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Real-Time Remote-Controlled Human Manipulation Medical Robot Using IoT Module

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Abstract

INTRODUCTION: Innovative robotics and advanced computer vision technology converge in the Human Manipulation-Controlled Robot, utilized for medical applications. The robot operates through human gestures, and includes a camera module for real-time visual feedback, enhancing its functionality and user interaction.
OBJECTIVES: The primary goal of the research was to harness the natural expressiveness of human gestures to provide a more intuitive and engaging method of controlling medical robots. The focus is on enabling precise control through programmed responses to specific gestures, ensuring effective interaction with medical tasks.
METHODS: The robot's hardware configuration consists of a mobile platform with motorized components, an ESP32 module, gesture recognition sensors and a camera modules. The ESP32 module interprets signals from gesture recognition sensors to execute precise commands for the robot's movements and actions. Simultaneously, the camera module captures live footage, providing visual feedback through an intuitive interface for seamless interaction.
RESULTS: The Human Manipulation-Controlled Robot has been successfully developed, featuring a fetch arm capable of autonomous movement and object manipulation. This research address critical needs in medical centers, demonstrating the feasibility of using only minimalistic EEG electrode wireless transmission to operate a robot effectively.
CONCLUSION: Through the provision of a more intuitive and engaging method of controlling and interacting with medical robots, this innovation has the potential to significantly improve user experience and operational efficiency through advanced human-robot interaction techniques.

Keywords: IoT, Robotics, Healthcare, Remote.

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1. Introduction

Study of IoT-based human manipulation-controlled robots requires a thorough analysis of the field's current research, technology, applications, and challenges. We delved deeply into the latest advancements and emerging developments in IoT-based medical robots [1, 2] to examine how remote control and data interchange for robots could be utilized in a practical setting.

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Bio signals refer to signals generated via the combination of electrical and mechanical potentials, or those acquired directly from the human body. Among these bio signals, the brain produces complex electric signals that are pivotal in the diagnosis of medical illnesses and underlying issues [3].

The brain consists of billions of neurons that interact with one another via electrochemical signals transmitted via synaptic fibres as ionic currents. These neural activities generate voltage fluctuations known as neural oscillations or brain waves [4].

Neuronal fluctuations manifest in two distinct states: the up state involves neuronal depolarization and action potential firing, while the down state corresponds to resting activity and hyperpolarization. These oscillations are substantial, and can even be detected outside the brain and skull [5].

The electrical activity of the brain can be recorded using scalp electrodes, enabling subsequent examination, validation, comparison, or visualization. These brain waves repeat at a rate of 30 to 100 cycles per minute, and these cycles are referred to as frequencies, measured in Hz [6].

BCI (Brain-Computer Interface) has captivated researchers for years, progressing most recently as a result of rapidly evolving technology, such as neural networks, artificial intelligence, and machine learning. These advancements enable more accurate study of brain activity, potentially harnessing an individual's emotions and thoughts to directly operate a machine or robot in the outside world [7].

Gesture control explores human manipulation and its role in human-robot interaction, with a focus on how it may be used to communicate more naturally and intuitively with robots. There are many sensors, including cameras, IMUs, and ultrasonic sensors, which can be used within these interactions [8].

For over a decade, robots have been utilized in the medical sector for a variety of purposes, including surgery, therapeutics, rehabilitation, telemedicine, disinfection, pharmacy, and companionship. Miniaturization and artificial intelligence have further accelerated the rate of adoptions of new developments in the field. Healthcare robots can be categorized into those which assist or support patients in their lives, and those deployed within medical facilities and homes [9]. IoT communication modules (such as Wi-Fi, Bluetooth, and cellular technology) facilitate remote control of robots via network connectivity.

The gesture recognition algorithm explores various approaches, such as computer vision, machine learning, and pattern recognition, used to interpret hand movements. Methods for gesture recognition based on computer vision include techniques such as image processing and deep learning, which enable IoT-based robots to recognize human manipulations. The process of integrating data from multiple sensors (e.g. cameras and IMUs) enhances the robustness and accuracy of gesture detection. Machine learning can adjust to user-specific motions in contrast to methods which use predetermined gesture patterns [10].

