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Multiplatform of SVC Device for User Experience Mobile Robot Teleoperation

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Abstract

The industrial revolution 4.0 and the rapid advancement of technology during pandemic era has made significant progress in robot industry. There are three types of robots based on the level of independent control such as autonomous mobile robots, semi-autonomous mobile robots, and controller mobile robots. Semi-autonomous mobile robot and Controlled mobile still require human intervention in carrying out the tasks. In this study, teleoperation on mobile robots is displayed on various platforms such as Smartphone, Virtual reality headset as a virtual reality platform, and Computer (SVC) device. A camera is used as a visual sensor that dispatches the information of the surroundings to each platform. The controller used for the teleoperation varies depending on the platforms. The computer platform uses the arrow key on the keyboard. The smartphone platform uses touchscreen. Virtual reality uses Oculus Touch that has been integrated with Oculus Quest 2. ROS# as a robot API framework with Unity engine is used for the communication process between the robot and each platform. Teleoperation Experiments on SVC devices refer to four parameters including task completion rates, task time, satisfaction, and error counts. all these parameters will be combined into a single usability metric (SUM). The SUM results from SVC devices show 54.9% on Smartphones, 79.5% on VR devices, and 90.4% on Computers.

A. Introduction

The industrial revolution 4.0 and the rapid advancement of technology during pandemic era has made significant progress in robot industry[1]–[6]. Several robots developed to assist human in handling the covid suspects without having a direct contact[7]–[12] . There are several applications for robots such as robot rescue[13]–[17], military robot[18]–[22]. There are three types of robots based on the level of independent control such as autonomous mobile robots, semi-autonomous mobile robots, and controller mobile robots. Autonomous mobile robots have full control capabilities without human assistance[23]–[28]. Semi-autonomous mobile robot[29]–[33] and Controlled mobile robot still require human intervention in carrying out the tasks. They needed to be controlled from either short distance or long distance which also known as teleoperation. In running the teleoperation, various communication devices are developed to help the user in controlling the robots from a distance. Initially, infra-red was used to control robots at short distance. Subsequently, another communication device used to control the robots at a wider range such as, Bluetooth [34]–[42], Wi-Fi [43]–[48], and a combination of Wi-Fi and Bluetooth[49].

There are several studies related to control in robot using joystick including Rahman *et al*. [50], Prabhakar *el al*.[51] and smartphones including Irawan *et al.* [52], Chamim *et al*. [36] Nadvornik *et al.* [53] and El-Fakdi *et al*. [54]. However, those studies do not provide camera visualization for the user. That becomes important if the user cannot see the robot directly. Several studies have displayed visualizations of robot teleoperation using computer displays including Zhang *et al.* [55]who created a rescue robot and then, Senft *et al.* [56] makes telemanipulation on the robotic arm. Apart from using computers, some studies use smartphones for camera visualization including Ainasoja *et al*. [57], and using augmented reality also virtual reality headset for camera visualization including Dardona *et al*. [58], Gonzalez *et al*. [59], Kot *et al*. [60], Wibowo *et al*. [61], Stotko *et al.* [62], Solanes *et al.* [63], and Doki *et al.* [64]. Those studies display a visual camera on teleoperation on each platform so that users can see the environment around the robot. Teleoperation on those robots is used in various fields such as rescue robots, military robots, and industrial robots. However, those studies only use one platform for teleoperation, so they cannot compare the user experience between one platform and another.

In this research, teleoperation to control a mobile robot uses a smartphone, virtual reality device and computer (SVC) device. The camera functions as a visual sensor on the mobile robot and appears on the SVC device display. The controller used for the teleoperation varies depending on the platforms. The computer platform uses the arrow key on the keyboard. The smartphone platform uses touchscreen. Virtual reality uses Oculus Touch that has been integrated with Oculus Quest 2. The communication process between robots and SVC devices uses the robot API framework in Unity called ROS#.

B. Research Method

This research used ROS (Robot Operating System) as a library to run the robot dan Unity Engine to build the teleoperation software. ROS# (ROS Sharp) used as a communication tool between ROS and Unity. The broad outline of the teleoperation between the mobile robot and the SVC device used can be seen in Figure 1. Roscore is used to collect all nodes and process communication between nodes. The robot used in this research is Turtlebot 3 equipped with Raspberry Pi Camera (G) fisheye lens. This camera serves as a visual sensor that dispatches information about the surroundings to the user.

