Revolutionizing Robotics: A Smartphone-Controlled Robotic Hand

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***Abstract*—Recent technological advancements, particularly within the domain of the Internet of Things (IoT), have catalyzed the creation of novel solutions designed to improve efficiency and precision. This endeavor entails the introduction of a fixed robotic hand that can be operated using a mobile application, enabling users to control all five fingers, including their individual movements, for activities like remote object manipulation. By utilizing an Arduino Uno with DIP code in conjunction with a Bluetooth module, seamless communication between the mobile device and the robotic hand is established. The mobile application captures and sends user instructions via Bluetooth to the Arduino, which coordinates the servomotors propelling the robotic fingers. This configuration guarantees accurate and prompt manipulation, demonstrating the sophisticated integration of contemporary technology and human interaction, making it indispensable for tasks that require delicate and precise handling. The potential applications of this innovative system are diverse, spanning sectors such as manufacturing, healthcare, accessibility solutions, research, and education, thus underscoring its adaptability and significant impact.**

***Index Terms*—Robotic hand, Smartphone application,Remote control,Bluetooth communication, Internet of Things (IoT).**

I. Introduction

In recent years, significant technological advancements, particularly within the domain of the Internet of Things (IoT), have driven the evolution of innovative solutions aimed at enhancing efficiency and precision across a wide array of sectors. These advancements have led to the emergence of groundbreaking developments, one of which involves the fusion of robotic systems with smartphone applications, fundamentally transforming the dynamics of human-machine interaction.

The project at hand introduces a pioneering stationary robotic hand that is controlled through a dedicated smartphone application. This system grants users the unprecedented capability to manipulate each of the five fingers individually, enabling precise movements and offering unparalleled control for tasks such as remote object manipulation. By utilizing the Arduino Uno microcontroller integrated with specialized DIP code and a Bluetooth module, the system establishes a seamless communication channel between the smartphone and the robotic hand. When commands are received from the smartphone app, the Arduino effectively coordinates the servomotors, thereby facilitating the intricate movements of the robotic fingers with utmost precision and responsiveness.

The amalgamation of cutting-edge technology with human input within this system presents a myriad of advantages across diverse sectors. Ranging from optimizing manufacturing processes to facilitating minimally invasive surgical procedures within the healthcare domain, the versatility of this system transcends boundaries. Furthermore, its utility extends to providing accessibility solutions for individuals with disabilities, fostering advanced research in the realm of human-machine interaction, and facilitating hands-on education and training in the field of robotics. The intricate fusion of technology and human control not only enhances the system's value but also renders it indispensable for tasks that demand delicate and precise handling. Additionally, this system enables the performance of tasks in remote or inaccessible locations, further broadening its applicability and promising a future where the collaboration between humans and machines attains unprecedented levels of sophistication and efficacy One particular utilization of this system is found in its capacity to execute tasks in far-off or hard-to-reach locations. Through the utilization of the smartphone-operated robotic hand, individuals are empowered to control objects and carry out complex tasks remotely, eliminating the necessity for physical proximity. This particular capability unveils a plethora of opportunities across various domains, encompassing activities in perilous surroundings, ventures into outer space or deep-sea domains, and distant upkeep in industrial setups. Furthermore, it facilitates interventions in circumstances where human entrance is restricted or hazardous, like emergency response scenarios or search and rescue operations. The accuracy and promptness exhibited by the system, in conjunction with its seamless fusion of cutting-edge technology and human interaction, render it an invaluable instrument for tackling obstacles in remote operations and broadening the horizons of human-machine cooperation.

II. Literature Review

Yusoff et al.[1] This section summarizes the insights obtained from the survey of various papers on the topic of Smartphone-Controlled Robot.The project successfully develops a wireless mobile robotic arm for efficient pick and place operations, overcoming challenges of remote object manipulation and hazardous material handling.The project integrates hardware and software components to create a reliable system for wireless robotic arm control.The Arduino Mega platform serves as the interface for the robot, while the PS2 wireless controller enables precise and user-friendly movement control.The wireless mobile robotic arm is capable of pick and place operations, controlled wirelessly for forward, reverse, right, and left movements.Performance analysis includes speed, distance, and load capacity evaluations to assess the robot's capabilities.