Gesture data and control instructions are transferred between robot and remote interfaces using popular communication protocols like MQTT, Web Socket, and RESTful APIs. Real-time and low-latency communication is necessary for effective robot control [11]. The research uses two motor driver shields (L239N) to precisely control the motion of the four gear motors [12].

An ESP32 was used, which simplifies overall circuit design and reduces the complexity of wiring and circuits. Additionally, a camera was included to capture images and provide users with a real-time perspective from the robot's point of view [13, 14].

The innovative concept blends gesture detection and remote viewing capabilities for an enhanced and engaging robotic experience. The Internet of Things (IoT) facilitates seamless human-machine communication. IoT devices can deliver outputs with high speed and precision thanks to sensor technology [15].

Smart detecting abilities in this approach Sensors like accelerometers can detect subtle movements, such as minor vibrations imperceptible to humans, with a tolerance range of 5 to 10%. This high accuracy makes the tool suitable for tasks requiring minimal errors [16].

This research involved developing and building a human manipulation control robot, a wireless mobile robot equipped with a pick-and-place end effector and powered by battery. An EEG Neurosky headband collected brain waves from volunteers to control a robot's movements [17]. The brain waves of each individual vary, and the criteria for the robot's control differ based on age and sex, with the findings evaluated and tallied. A full-band simultaneous capture of raw data from the participants was also acquired using a wired 24-channel EEG RMS Maximus. The findings of the numerous wired electrodes and the results of the wireless EEG were compared and evaluated [18]. EEG signals were also given to several children with autism, assessing its potential benefits for them.

2. Literature Survey & Specification

Certain components must be included in both the transmitter and receiver units to build a wirelessly operated robot with motion detection and potential camera functionality [19].

The transmitter makes use of an ESP32 Module, a versatile microcontroller known for its integrated Bluetooth and Wi-

Fi capabilities, ideal for IoT applications and wireless communication [20]. It also incorporates a MPU6050 motion- tracking system that uses an accelerometer and gyroscope to measure motion and direction [21].

All transmitter components require a power source, and breadboards with jumper wires facilitate temporary electric connections and prototyping [22]. The receiver unit features four gear motors — electric motors with gears built into them often used to power wheels or other mechanical components in robotics projects [23]. These motors are paired with four rubber wheels to provide traction and offer movement. An ESP32 Module, similar to the transmitter, is used for wireless communication and control [24]. The direction and speed of the gear motors are controlled by two motor driver shields, specifically the L293N. A 7-12V DC battery powers the receiver's components, particularly the motors [25].

Jumper wires aid in making connections on the receiver's breadboard, while single strip wire helps with electrical connections and soldering in electronic projects [26-28]. Last but not least, the addition of an ESP Cam Module provides a visual component, enabling video or image capture [29].

Together, these components provide the foundation for a flexible and powerful wirelessly operated robot, leveraging the capabilities of the ESP32 microprocessor and integrating various sensors and motor control systems [30].

3. Working Methodology

Control of the human manipulation control robot is achieved through human hand robots. The robot operates in two phases, the transmitter phase and the reception phase.

An ESP32 module is used to implement gesture-based algorithms and control the robot during the transmitter phase. [31, 32]. This module acts as a Wi-Fi transmitter, sending data to another ESP32 module located at the receiver end while acting as a Wi-Fi transmitter [33].

The transmitter phase includes an MPU6040 module to capture gyroscope and acceleration data, detecting motion. Commands are sent to the robot based on the hand's motions along the x, y, and z axes [34]. The transmitter's code includes the receiver's ESP32 MAC address to create a link between the two devices, enabling automatic pairing as soon as both devices are powered up [35].

The receiving phase of the robot features a second ESP32 module, which serves as the central component, driving the robot using specialized code and necessary libraries. Four motors are directly controlled by the ESP32 via two L293N motor driver shields, responding to human manipulations.

These motor drivers control the front right, front left, rear right, and back left motors.