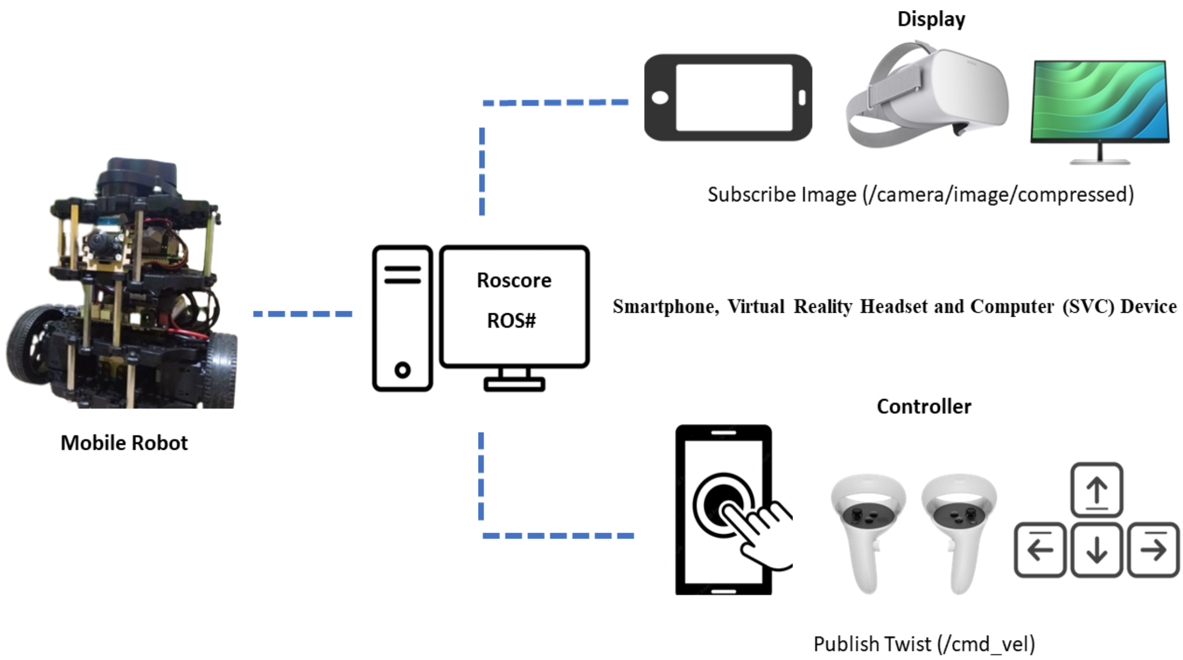

Figure 1 The Diagram of Mobile Robot Teleoperation Using SVC devices

For smartphone platforms, touchscreen display is used to visualize the image from the robot camera and to control the robot. For the virtual reality headset platform, the head-mounted display on Oculus Quest 2 (now called Meta Quest 2) is used to visualize images from the robot camera and Oculus Touch is used for robot movement. For the computer platform, a computer monitor is used to display visualization of the camera image, and arrow keys on the keyboard are used to control the robot's movement.

For communication between robots and SVC devices, there are several topics sent via Rosbridge. Rosbridge allows devices to send JSON to subscribe or publish a node. The camera node will be subscribed by the SVC device via the /camera/image/compressed message. The subscribed image can be displayed on the SVC device as the visualization of the robot's environment. SVC devices publishes twist nodes to mobile robot via the /cmd_vel message. The twist node sent to the mobile robot will determine the robot's movement. visualization of each topic and node in the system can be seen in Figure 2.

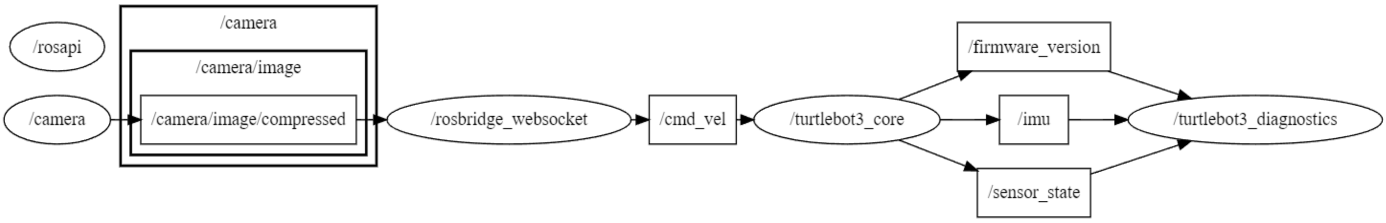

Figure 2 ROS Graph Visualization in the system

C. Result and Discussion

SVC devices can display captured images from mobile robot cameras. This captured image appears on every screen on each platform. Figure 3 shows the smartphone can display mobile robot camera captures. Camera capture can also run in real time on a smartphone. On the smartphone device, mobile robot movement control is placed on the touchscreen button. The two buttons on the left control the forward and backward movement of the mobile robot. The two buttons on the right control the right and left turning movements of the mobile robot. Those four buttons can move the robot in real time both forwards and backwards as well as turning right and left.

