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Design Principles and Applications of Virtual Telepresence Robots: A Comprehensive Review

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Abstract

The primary objective of this project is to develop an advanced virtual telepresence robot system that facilitates remote communication and collaboration in various environments. Through the integration of cutting-edge robotics, sensing, and communication technologies, our virtual telepresence robot enables real-time interaction between users located at different physical locations. This technology combines wireless connectivity, robotics, and user interfaces to provide people with an immersive experience. This study explores the development, functionality, applications, and future possibilities of virtual telepresence robots. By leveraging the power of interconnected devices and real-time communication, our system contributes to the evolution of telepresence technology, offering new possibilities for remote interaction and engagement in the digital age. The system aims to enhance human presence and engagement in remote scenarios, offering a seamless platform for individuals to interact and collaborate irrespective of geographical constraints. We hope to demonstrate how this technology is changing several industries, such as healthcare, education, business, and personal communication, through a thorough analysis. With the advancement of technology, virtual telepresence robots represent a significant innovation in remote communication and collaboration. Robots that simulate telepresence are transforming remote communication by allowing people to be physically present in far-off places without being there.

Keywords: Raspberry Pi, telepresence robots, Wi-Fi technology, remote communication, Bluetooth, technology, NodeMCU

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INTRODUCTION

A wheeled, remote-controlled gadget with wireless internet connectivity is called a telepresence robot (Wi-Fi technology). Usually, the robot streams videos using a smartphone and provides details on the environment in which the robot is positioned. There is a greater need than ever for efficient remote communication solutions in our increasingly interconnected world. Robots that simulate telepresence and deliver a physical presence in remote areas offer a solution. With the cameras, microphones, and speakers built inside these robots, users can see, hear, and interact with their surroundings in real time. Virtual telepresence robots are becoming more and more popular because of their ability to promote accessibility to

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services and experiences that would otherwise be out of reach for people with mobility or distance-related problems, improve cooperation among team members, and bridge geographical distances.

In virtual presence, the remote environment is constructed artificially, making it a specific case of telepresence. The Raspberry Pi and camera are interfaced, enabling the camera to record and live stream video. Furthermore, Node MCU operates a robot by means of a motor driver. Additionally, we can order the robot in any direction by utilising a smartphone application to operate it. However, it can be difficult for people without much experience to operate and navigate these robots without a map of the distant area [1].

Usually, the robot's voice and video capabilities come via a smartphone provides surroundings information. In virtual presence, the remote environment is constructed artificially, making it a specific case of telepresence. The Raspberry Pi and camera are interfaced, enabling the camera to record and live stream video. Additionally, an Arduino UNO is used to operate a robot using a motor driver. Additionally, we may direct the robot in any direction by utilising a smartphone application to operate it [2].

RESEARCH PAPERS' OVERVIEW

The following list comprises the research papers that served as sources for our Virtual Telepresence Robot project:

Reshma *et al*. discussed a brand-new virtual telepresence robot with the added capability of head movement control, which can be utilised for both military and educational applications as well as dangerous occupations like mining [1]. Robots used in mining and defence can withstand harsh environments with ease. A camera records the head movement of the robot, which is controlled continuously by an accelerometer. This allows the user to see the virtual telepresence robot in real time, just as if they were there for the live stream video. The experiments' findings indicate that user can manipulate robots [1]. Robots that perform telepresence can be compared to mobile, embodied video conferences. These robots' manufacturers see a wide range of applications for them, such as spontaneous office discussions, factory inspections and troubleshooting, and patient rounds at healthcare facilities. Using two prototype robots (Anybots' QB and VGo Communications' VGo), Katherine *et al*. conducted a series of tests [2]. The usefulness of telepresence characteristics for both outdoor and indoor beyond-line-of-sight robot reconnaissance missions was investigated in two tests. In the first trial, soldiers used two controllers, one with telepresence capabilities and the other without, developed by TNO Human Factors, to operate a reconnaissance robot. Telepresence features included a head-mounted camera that followed the movements of the operator and a stereo visual display [3]. The survey by Abuatiq *et al*. provides a comprehensive overview of virtual telepresence robots, covering their technological advancements, diverse applications across industries, and the challenges hindering their widespread adoption [4].

A survey of the literature on advancements facilitating robotic social interactions was given by Almeida *et al.* This helped to enhance the experience of co-presence and presence through robot mediation. Almeida *et al.* sought to categorise "co-presence" mechanisms, define social presence and co-presence, and identify autonomous "user-adaptive systems" for social robots [5].

