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Voice Activated Prosthetic Arm for Upper Limb Rehabilitation

R.Reshma
Assistant Professor, Department of Medical Electronics
Sengunthar Engineering College (Autonomous), Tiruchengode, India
reshmapraveen027@gmail.com
https://orcid.org/0009-0008-7628-4712
Vijay.M, Vetrivel.S,Vishal Rakksun.RB, Vigneshwaran.CR
UG Student, Department of Medical Electronics,
Sengunthar Engineering College (Autonomous), Tiruchengode, India
vijayvijay862024@gmail.com, vetri8478@gmail.com, vishalrakksun@gmail.com, vignesh2025official@gmail.com

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Abstract: A Voice activated prosthetic arm for upper limb rehabilitation significantly improves the quality of life of individuals by limiting their ability to perform daily tasks. Prosthetic technology has improved over the years, yet many devices remain expensive and difficult to control. This project proposes a voice controlled prosthetic upper limb that allows amputees to operate an artificial arm using simple voice commands. The system uses a voice recognition module to interpret spoken commands and convert them into electrical signals. These signals are processed by a microcontroller which controls servo motors to perform actions such as gripping, releasing, and wrist movement. The proposed design aims to prosthetic solution for physically challenged individuals. Experimental results demonstrate that voice commands can effectively control the prosthetic limb with good accuracy and response time.
Keywords: Prosthetic limb, Voice recognition, Assistive technology, Microcontroller, Rehabilitation Engineering.

1.INTRODUCTION

The loss of an upper limb can greatly affect a person's ability to perform daily activities and reduce their independence. Amputation may occur due to accidents, congenital defects, or medical conditions. Individuals who lose their upper limbs often face challenges in performing basic tasks such as holding objects, writing, and carrying items. Prosthetic limbs are artificial devices designed to replace missing body parts and help restore some level of functionality. Traditional prosthetic arms were mainly mechanical devices that relied on body movements to control their operation. These systems used cables and harness mechanisms connected to the user's body. Although they were simple and reliable, they offered limited movement and required significant physical effort. With the advancement of electronics and embedded systems, modern prosthetic devices have become more advanced and capable of performing more complex movements. Recent research has focused on developing electrically controlled prosthetic limbs using microcontrollers, sensors, and actuators. Some prosthetic systems use electromyography (EMG) signals to detect muscle activity and control the movement of the prosthetic hand. While EMG-based systems provide more natural control, they require complex signal processing and expensive sensors, which can increase the cost of the device. Voice recognition technology has emerged as a promising alternative for controlling assistive devices. Voice-controlled systems allow users to operate devices using simple spoken commands. A voice recognition module captures the speech input and converts it into digital signals that can be processed by a microcontroller. The microcontroller then controls actuators such as servo motors to produce the desired movement. In this project, a voice-controlled prosthetic upper limb is designed and developed using a voice recognition module, Arduino microcontroller, and servo motors. The system allows the user to control the prosthetic hand through predefined voice commands. The objective of the proposed system is to provide a simple, cost-effective, and user- friendly prosthetic solution that can assist individuals with upper limb loss in performing basic daily activities.

2. LITERATURE SURVEY

The development of prosthetic limbs has gained significant attention in recent years due to advancements in biomedical engineering, robotics, and assistive technologies. Researchers have focused on designing prosthetic devices that are capable of restoring functional abilities for individuals who have lost their upper limbs. Modern prosthetic systems aim to provide improved control, better functionality, and enhanced user comfort. Several studies have explored the use of voice recognition technology to control prosthetic limbs. Sharma and Gupta[1] proposed a voice-controlled robotic prosthetic hand using embedded systems, demonstrating that voice commands can effectively control finger movements through a microcontroller.