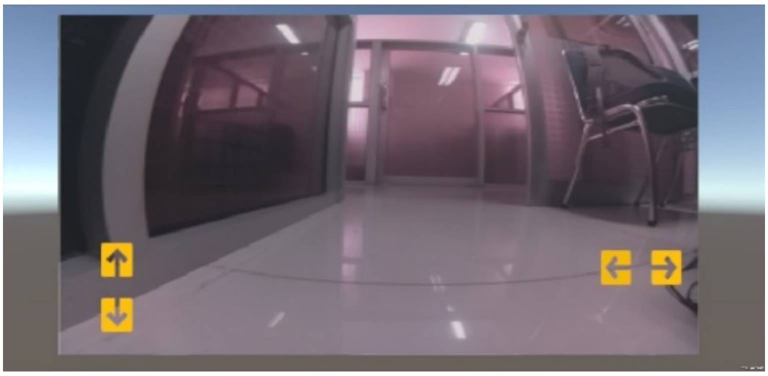

Figure 3 Screen Display on Smartphone

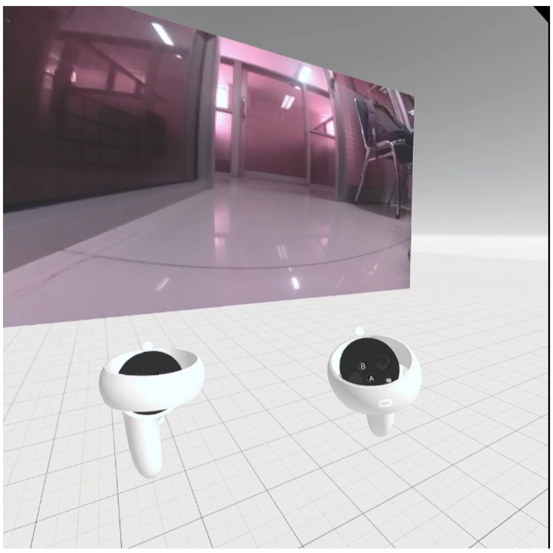

Figure 4 Screen Display on Virtual Reality Device

Figure 4 shows the camera capture displayed in the virtual reality application. On the virtual reality device (Oculus Quest 2), the robot control process is located on the oculus touch, especially on the right thumb stick. In the experiment, the image from the camera and control of the mobile robot on the integrated Oculus Touch can run in real time. Figure 5 shows the computer can receive camera captures from the mobile robot. On a computer device, the movement of the mobile robot is controlled via the keyboard, especially the arrow keys. From the experiment, the camera display and mobile robot control can run in real time.

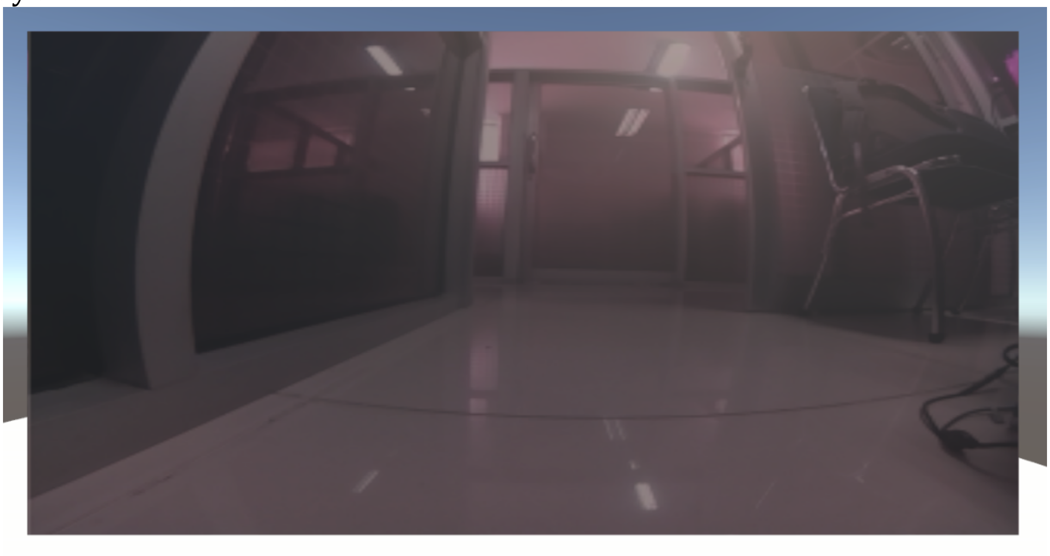

Figure 5 Screen Display on Computer

The experiment in this study used a single usability metric (SUM) to determine the level of usability of teleoperation devices. There are four items used in measuring the single usability metric, including task completion rates, task time, satisfaction, and error counts. Task completion rates show how much the user can complete the task given in the experiment. Task time measures how quickly the user completes the task given in the experiment. There is also a measurement of user satisfaction in controlling the robot on each platform. And there is also a calculation of the number of errors made by the user when using each device.

