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EMG CONTROLLED ROBOTIC ARM WITH VOICE COMMAND

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Abstract: Human machine interface technologies have significantly advanced the development of assistive robotic systems. This paper presents the design and implementation of a hybrid control system for a robotic arm using electromyography (EMG) signals combined with voice commands. Surface EMG sensors are used to capture electrical signals generated by muscle contractions from the user's forearm. These signals represent the user's muscle activity and intention to perform certain movements. The EMG signals obtained from the electrodes are very weak and susceptible to noise. Therefore, they are first amplified and filtered using an EMG sensor module before being processed by an Arduino Nano microcontroller. The processed signals are analyzed to detect muscle contraction levels, which are then translated into commands to control the movements of the robotic fingers. However, relying solely on EMG signals can lead to limitations due to signal variability, muscle fatigue, and differences in electrode placement. To enhance system flexibility and usability, a smartphone-based voice command interface is integrated into the system. Voice commands are transmitted through a Bluetooth communication module (HC-05), allowing the user to control additional robotic movements through speech .The robotic arm consists of five servo motors that simulate the motion of human fingers. The Arduino Nano processes both EMG signals and voice commands to generate appropriate control signals for the motors. Experimental results demonstrate that the proposed hybrid control approach improves interaction efficiency, response time, and usability .This system provides a low-cost assistive solution that can be beneficial for individuals with upper-limb disabilities, rehabilitation therapy, and human-machine interaction research

***Index Terms* -** EMG, Robotic Arm, Bluetooth Control, Assistive Robotics, Human-Machine Interface, Rehabilitation Robotics.

I. INTRODUCTION

Robotic arms have become an important part of modern automation systems and assistive technologies. They are widely used in industrial automation, medical rehabilitation, prosthetics, and human–machine interaction systems. Robotic manipulators can perform repetitive tasks with high precision and reliability, making them valuable tools in various engineering and medical applications. In the field of assistive robotics, robotic arms can help individuals with motor impairments perform daily tasks such as grasping objects, lifting items, and interacting with their environment. However, designing an intuitive control interface between humans and robotic systems remains a significant challenge. Traditional control methods such as joysticks or keyboards may not be suitable for individuals with disabilities. Electromyography (EMG) provides a promising solution for intuitive human–machine interaction. EMG signals are electrical signals generated by muscle fibers during contraction and relaxation. These signals can be detected using surface electrodes placed on the skin above specific muscles. By analyzing EMG signals, it is possible to interpret human muscle activity and translate it into control commands for robotic systems. Surface EMG (sEMG) sensors have been widely used in prosthetic hand control, rehabilitation devices, and gesture recognition systems. When a person contracts their forearm muscles, electrical potentials are generated that can be measured by electrodes and converted into digital signals for processing. Despite their advantages, EMG signals have several limitations. The signals are highly sensitive to noise, electrode placement, and muscle fatigue. Additionally, EMG signals alone may not be sufficient to control complex robotic movements with high accuracy. To overcome these limitations, this research proposes a hybrid control system that combines EMG-based control with voice command functionality. Voice commands are transmitted through a smartphone application using Bluetooth communication. The integration of voice control allows the user to perform additional robotic actions that may be difficult to detect using EMG signals alone.The proposed system aims to develop a low-cost, user-friendly robotic arm that can be controlled through both muscle activity and voice commands. This hybrid approach improves system flexibility, enhances usability, and provides an effective solution for assistive robotics applications.

II. MATERIALS AND METHODS

Hardware Components The proposed robotic arm system consists of several hardware components that work together to detect muscle activity, process control signals, and drive the robotic motors . The main components used in the system include :EMG Muscle Sensor the EMG sensor is responsible for detecting electrical signals generated by muscle contractions. Surface electrodes are attached to the user's forearm muscles to capture the EMG signals. These signals are extremely weak, typically in the range of microvolts to millivolts, and require amplification before processing .Surface Electrodes Surface electrodes are used to capture EMG signals from the skin surface. Proper electrode placement is important to obtain accurate muscle activity readings .Arduino Nano Microcontroller the Arduino Nano acts as the central processing unit of the system. It receives the processed EMG signals from the sensor module and interprets them to control the robotic arm. The Arduino also receives voice commands via the Bluetooth module and generates PWM signals to control the servo motors. HC-05 Bluetooth Module the HC-05 Bluetooth module enables wireless communication between the smartphone and the Arduino Nano. Voice commands given through the smartphone application are transmitted via Bluetooth to control the robotic arm. servo Motors Five servo motors are used to simulate the motion of the fingers in the robotic hand. Each servo motor controls one finger of the robotic arm.
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A. 3D PRINTING PROCESS

Here 3D printer is used to construct the robotic arms with precision. CAD software is used for this and the designed parts are converted into STL files. These STL files are processed using several software like Slicing and finally G-code is created. FDM Technology is used for layering process. After this, post-processing steps are done. Finally the designed parts are assembled using screws, bearings and shafts.

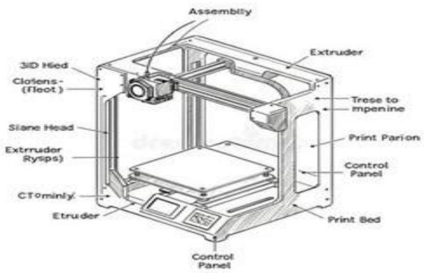

Fig1.3D Printer

The steps in 3D printing involves design of robotic arm with proper dimensions, then conversion to STL files, slicing process, selection of materials like PLA, ABS, PETG , 3D printing of parts by uploading G code, post processing, mechanical, actuator integration, electronics and control procedures and finally programming and testing.