Mohammed Ali et al. [2] The project involved designing and constructing an Arduino-based robotic arm controlled through a mobile application. Mechanical parts were designed using software and a 3D printer, with MIT App Inventor used for creating the mobile application. The robotic arm consists of six servo motors, including MG945 and MG90S Micro servos, along with an Arduino Uno and HC05 Bluetooth module. SolidWorks was used for designing each link of the robotic arm, which was then 3D printed. The mobile application created for the project contained a Bluetooth enabling button and six sliders for controlling each servo motor. The robotic arm was fully controlled by the Arduino platform, emphasizing the importance of understanding the programming side of the Arduino micro-controller. The robotic arm's functionality was tested through wireless controlling signals via Bluetooth from the mobile application. The final prototype of the robotic arm was produced through the assembly of mechanical parts and motor configurations, demonstrating the successful implementation of the project.

Safaric et al. [3] The paper delves into the utilization of Virtual Environments (VE) for education and training purposes, focusing on task planning where tasks are initially crafted in a virtual world and subsequently exported to remote physical hardware for real-world execution. A remote laboratory system, RLab, is developed, which is seamlessly integrated with an online video system to facilitate training experiments in telerobotics. The approach entails developing robot tasks within a virtual environment on the RLab server's webpage, conducting collision detection, and transmitting completed task files to a laboratory execution computer for task execution. Methods employed include utilizing Matlab with xPC supplement for position control of servo drives and incorporating a non-immersive VR environment with teach pendants for simulating robot activities and effective collision detection before executing tasks on remote physical hardware. Evaluations emphasize the use of a simulated representation of the real-world apparatus for configuring experiments, downloading data to the real work-cell, and verifying execution results to prevent collisions and ensure user safety. The system's output enables users to develop, execute, and receive results of robot tasks remotely, providing real-time feedback and a live video feed of the robot arm's actions.

Li-Hu Jhang et al. [4] A wireless sensor-based glove controller has been designed to control a mobile robot [4]. This model has several sensors and control modes that allow for wireless control over the robotic arm to perform different human tasks. A 6-axis robotic arm has been used in this approach. The model has been designed to do basic human tasks like picking up things and placing them etc. The main motive of this model is to assist people in performing human tasks at industries with enhanced safety.

Shamman Noor et al. [5] An "Artificial Human Hand Model" has been proposed that is capable of performing actions like base rotation, grip motions, elbow motions, grip rotation, etc. [5]. A webcam has been used to capture the human actions that will be mimicked by the model. Distant control in this model allows flexibility to control distant objects alongside ensuring human safety. The main focus of this model is to capture and perform the finger actions.

Keerthi Premkumar et al.[6] An android application-based control for a robotic arm has been designed [6]. The robotic arm is set to perform human tasks, Raspberry Pi has been connected over Wi-Fi to the Android phone to control the robotic arm. A Python program written in the Raspberry Pi acts as the central control. This model has been developed to replicate human tasks so that repetitive actions by these robot controls.

Ahmed et al. [7]In the proposed model an Arduino ESP32 microcontroller was used along with four servo motors to enable the robotic arm to perform pick and place tasks. Commands are sent wirelessly through a web interface designed with HTML which interacts with controller using a WIFI router . Ultra sonic sensors are incorporated to ensure precision in arm's movements. The Proteus software is used to stimulate the system before physical implementation. The main aim of this project is to enhance efficiency and safety in industrial environments by automating manual tasks which can be hazardous to workers.

Bhargava et al. [8]A robotic arm whose degree of freedom is 5 has been developed. It is integrated with an Arduino Uno microcontroller which accepts inputs from user using a set of potentiometers. The arm consists of 4 rotary joints and an end effector where rotary motion is provided by a servomotor. The servo motors and links are assembled with fasteners to produce the final shape of the arm. The Arduino has been programmed to provide rotation to each servo motor corresponding to the amount of rotation of the potentiometer shaft.

Lee et al. [9]In this paper an efficient wireless control protocol for a small scale robotic arm has been developed. The system incorporates joysticks , two Arduino microcontrollers communicating via RF transmission link and a servo controller. The robotic arm is designed to pick objects weighing up to 200 g with a gripper opening of 42 mm. This project aims to address the industrial need for automation of repetitive tasks , enhancing accuracy and speed while reducing costs.

III. Methodology

A. Components used

1) Arduino UNO : The Arduino UNO is a standard board of Arduino. Arduino UNO is based on an ATmega328P microcontroller. It is easy to use compared to other boards, such as the Arduino Mega board, etc. The board consists of digital and analog Input/Output pins (I/O), shields, and other circuits. The Arduino UNO consist of 6 analog pin inputs, 14

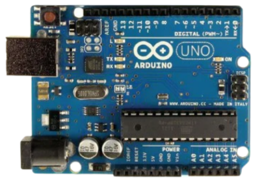

Fig. 1. Arduino UNO

Fig. 2. HC-05 Bluetooth Module

digital pins, a USB connector, a power jack, and an ICSP (In-Circuit Serial Programming) header. Fig. 1. depicts the picture of Arduino UNO.

