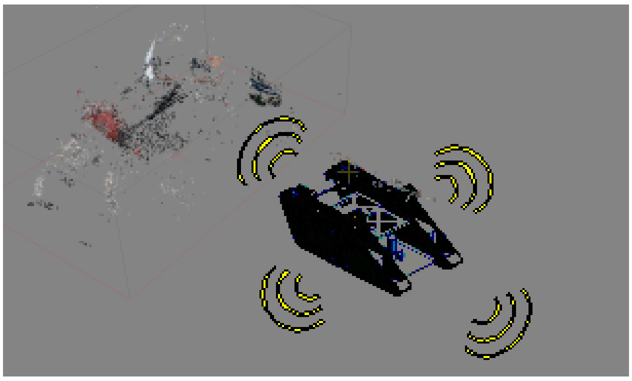

Figure 15. Image of pseudo third person viewpoint using SLAM.

The visual information to be displayed should not interfere with maneuvering or reduce the feeling of operation. Therefore, we are currently considering an index to conduct a quantitative evaluation of the feeling of operation. The CCE (Crossmodal Congruency Effect) [15] can be used to evaluate the sense of oneness between the robot and the operator. This is an index that shows whether or not a sense of unity is obtained from the difference by performing CCE evaluation with the factors affecting operability being changed. Similar to this in this research, we are going to prepare the task of steering, and confirm the usefulness of the MR device by comparing the achievement time between the time when using the display or VR device and the time when using the MR device. As soon as the concept is finalized, we will be actually installed on the robot to evaluate and compare the feeling of operation.

V. Conclusion

In this research, in order to solve the problem that it is not possible to maneuver while visually recognizing the controller by the maneuvering method using VR as the maneuvering method of the robot, we developed the maneuvering support system using MR device. By using the MR device, both the robot's viewpoint and the controller at hand can be checked simultaneously. Then, in consideration of mounting on the U-bo series, which is a decommissioning robot, the image from the web camera mounted on the robot is projected onto the MR device through the wireless LAN, with low delay (0.2 to 0.4 seconds). It was confirmed that smooth video (20 fps) could be transferred. In this way, the robot operator can maneuver while simultaneously checking the image sent from the robot and the controller at hand. In this research, a simple remote control system using MR device and Web camera could be realized, and the basis of the future operation system using MR device could be created. In addition, we examined how to strengthen the user interface, devise examples of application to a 360-degree camera, and compare with existing systems (methods using VR devices).

In the future, we plan to develop and implement the application examples of this system we have studied, and to improve the whole system.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

N. Igo, Y. Nagase, R. Hanabusa and T. Satake constructed the algorithms of the research. N. Igo and Y. Nagase conducted the research. Y. Nagase, R. Hanabusa and S. Mitsui created the programs for the experiments. T. Satake and S. Mitsui created the hardware used for the experiments. Y. Nagase, R. Hanabusa and S. Mitsui performed the experiments.

All authors were involved in the drafting of the manuscript. All authors had approved the final version.

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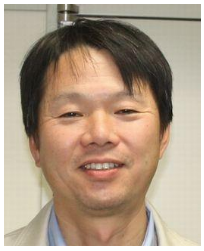

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