Analysis of VR Usability in Mobile Manipulator Teleoperation

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Abstract—**Hazardous materials incident responding and explosive ordnance disposal (EOD) are two of mobile manipulators' most common deployment areas. Most of the time, these incidents happen in open environments and even ruin structures. Therefore, teleoperation is still the dominant robot control method. However, a direct line of sight can be limited. This study includes an experiment demonstrating a virtual reality device application in a real-world mobile manipulator EOD mission. The result support the feasibility of teleoperating a mobile manipulator using VR to complete complex missions.**

Index Terms—**VR, teleoperation, mobile manipulator**

I. Introduction

In response to hazardous material (HAZMAT) incidents and explosive ordnance disposal (EOD) tasks with high risk levels, which can potentially cause harm to the human first-responders, a defensive response strategy is usually preferred. However, in certain HAZMAT and EOD incidents, an offensive strategy is needed to isolate or stabilise an incident and prevent a chain reaction [1]. Therefore, having robots, specifically mobile manipulators, replacing human labour in these cases can reduce the risk level for human responders. However, the complexity of missions and the uncertainty of the open environment creates hardships for autonomous systems and makes teleoperation the first choice of control method. Therefore, an efficient teleoperation system is critical for mission success.

Furthermore, in these applications, the robot operator needs to keep a safe distance from the subject and subsequently does not have a direct line of sight. Therefore, the visual feedback needs to be provided to the robot operator in an alternative form. RGB-D cameras can represent both coloured 2D imaging and distance data, and VR can efficiently present multiple forms of information to the operator [2] without limiting the operator's orientation and body movement.

Among these teleoperation technologies, the gamepad is used with the advantage of being low cost. However, more recent studies have investigated the approach of using human body movements to teleoperate a robot with motion capture technology [3]. Compared to the traditional gamepad, the motion capture technology has advantages in manipulation movement [4], therefore, it is more suitable for EOD tasks [5]. On the other hand, compared to the wheeled manipulator, the quadruped manipulator [6] can conquer a broader range of terrain and structures.

In this study, we have built the experiment setup based on our previous work [6], where a legged manipulator and a motion capture system were integrated for teleoperating locomotion and manipulation movement simultaneously. By introducing an RGB-D camera on the robot and a VR system for the teleoperator to perceive the visual feedback from the robot, the system can perform tasks where direct line of sight is not available. Three volunteers performed a EOD task experiment with direct line of sight and then using the proposed VR system. The performance is compared through completion time, and usability is evaluated through participant feedback.

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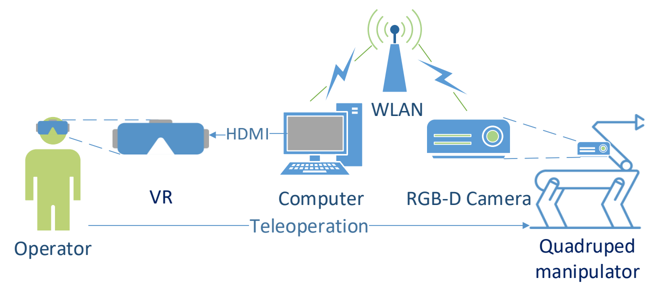

Fig. 1: The structure of the visual feedback system used in the experiment.

II. System Overview

As illustrated in Fig. 1, the developed remote visual feedback system is composed of three parts, the RGB-D camera on the robot, the processing computer, and the VR device.

A. RGB-D Camera

In this study, an Intel RealSense D435 RGB-D camera is installed on the side of the robot arm for a third-person view. The camera is mounted on the base joint of the arm, where it is coupled with the yaw rotation of the arm. The camera generates a coloured 3D depth point cloud from a 2D colour image and the depth sensor. This information is then sent to the computer.

B. Processing Computer

In the proposed system, a computer collects input from the camera through a wireless LAN (WLAN) network, as shown in Fig. 1. Then, the computer combines the coloured 3D depth point cloud with the directly mapped 2D image placed overhead. The combined signal is then sent to VR together.