Similarly, Kumar etal.[2] developed a low-cost prosthetic arm that uses voice recognition technology to perform basic hand movements, making the device more affordable for users. Patel and Shah [3] introduced an assistive robotic arm controlled through voice commands for upper limb rehabilitation. Their research showed that voice-based control systems can help individuals perform simple daily activities. Lee et al. [4] also developed a smart prosthetic limb system using voice-based control mechanisms, emphasizing the importance of human–machine interaction in improving prosthetic usability. In another study, Ahmed and Hassan [5] designed an intelligent prosthetic arm using Arduino and speech recognition modules. Their work demonstrated that microcontroller-based systems can provide reliable control for prosthetic devices. Nguyen and Tran [6] proposed a speech recognition assisted robotic prosthetic hand that improves interaction between the user and the prosthetic system, enabling efficient command recognition. Chen and Wang [7] presented a smart voice-activated prosthetic hand designed for rehabilitation applications. Their research highlighted the importance of integrating voice recognition modules with embedded systems for effective prosthetic control. Kumar and Nair [8] developed a voice-enabled assistive robotic arm aimed at helping disabled individuals perform everyday tasks more easily. Further research has focused on improving human-machine interaction in prosthetic devices. Zhang et al. [9] proposed a speech-based interface for prosthetic control, which allows users to operate prosthetic devices using simple voice commands. Park and Kim [10] developed a low-cost voice- controlled prosthetic hand that uses embedded control systems to achieve efficient finger movement. Singh and Patel [11] designed a voice-activated robotic hand specifically for assistive technology applications. Their work demonstrated that voice commands can provide a convenient control interface for prosthetic systems. Verma et al. [12] developed a smart prosthetic arm controlled by voice commands using a microcontroller, emphasizing the importance of simple and efficient control mechanisms. Li and Chen [13] proposed a speech-based human-robot interaction system for prosthetic and control, which improves the accuracy of command recognition. Brown and Miller [14] designed a voice-controlled robotic arm intended for rehabilitation purposes, showing that such systems can assist users in performing basic functional tasks. Rao and Reddy [15] developed a prosthetic arm based on voice recognition technology to support daily activities ,highlighting the practical benefits of voice-controlled assistive devices. From the literature reviewed, it is evident that voice recognition technology provides a simple, user-friendly, and cost-effective method for controlling prosthetic devices. However, many existing systems still face challenges such as limited command recognition, noise interference, and system complexity. Therefore, this project focuses on developing a voice-controlled prosthetic upper limb using Arduino and servo motors, aiming to provide a reliable and affordable solution for individuals with upper limb loss.

3. METHODOLOGY

A. System Overview

The proposed system is designed to control a prosthetic upper limb using voice commands. The system mainly consists of a voice recognition module, an Arduino microcontroller, servo motors, a power supply unit, and the prosthetic hand structure. The main objective of the system is to allow the user to control the movements of the prosthetic hand through simple spoken commands, making it easier for individuals with upper limb loss to perform basic daily activities. In this system, the user provides voice commands through a microphone connected to the voice recognition module. The module processes the speech input and compares it with the predefined commands stored in its memory. Oncea command is recognized, the module converts the speech signal into a digital output signal. This signal is then transmitted to the Arduino microcontroller for further processing. The Arduino microcontroller acts as the central control unit of the system. It receives the signal from the voice recognition module and interprets the command according to the programmed instructions. Based on the received command, the microcontroller sends control signals to the servo motors connected to the prosthetic fingers.

B. Software Implementation

The software implementation of the proposed voice- controlled prosthetic upper limb plays a crucial role in enabling communication between the voice recognition module, the Arduino microcontroller, and the servo motors. The software is developed using the Arduino Integrated Development Environment (IDE), which provides a simple and effective platform for writing, compiling, and uploading programs to the Arduino microcontroller. The program is written using the Arduino programming language, which is based on the C/C++programming language and supports easy integration with various hardware components. In this system, the software is responsible for receiving the voice command signals from the voice recognition module and processing them to control the movement of the prosthetic hand. Initially, the voice recognition module is trained with predefined commands such as “open” and “close.” When the user speaks a command, the module processes the speech signal and converts it into a corresponding digital output signal. This signal is transmitted to the Arduino microcontroller through serial communication. The Arduino microcontroller reads the incoming data from the voice recognition module and compares it with the programmed command instructions stored in its memory. Based on the recognized command, the program executes specific control actions. For example, when the command “open” is detected, the Arduino sends a signal to rotate the servo motors to a predefined angle, which causes the prosthetic fingers to open. Similarly, when the command “close” is detected, the microcontroller sends a signal that moves the servo motors in the opposite direction, allowing the prosthetic fingers to close.