The survey paper by Elliott *et al*. reviews recent advancements in virtual telepresence robotics, including state-of-the-art technologies, emerging trends, and promising applications, offering insights into the current landscape of the field [3]. The paper by Abuatiq *et al*. focused on healthcare applications, this survey explores the use of virtual telepresence robots for remote patient care, medical consultations, and training, while also discussing future directions for research and development [4]. The survey by Almeida *et al.* examines user experience and interaction design considerations in virtual telepresence robots, discussing human-robot interaction modalities, design principles, and factors influencing user acceptance and satisfaction [5]. The paper by Kristoffersson *et al*. focused on security and privacy concerns, this survey assesses the vulnerabilities and risks associated with virtual telepresence robots, while also exploring potential mitigation strategies and regulatory frameworks [6].

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The possibility of using NARS with telepresence robots was examined by Tsui *et al*. They carried out three experiments where participants interacted with telepresence robots (n=12), controlled telepresence robots (n=38), and watched movies of telepresence robots (n=70) [7, 8]. A narrative assessment of the literature detailing experimental MTR investigations with senior citizens during the past 20 years, including the COVID-19 period, was carried out by Isabet *et al*. [9]. Du *et al*. created a robotic telepresence system that uses a specially made mobile robot to provide distant users an immersive embodiment in local settings [10]. Charteris *et al*. present a conceptualization of virtual inclusion by drawing on the body of literature already in existence regarding the usage of telepresence robots [11]. Yeonju presented a brand-new mobile robot teleoperation interface that shows how a virtual reality (VR) gadget combined with a robot-assisted remote telepresence system may be used in a virtual tour setting [12].

BLOCK DIAGRAM OF PROPOSED SYSTEM

The block diagram of VTR project is presented in Figure 1. Start the power bank/on the supply. Raspberry pi 3 B+ module and Arduino uno will be on. The camera module relates to the Raspberry pi module and the rotation of camera is done with the help of motor. The navigation and live video streaming starts, and we were able to see this on screen with the help of WI-FI. Arduino relates to the motor driver and Bluetooth HC05. Here the control of robot is done with the help of an android app which relates to the Bluetooth module HC05.We can also rotate the camera angle with the use of android app.

Many cutting-edge technologies are coming together to create virtual telepresence robots. Real-time communication interfaces, multidirectional microphones, high-definition cameras, and a mobile robotic base are important parts. Robots are often propelled by wheels or tracks that are remotely controlled online. With a variety of input devices, including PCs, tablets, and smartphones, users may control the robot and see their surroundings via the camera stream. These robots are primarily designed to offer a smooth telepresence experience. Live footage is recorded by high-definition cameras and broadcast to the user's device. Natural discussions are made possible via two-way audio communication facilitated by built-in microphones and speakers. Moreover, some sophisticated versions come equipped with robotic arms for object engagement, obstacle recognition, and autonomous navigation.

HARDWARE REQUIREMENTS

Raspberry Pi 3 Model B+

Raspberry Pi is a series of small single-board computers, i.e. it is a computer, just like a desktop, laptop, or smartphone, but built on a single printed circuit board as shown in Figure 2. The Raspberry Pi 3 Model B+ was launched in March 2018. It contains an integrated 802.11ac/n wireless LAN, a 1.4 GHz 64-bit quad-core Arm Cortex-A53 CPU, 1 GB RAM, gigabit Ethernet, and Bluetooth connectivity 4.2.

Arduino UNO

According to the datasheet, the Arduino Uno is a microcontroller board built around the ATmega328. It features a 16 MHz ceramic resonator, 6 analogue inputs, 14 digital input/output pins (six of which can be used as PWM outputs), a USB port, a power jack, an ICSP header, and a reset button as shown in Figure 3. It comes with everything required to support the microcontroller; all you need to do is power it with an AC-to-DC adapter or connect it to a computer with a USB cable to get going.

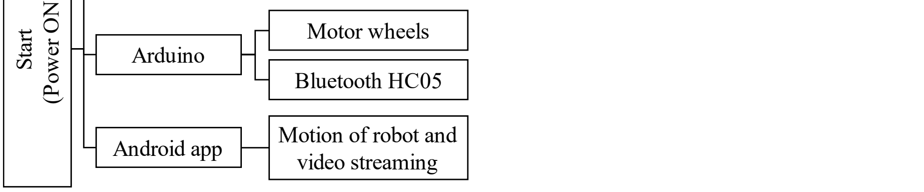

Figure 1. Block Diagram of the proposed system.