2) HC-05 Bluetooth Module: The HC-05 is a class 2 Bluetooth module designed for transparent wireless serial communication. It is pre-configured as a slave Bluetooth device. Once it is paired to a master Bluetooth device such as PC, smart phones and tablet, its operation becomes transparent to the user. All data received through the serial input is immediately transmitted over the air. When the module receives wireless data, it is sent out through the serial interface exactly at it is received. No user code specific to the Bluetooth module is needed at all in the user microcontroller program.The HC-05 supports two work modes: Command and Data mode. The work mode of the HC-05 can be switched by the onboard push button. The HC-05 is put in Command mode if the push button is activated. In Command mode, user can change the system parameters (e.g. pin code, baud rate, etc) using host controller itself of a PC running terminal software using a serial to TTL converter. Any changes made to system parameters will be retained even after power is removed. Power cycle the HC-05 will set it back to Data Mode. Transparent UART data transfer with a connected remote device occurs only while in Data Mode.

3) Robotic Arm: The prosthetic robot hand is a sophisticated and essential component of the project, designed to emulate the functionality and movements of a human hand. It features multiple fingers, each equipped with servo motors that facilitate precise and controlled movements. These servo motors are responsible for the flexion and extension of the fingers, allowing the prosthetic hand to perform a variety of tasks such as gripping, pinching, and holding objects. The design of the prosthetic hand is engineered to closely mimic natural hand movements, providing users with a tool that can handle everyday tasks with ease and accuracy. The robotic hand's mechanical structure, combined with the electronic control system, ensures that it can adapt to different shapes and sizes of objects, enhancing its utility and versatility.

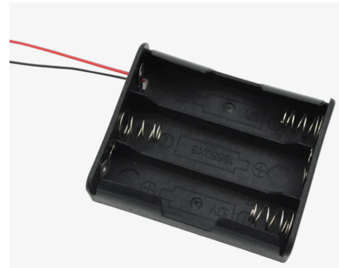

Fig. 3. Cell Holder

4) 18650 Cells: 18650 cells serve as the primary power source, offering a reliable and efficient energy supply essential for the device's functionality. These rechargeable lithium-ion batteries are known for their high energy density, long cycle life, and stable performance, making them an ideal choice for this application. Each 18650 cell, with a typical capacity ranging from 2000mAh to 3500mAh and a voltage of 3.7V, provides ample power to the servo motors, microcontroller, and other electronic components of the prosthetic hand. Their compact size (18mm in diameter and 65mm in length) ensures that the battery pack remains lightweight and unobtrusive, enhancing the overall portability and user comfort. Additionally, the 18650 cells can be recharged hundreds of times, contributing to the long-term usability and sustainability of the prosthetic hand. By integrating 18650 cells, our project benefits from a dependable and robust power source that supports extended operation and efficient performance, enabling users to rely on the prosthetic hand for various daily tasks with ease and confidence.

5) Cell Holder: A 3-cell holder is used to securely house and connect three 18650 cells, providing a stable and organized power source for the device. This holder is designed to align the batteries in a series or parallel configuration, depending on the required voltage and capacity for the prosthetic hand's operation. Using a 3-cell holder ensures that the 18650 cells are properly connected and maintained, preventing disconnections and electrical issues during use.The 3-cell holder simplifies battery installation and replacement, allowing users to easily swap out or recharge the batteries as needed. It also includes safety features such as secure contacts and insulation to prevent short circuits and ensure safe handling. By utilizing a 3-cell holder, our project benefits from a compact and efficient power management system, enhancing the reliability and convenience of the prosthetic robot hand. This setup ensures that the device receives a consistent and adequate power supply, enabling smooth and precise movements of the robotic fingers for various tasks.