In the absence of input commands, the motors remain stationary. Additionally, a two-axis servo assembly combined with an ESP cam module allows for camera control, permitting movement in all four directions—up, down, left and right.

A cell phone may be used to view the camera stream. The camera module has its own power supply, with connections made with the use of jumper wires. The transmitter phase is supplied by a power bank, whilst the receiving phase is powered by a 7–12V DC power source.

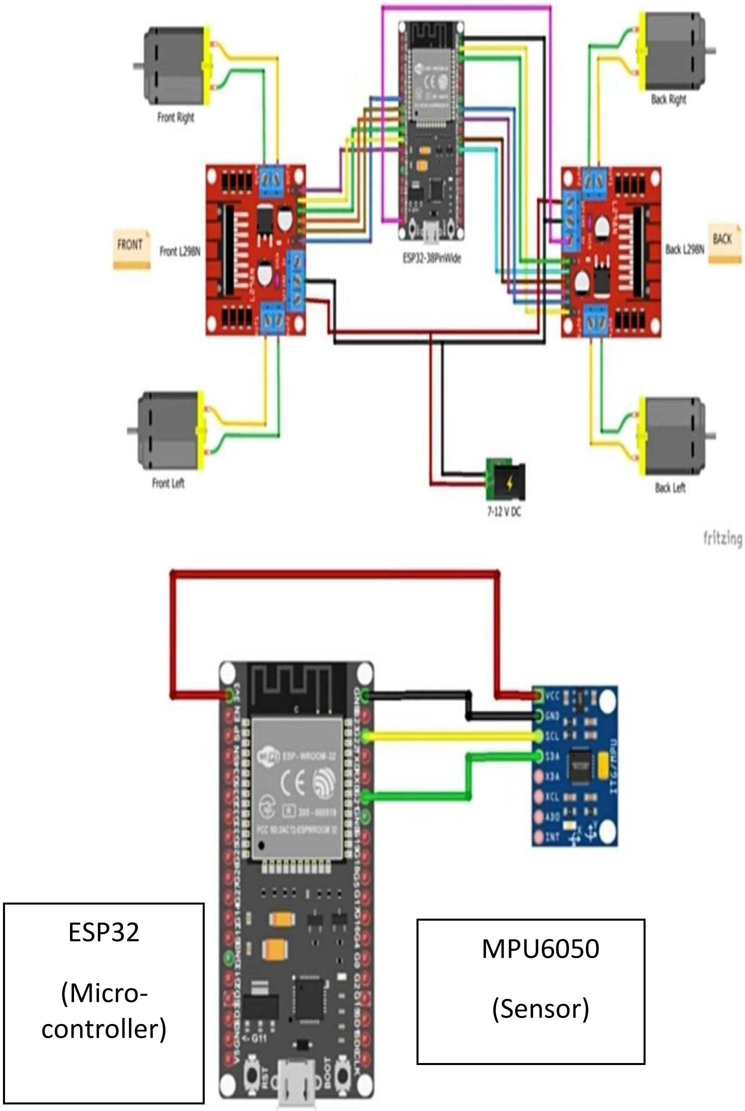

Figure 1. Functional Circuit Diagram

The human manipulation circuit diagram depicted here typically consists of sensors (e.g. flex sensors or proximity sensors), a microcontroller, power supply components, LEDs or displays to represent motion, and connecting cables. Hand motions are detected by sensors, which the microcontroller then processes to start certain activities or display the appropriate data on the LEDs or screens. Wires link components while the power supply makes certain the circuit is operational. The diagram illustrates how the hardware components work together to recognize and react to hand motions in general.

4.Remote Robot Construction

The human manipulation control robot circuit diagram (Fig. 1) is a schematic illustration of the electrical connections and parts that allow a robot to be controlled by human manipulations.

Typical parts include motor drivers, motors or wheels for movement, a power source, connecting cables, gesture sensors (such as accelerometers or cameras), and a microprocessor.

The microcontroller processes the hand motions that the gesture sensors have identified and understood. These motions are converted into instructions for the motor drivers, which move the robot, by the microcontroller.