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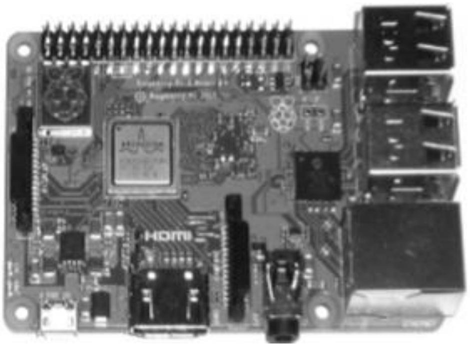

Figure 2. Raspberry Pi 3.

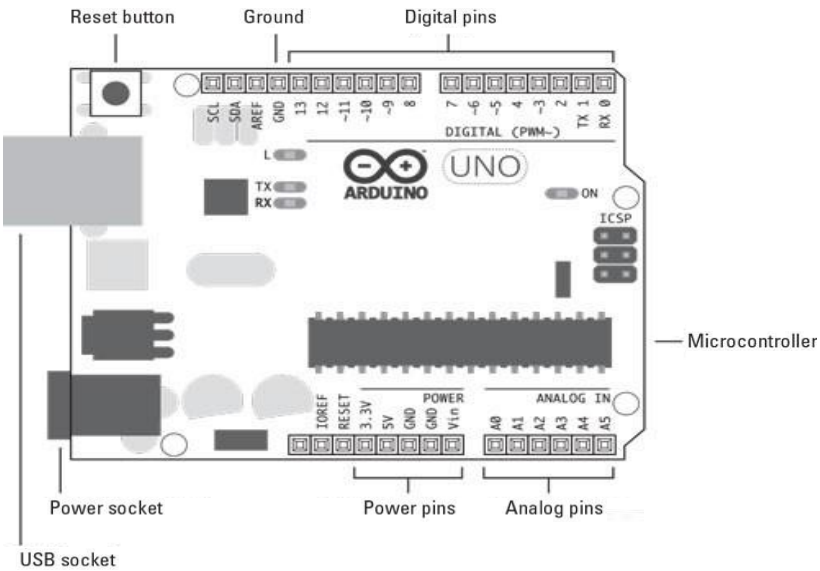

Figure 3. Arduino uno.

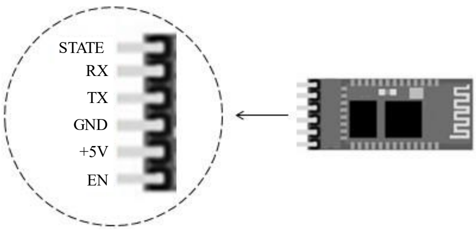

Figure 4. Servo motor.

Servo Motor

A servo motor is a kind of electric motor that, in response to an input signal from a controller, can rotate or move to a particular location, speed, or torque as shown in Figure 4. This is in line with the traditional application of servo motors as backup drives to support the primary drive system.

Bluetooth Module

HC-05 is a module that supports wireless communication through Bluetooth technology. It is possible to use this module as a slave or master configuration as shown in Figure 5. All serial-enabled devices can use Bluetooth serial modules to interact with one another.

L293D Motor Driver

Typically utilised to regulate the motors in an autonomous system, an integrated circuit (IC) has the capacity to drive two motors at once as shown in Figure 6.

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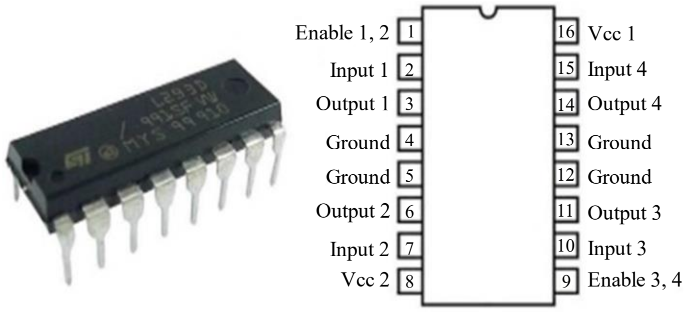

Figure 5. Bluetooth module.