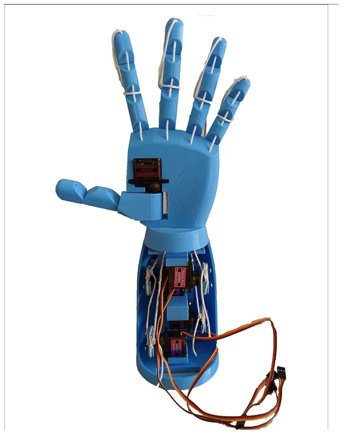

Fig. 4. Prosthetic robot hand

6) RC Bluetooth Controller app: The RC Bluetooth Controller app is integral to the functionality of the smartphone-controlled prosthetic hand, enabling users to issue a range of commands, including ”open,” ”close,” and directional movements such as ”rotate left” and ”rotate right.” This user-friendly application serves as the primary interface for sending commands via the HC-05 Bluetooth module. Designed for intuitive use, the app allows users to control the prosthetic hand’s movements with ease, providing buttons for each command. When a command is selected, the app transmits the signal wirelessly to the Arduino UNO microcontroller, which processes the input and activates the corresponding servo motors. The ”open” and ”close” commands facilitate smooth and precise finger movements for gripping and releasing objects, while the ”rotate left” and ”rotate right” commands enable the hand to perform rotational movements. This seamless integration ensures accurate and coordinated control of the prosthetic hand, enhancing its functionality and usability in various tasks. The RC Bluetooth Controller app thus plays a critical role in making the prosthetic hand a versatile and practical tool for users.

7) Prosthetic robot hand: The prosthetic robot hand features multiple fingers, each capable of individual and coordinated movements. Each finger of the prosthetic hand is equipped with joints that allow for flexion and extension, closely mimicking the natural movements of human fingers. The servo motors are programmed to move the fingers in a smooth and coordinated manner, enabling actions such as gripping, pinching, and lifting. The hand can perform complex movements, allowing the user to handle objects of different shapes and sizes with ease.The control of the prosthetic hand is managed by an Arduino Uno microcontroller, which acts as the brain of the system. The microcontroller processes input signals and sends precise commands to the servo motors, ensuring accurate and responsive finger movements. To facilitate wireless control, the system includes an HC05 Bluetooth module that enables communication between the prosthetic hand and a smartphone application.

Fig. 5. MG90S servo motor

Fig. 6. Berg Stick

8) MG90S servo motor: The MG90S servo motors are essential for providing precise and responsive finger movements. These micro servo motors are known for their high torque (2.2 kg/cm at 4.8V) and speed (0.1 seconds per 60 degrees at 4.8V), ensuring the prosthetic hand can perform delicate tasks efficiently. The MG90S features durable metal gears, enhancing its longevity and reliability, which is crucial for consistent performance. Its compact and lightweight design (22.8 x 12.2 x 28.5 mm, 13.4 grams) allows seamless integration into the prosthetic hand without adding excessive bulk. With a rotation range of 180 degrees, these servo motors enable a wide range of finger movements, from gripping to pinching. Additionally, their compatibility with the Arduino Uno microcontroller facilitates easy programming and precise control via the smartphone application and Bluetooth communication, making the MG90S an ideal choice for achieving smooth, natural finger motions in the prosthetic hand.

9) Berg Sticks: Berg sticks, also known as header pins or pin strips, play a vital role in enhancing the modularity and flexibility of the prosthetic hand project. These components are soldered onto the PCB to provide convenient connection points for various modules and peripherals. By using Berg sticks, each electronic component, such as the Arduino UNO, servo motors, and the HC-05 Bluetooth module, can be easily plugged into or removed from the PCB. This modular approach not only simplifies the initial assembly process but also makes subsequent maintenance and upgrades more straightforward. For instance, if a servo motor fails or needs replacement, it can be detached from the Berg stick without desoldering or extensive rewiring, ensuring minimal downtime and hassle.

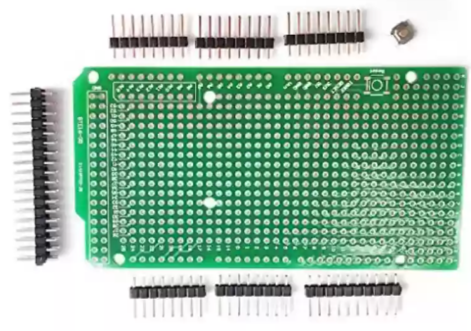

Fig. 7. Printed Circuit Board

10) Printed Circuit Board: Printed Circuit Board (PCB) serves as a crucial element in the system's infrastructure. The PCB centralizes the electronic components and connections, offering a stable platform that ensures reliable performance. By incorporating etched copper traces, the PCB efficiently routes signals and power to various parts of the prosthetic hand. This not only reduces the mess of wiring but also minimizes potential points of failure, which is essential for maintaining the precise control needed for the servo motors that manipulate the hand's fingers. Furthermore, the PCB helps in compactly organizing components like the Arduino UNO, HC-05 Bluetooth module, and the servo motor connectors, making the entire system more robust and less prone to physical and electrical issues.