This usability testing involved seven people aged between 18 and 22. All users often use smartphones and computers but never use virtual reality devices. Figure 6 shows the trajectory of a mobile robot controlled by users. Time and errors from start to finish will be recorded and included in the SUM calculation. The error is calculated when the robot hits the line on the trajectory. After the user successfully controls the mobile robot with all SVC devices, the user will be given a survey to measure user satisfaction in controlling the robot. This level of user satisfaction will also influence the score of the SUM calculation. Table 1 displays the results of the SUM calculation.

The average SUM score on smartphone devices is 54%, 37% on the low score, and 64.1% on the high score. The test results with a smartphone got the lowest score. That's because there is a delay when using a smartphone as a controller device. These results can increase task time and lower user satisfaction scores. Apart from that, the small screen size makes it difficult for users to control the mobile robot.. The number of errors during testing is almost the same as testing using other devices. On Virtual Reality Device, the average SUM score is 79.5%, 61.8% on the low score, and 88.1% on the high score. These result is higher than Smartphone device SUM results but lower than computer device SUM results. On a virtual reality device, there is no delay when performing teleoperation, however users is still not used to using a virtual reality device, so the time needed for users to complete the task is slightly slower than on a computer. Teleoperation using a computer has the highest SUM score with an average of 90.4%, a low score of 74.6% and a high score of 95.4%. This score is obtained because the user is used to using the computer and there is no delay when the user performs teleoperation using the computer.

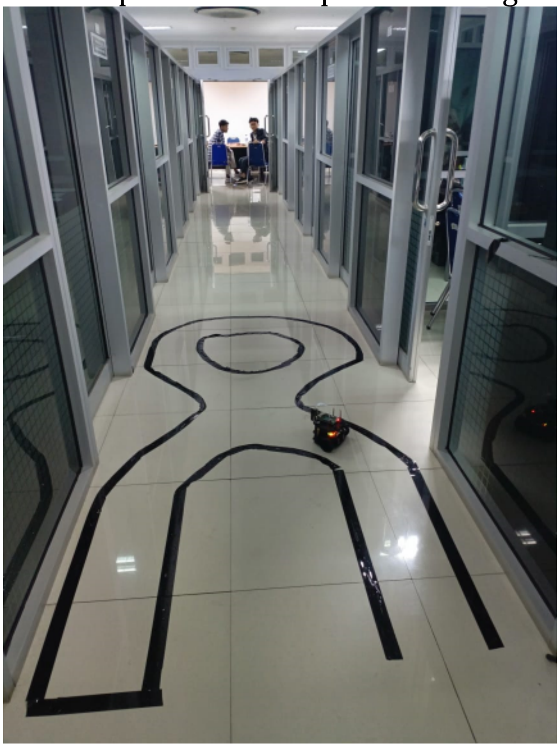

Figure 6 Controlled Mobile Robot Trajectory

Table 1 SUM Calculation Results

Device	Low	Average	High
Smartphone	37.0%	54.9%	64.1%
Virtual Reality Device	61.8%	79.5%	88.1%
Computer	74.6%	90.4%	95.4%

D. Conclusion

This research controls a mobile robot remotely using Smartphone, Virtual Reality, and Computer (SVC) devices. ROS# (ROS Sharp) used as a communication tool between ROS and Unity Engine. Mobile robots use cameras to provide visual displays to users. The controller used for the teleoperation varies depending on the platforms. SVC devices can display captured images from mobile robot cameras. On the smartphone device, mobile robot movement control is placed on the touchscreen button. On the virtual reality device (Oculus Quest 2), the robot control process is located on the oculus touch, especially on the right thumb stick. On a computer device, the movement of the mobile robot is controlled via the keyboard, especially the arrow keys.

This experiment used a single usability metric (SUM) to determine the level of usability of teleoperation devices. There are four items used in measuring the single usability metric, including task completion rates, task time, satisfaction, and error counts. The smartphone device has the smallest SUM score because there is a delay when the user uses it. SUM score of Virtual Reality Device result is higher than Smartphone device SUM score but lower than computer device SUM score. That's because virtual reality devices have no delay but are rarely used by users compared to computers. The highest SUM score in the study was when the user used a computer device because there was no delay and it was familiar to the user.

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