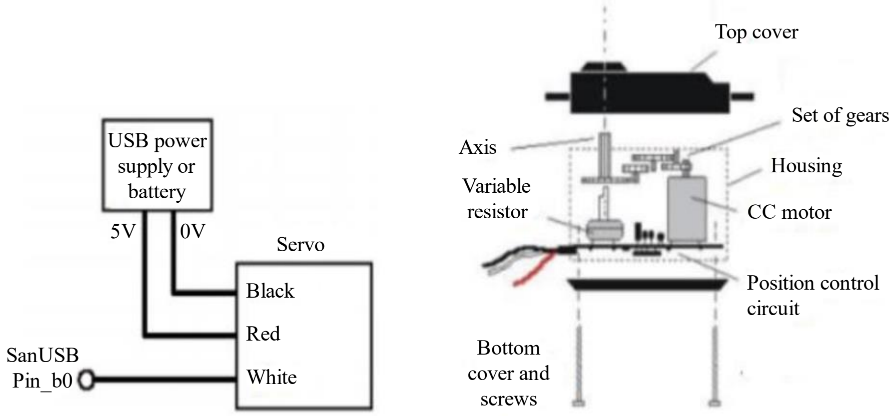

Figure 6. Motor driver.

Figure 7. Camera module.

CAMERA MODULE

Webcams, short for “web cameras”, have become an integral part of modern computing and communication technology. Among the various webcam options available in the market, Logitech Digital Webcam stands out as a reliable and feature-rich choice, offering users a seamless experience for their video communication needs. One example is shown in Figure 7.

SOFTWARE REQUIREMENTS

The important programming language and software are used as follows:

- Python and C language;
- Thonny IDE and Command line; and
- Arduino UNO IDE.

CONSTRUCTION

Virtual telepresence robots are created and used through several methodological steps: To produce a prototype that satisfies the required standards for mobility, communication, and user interface, engineers and designers work together.

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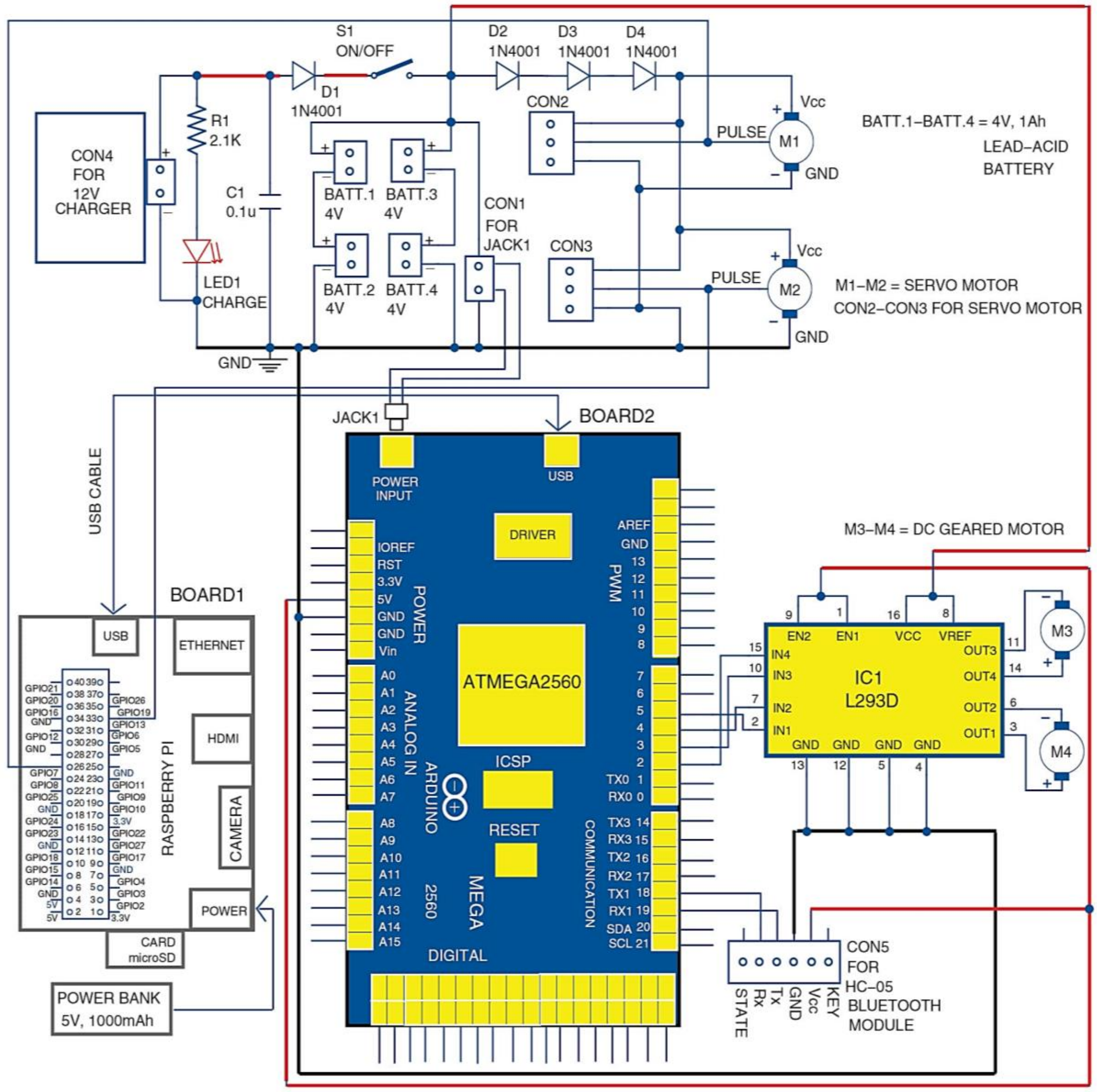