B. Implementation

The execution of the project begins with the user powering on the system, activating the Arduino UNO microcontroller and the prosthetic hand by flipping the on-off switch. Subsequently, the user pairs their smartphone with the HC-05 Bluetooth module, establishing a wireless connection. Through a custom-designed smartphone application, the user sends commands to the prosthetic hand, specifying actions like ”open” or ”close” for the fingers. These commands are transmitted via Bluetooth to the HC-05 module, which relays them to the Arduino UNO. Upon receiving the commands, the Arduino UNO processes them, generating signals to control the servo motors embedded within the prosthetic hand. These servo motors, in turn, execute the instructed finger movements, enabling the prosthetic hand to perform gripping actions or release objects. Throughout the operation, the on-off switch provides a means for the user to control the power supply, ensuring safe usage. Once the desired tasks are completed, the user can power off the system, deactivating the prosthetic hand until its next use. This seamless interaction between the smartphone, Bluetooth module, Arduino UNO, and servo motors enables users to wirelessly control the prosthetic hand, enhancing accessibility and usability in daily activities.

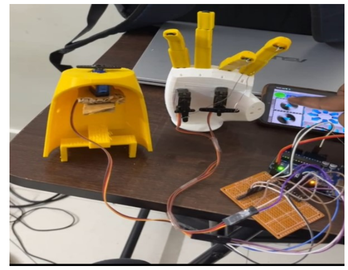

Fig. 8. Implementation of the robotic hand

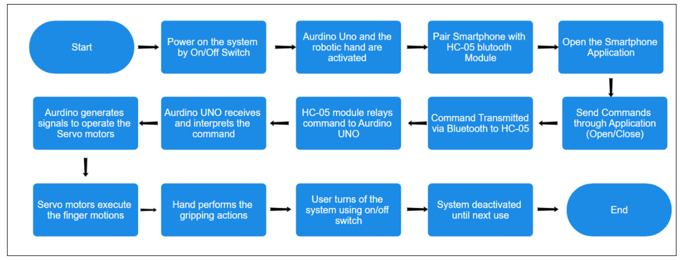

Fig. 9. Flow diagram representing sequence of the project steps.

IV. Results and Discussions

The prosthetic hand effectively responded to the ”open” and ”close” commands transmitted via the smartphone application. When the ”open” command was issued, the HC-05 Bluetooth module reliably received the signal and communicated it to the Arduino UNO microcontroller. The Arduino processed the command and sent precise control signals to the servo motors, causing the fingers to extend smoothly. This response allowed the hand to release objects or prepare for a new grip, demonstrating accurate and coordinated finger movements. Similarly, the ”close” command prompted the servo motors to contract, pulling the fingers into a closed position. This action enabled the prosthetic hand to grip objects firmly. The system's responsiveness to these commands was consistent, with no noticeable lag or errors, highlighting the effectiveness of the wireless control mechanism.

The successful implementation of the ”open” and ”close” commands underscores the reliability and precision of the prosthetic hand's control system. The seamless interaction between the smartphone, Bluetooth module, Arduino UNO, and servo motors resulted in a user-friendly experience, allowing users to intuitively control the hand's movements. The stability of the wireless connection and the accuracy of the servo motor responses are critical factors that contribute to the overall functionality of the device. These results indicate that the prosthetic hand can perform essential gripping and releasing tasks efficiently, making it a practical tool for users in their daily activities. The project's outcomes demonstrate the potential for further enhancements and the feasibility of developing more sophisticated control features to expand the hand's capabilities.

V. Conclusion and Future Scope

The project successfully demonstrated the development of a smartphone-controlled prosthetic hand that responds accurately to user commands to open and close its fingers. The integration of the Arduino UNO microcontroller, HC-05 Bluetooth module, and servo motors provided a reliable and efficient system for controlling the prosthetic hand wirelessly. The custom-designed smartphone application enabled users to send commands seamlessly, resulting in precise and smooth finger movements. The stable wireless connectivity and responsive servo motors ensured consistent performance, making the prosthetic hand practical for everyday use. Overall, the project showcased the feasibility of using off-the-shelf components to create a functional and user-friendly prosthetic device, significantly enhancing accessibility and usability for individuals requiring prosthetic assistance.

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