C. System Integration

System integration involves connecting and coordinating all hardware and software components so that the entire system works as a single functional unit. In this project, the voice recognition module, Arduino microcontroller, servo motors, and power supply are integrated together. The voice recognition module is connected to the input pins of the Arduino to transmit the detected voice commands. The servomotors are connected to the output ins of the Arduino, allowing the microcontroller to control the movement of the prosthetic fingers.

Proper wiring and circuit connections ensure smooth communication between all components. Once integrated, the system is capable of receiving voice commands and converting them into mechanical movements of the prosthetic hand.

D. Testing and Validation

Testing and validation are performed to evaluate the functionality and reliability of the developed prosthetic system. The voice recognition module is trained with predefined commands, and several tests are conducted to verify whether the system correctly responds to these commands. The prosthetic fingers move as expected, demonstrating the proper functioning of the system. The results indicate that the system can reliably perform basic hand movements with minimal delay between the voice command and the prosthetic hand action.

4. RESULT AND DISCUSSION

The developed voice-controlled prosthetic upper limb was successfully implemented and tested to evaluate its performance and functionality. The voice recognition module was trained to recognize specific commands such as "open" and "close." During testing, the module was able to detect the spoken commands and transmit the corresponding signals to the Arduino microcontroller.

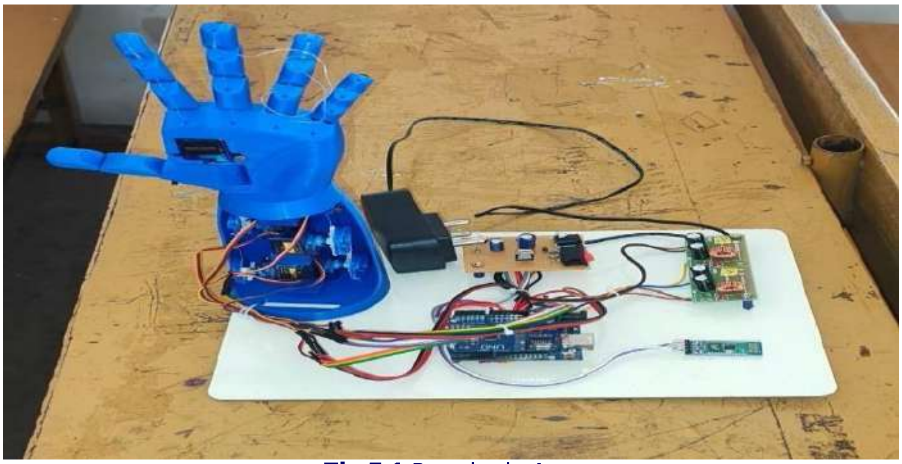

Fig:5.1 Prosthetic Arm

The Arduino processed the received signals and generated control outputs to the servo motors connected to the prosthetic fingers. As a result, the servo motors rotated to the required angles, enabling the prosthetic hand to perform movements such as opening and closing. The response time between the voice command and the movement of the prosthetic hand was observed to be minimal, indicating efficient system performance.