Figure 8. Circuit diagram of VTR.

The robotic platform incorporates hardware like cameras, microphones, speakers, and sensors. It is vital to guarantee smooth communication amongst these constituents. One of the most important steps is creating software that will operate the robot, interpret audio and video input, and offer an intuitive user interface. This entails setting up the communication and navigation protocols for the robot. To find and fix any problems, prototypes are put through a thorough testing process. Incorporating user feedback helps to improve the functionality and design. The graphic below displays the virtual telepresence robot's primary circuit diagram. The following components make up the project: servo motors, DC geared motors, Bluetooth module, Raspberry Pi board, Arduino UNO board, and 12 V charger. You also need an Arduino sketch for an Arduino board, Python programmes for a Raspberry Pi, and an Android smartphone with the necessary apps. The circuit diagram for the VTR is shown in Figure 8. After everything is in order, the robots are put into service. To maintain optimal performance, software upgrades and ongoing maintenance are required.

RESULT

After assembling the hardware and installing and running the software we successfully demonstrated that the telepresence robot provides us the video streaming in the direction of our requirement as shown in Figure 9.

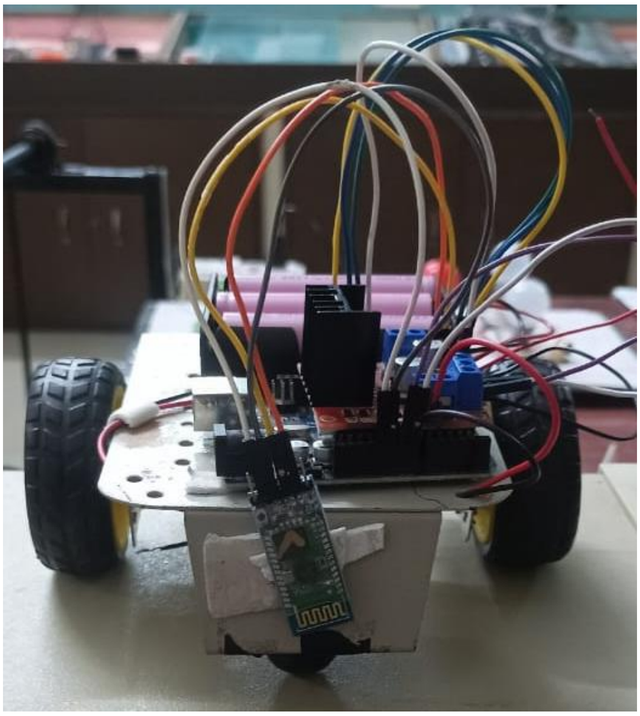

Figure 9. Prototype of the proposed system.

CONCLUSION

- This robot can enable its users to remotely interact with and observe the people and their surrounding without being physically present there themselves.
- These robots can change dynamics of countless domains: they can provide homecare assistance to the elders and even facilitate virtual attendance for physically challenged students.
- In businesses, these robots can significantly reduce the need for travelling for meetings.
- Thus, the virtual telepresence robot is a simple, cost-effective and efficient solution to multiple real-world problems.

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