B. Determining the threshold values

The image shows how EMG signals change based on muscle activity and how a threshold is used to detect movement

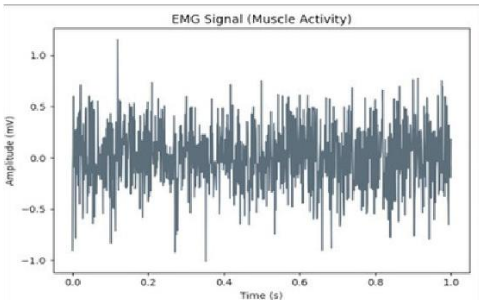

Fig2. EMG Signal

This is the graph between the amplitude of the muscle signal and time. The given signal is noisy and irregular, it is a real biological behavior. The spikes represents muscle activity. It shows the fluctuation of multiple small electric signals from different muscle fibres. The signal is around 0 mV which represents normal or low muscle activity. When it reaches about 1.2mV , it represents sudden strong muscle activity.

There are three conditions:

i) when muscle is relaxed, small electric field activity is produced
= 0.01-0.1mV. So low amplitude fluctuation.

ii) when muscle contracts slightly, more electrical signal are produced
=0.2-1mV. So high peaks slight high peaks.

iii) when muscle contract strongly, more signals are again produced
= 5mV. So very high peaks.

Threshold value: - for example = 0.15

EMS voltage >0.15=muscle contraction

EMS voltage </= 0.15= muscle relaxation

C. Block diagram

The diagram represents the EMG-controlled robotic hand system used to control a robotic hand using human muscle signals. The system mainly consists of electrodes, an EMG Module, Arduino Nano, Servo Motors, a Bluetooth Module, power supply, and a smartphone.

First, three electrodes are placed on the user’s arm muscles to detect the electrical signals generated during muscle contraction. These very small signals are collected and sent to the EMG module. The EMG module amplifies, filters, and processes the weak bio-signals so that they can be used by the microcontroller. A battery is used to power the EMG module and ensure stable signal detection. The processed EMG signal is then given as input to the Arduino Nano, which acts as the main controller of the system. The Arduino reads the signal levels and converts them into control commands based on the programmed logic. A 5V adapter supplies power to the Arduino and the servo motors to ensure proper operation.

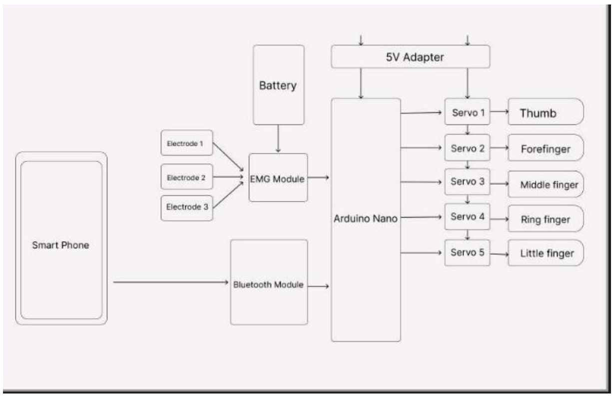

Fig3. Block Diagram

The Arduino controls five servo motors connected to the robotic hand. Each servo motor is responsible for the movement of one finger: Servo 1 controls the thumb, Servo 2 controls the forefinger, Servo 3 controls the middle finger, Servo 4 controls the ring finger, and Servo 5 controls the little finger. When the user contracts or relaxes the muscles, the EMG signals change, and the Arduino moves the corresponding servo motors, resulting in finger movement similar to a real human hand.

D. Software

The images show the interface of a Robo Hand control app used to control a robotic hand. The app has different sections that help the user operate the hand easily. In the Fingers Control section, each finger such as the thumb, index, middle, ring, and pinky has Open and Close buttons.

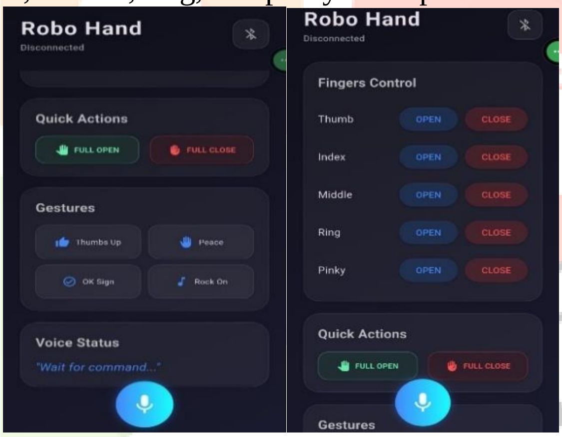

Fig4.software

These buttons allow the user to move each finger separately. The Quick Actions section includes options like Full Open and Full Close, which open or close all the fingers at the same time. The Gestures section provides preset gestures such as Thumbs Up, Peace, OK Sign, and Rock On, so the robotic hand can perform these actions automatically. At the bottom, there is a microphone button for voice control, and the Voice Status shows messages like "Wait for command," which means the system is ready to receive voice instructions. This interface helps the user control the robotic hand easily using buttons, gestures, and voice commands.

III. RESULTS AND DISCUSSION

The developed system was tested to evaluate its performance in controlling the robotic arm using both EMG signals and voice commands. Experimental testing showed that the EMG sensor successfully detected muscle contractions from the forearm muscles. The Arduino Nano processed the EMG signals and converted them into control signals for the servo motors. When the user contracted their forearm muscles, the robotic fingers responded by performing predefined movements such as closing or opening the hand. Voice commands transmitted through the smartphone application were also successfully received by the Bluetooth module. The robotic arm responded accurately to commands such as finger movement and grip control.

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