The components are powered by the power supply, which also establishes the connections between the components via cables. This circuit diagram demonstrates how the different hardware components function together to let the robot react to certain human manipulations, allowing users to command its motions and actions.

Figure 3. human manipulation Control Robot

Figure 4. Actual image of human manipulation control robot

The human manipulation circuit prototype (Fig. 4) is a physical, working representation of a circuit designed to recognize and react to hand motions. It is typically comprises actual electrical parts such as sensors, microcontroller, feedback LEDs or displays, and interconnecting wires on a breadboard.

Significant advancements in healthcare and lifestyle have led to an increase in human lifespan over the previous century. While longevity is a notable achievement, it also presents challenges in caring for an ageing population.

The number of older individuals who need prolonged bed-based care for an extended period of time has risen dramatically in recent years. In addition, many struggles occur in walking or self-care due to traffic accident or congenital conditions.

A "bedridden patient" is someone confined to bed due to illness or old age. Caring for someone in these conditions is demanding. In India almost 230 million people are elderly, with 42 million of those bedridden and 124 million considered to have some mobility disability. Reports indicate substantial challenges, with 54% manual work required to care for bedridden individuals globally.

The use of medical robots in elderly care would significantly reduce the high costs of senior care. As the ratio of elderly to non-elderly changes, medical robots could compensate for the shortage of healthcare, which is consequently increasing the popularity of their use.

The human manipulation control robot is a mobile assistive robot developed with a fetch arm to grasp objects and autonomous movement. This research was made to examine the possibility of easing the circumstances of those who face mobility impairment. This is a basic explanation of how with minimalistic use of an EEG electrode with wireless transmission, it is possible to make a robot work sufficiently to fulfil user needs.

A Biorobot Interfaced Manipulated Assistant Robot can be designed to cater to an individual's usage and needs, leveraging Brain-Computer Interface (BCI) technology. The study used two main important components - the RMS Maximus 24 EEG channel and the Brain Sense Headband from Neurosky. Data from these devices is acquired, analysed and compared to evaluate efficiency. The goal is to design clinical instruments that are simple and efficient enough to be used for everyday use. The human manipulation control robot, employing BCI, is capable of significantly improving the quality of life for many users.

The human manipulation control robot is user-friendly, portable, cost-effective and space-efficient when compared to other EEG machines on the market, and can be used anywhere. One main benefit of the real-time human manipulation is the versatility in working with any type of EEG waves, analyzing and then using the most frequently occurring waves for efficiency.

While wired transmission is currently more efficient than wireless, wireless technology is sufficient to move a robot in an external environment. Future developments could include modifying the structure of the robot and additional accessories to enhance the robot's capabilities in the BCI field.

The sensors in this prototype detect hand motions, which the microcontroller processes into specific actions, such as turning on LEDs or controlling other devices.

This robot offers a number of clear benefits. Operated by human hand movements, it provides a more natural and engaging experience compared to manual operation or smartphone control. It has a good range, allowing it to function well in a variety of settings. It is also customizable allowing the addition of other control options, such as Bluetooth, voice control, and obstacle avoidance.

This adaptability enables users to manoeuvre the robot in multiple directions, using the same accelerometer sensor to control the throttle. The straightforward circuit design reduces complexity during construction and makes it accessible to a wide range of users.

The robot might not be as adaptable in certain situations because of its restricted gesture language, which also implies that its range of response motions may not be as extensive as those of some other robotic systems. Taking this into account, there will be systems which can expanding gesture recognition capabilities and incorporating more advanced sensors, ultimately enhancing the robot's versatility and responsiveness in diverse environments.

5. Conclusion

Medical robots are poised to revolutionize health care delivery, offering advanced capabilities to attend to patient needs. Such robots can be used to assist in various medical tasks, whilst the utilization of miniaturization and artificial intelligence further enhances their possibilities. An individual's specific brain patterns and gestures can be leveraged to adapt robots to user-specific needs, and so continued development in this field promises increased potential, making them indispensable human-robot and brain-computer interfaces within the field of health care.

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