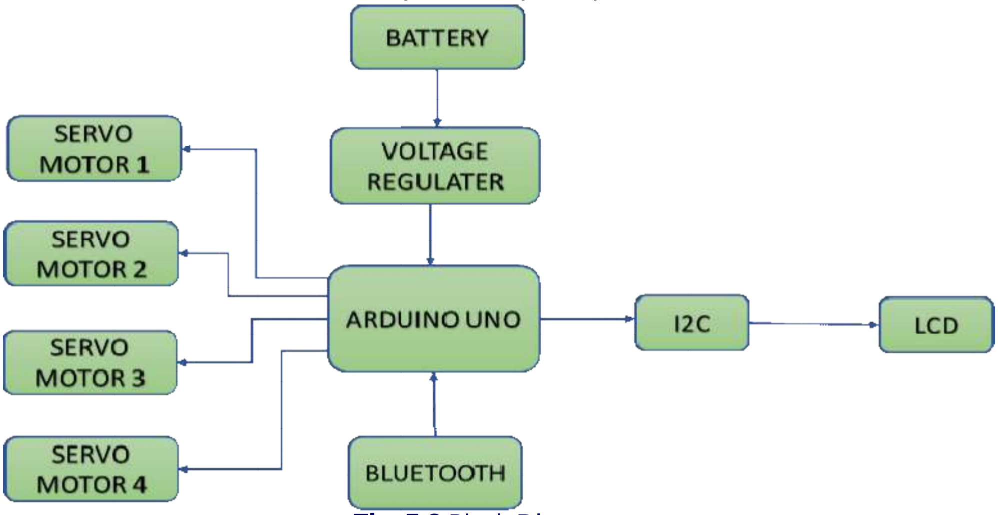

Fig: 5.2 Block Diagram

When a command was given through the microphone, the voice recognition module successfully identified the command and transmitted the corresponding signal to the Arduino controller. The microcontroller then processed the command and activated the servo motors to perform the desired movement of the prosthetic hand. During testing, the prosthetic hand was able to respond to voice commands with satisfactory accuracy and responsiveness. The servo motors moved according to the programmed instructions, allowing the prosthetic fingers to open and close properly. The response time of the system was observed to be fast enough for basic assistive tasks. The integration of the voice recognition module with the Arduino microcontroller worked effectively, demonstrating that voice- based control can be a reliable method for operating prosthetic devices. The system also showed advantages in terms of simplicity and affordability. Compared to complex EMG-based prosthetic systems, the proposed voice-controlled system requires fewer sensors and less complex signal processing. This makes the device easier to implement and more cost- effective for practical applications. The hardware components were successfully integrated and operated without major compatibility issues, which indicates that the system architecture is suitable for assistive prosthetic applications. However, certain limitations were observed during testing. The accuracy of voice recognition can be affected by background noise or variations in the user's pronunciation.

In noisy environments, the system may occasionally misinterpret commands or fail to recognize them. Additionally, the current prototype supports only a limited number of predefined commands, which restricts the range of movements that can be performed by the prosthetic hand. Overall, the experimental results demonstrate that the proposed voice-controlled prosthetic upper limb system can effectively perform basic hand movements through speech commands. The system provides a simple and user-friendly solution that can assist individuals with upper limb loss in performing basic daily tasks. With further improvements in speech recognition accuracy and additional control features, the system has the potential to become a more advanced and reliable assistive technology.

5. CONCLUSION

This project focused on the design and development of a voice-controlled prosthetic upper limb intended to assist individuals who have lost their upper limbs due to accidents, medical conditions, or congenital disabilities. The proposed system integrates a voice recognition module, an Arduino microcontroller, and servo motors to enable the prosthetic hand to perform movements based on spoken commands. The main objective of the project was to develop a simple, reliable, and cost-effective assistive device that allows users to control prosthetic hand movements through voice instructions. The developed prototype demonstrated that voice recognition technology can be effectively used as a control interface for prosthetic devices. The voice recognition module was able to detect predefined commands and transmit the corresponding signals to the Arduino controller. The microcontroller then processed these commands and controlled the servo motors to perform the required movements, such as opening and closing the prosthetic fingers. The testing results indicated that the system responded correctly to the trained voice commands and provided satisfactory performance in performing basic assistive tasks. One of the major advantages of the proposed system is its simplicity and affordability. Compared to traditional prosthetic control methods such as electro myography (EMG)-based systems, the voice-controlled approach requires fewer sensors and less complex signal processing. This reduces the overall cost of the device and makes it more accessible for users who require assistive technology. Additionally, the integration of commonly available components such as Arduino and servo motors makes the system easy to implement and maintain. However, the system still has certain limitations. The accuracy of voice recognition may be affected by background noise, environmental disturbances, or variations in the user's speech. In addition, the current prototype supports only a limited number of predefined commands, which restricts the range of possible hand movements. Future improvements can focus on enhancing speech recognition accuracy, incorporating advanced machine learning techniques, and increasing the number of controllable movements to improve functionality. In conclusion, the proposed voice-controlled prosthetic upper limb provides a practical and effective solution for assisting individuals with upper limb loss. The system demonstrates how voice recognition technology can be integrated with embedded systems to create an accessible and user-friendly assistive device. With further development and optimization, this technology has the potential to improve the independence, mobility, and quality of life of people with physical disabilities.

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