International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN: 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)
doi : https://doi.org/10.32628/IJSRSET

Design And Construction of 5-Dof EMG Based Robotic Arm System

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ARTICLEINFO

Article History:

Accepted: 01 April 2023
Published: 14 April 2023

Publication Issue
Volume 10, Issue 2
March-April-2023

Page Number
440-445

ABSTRACT

Electromyography (EMG) is an alternate method of obtaining muscle signal outputs. As a result, the current development in designing myoelectric plans has piqued the attention of researchers in this subject. This is because standard controllers lack essential components, limiting the use of limbs to operate equipment, namely an arm controlled by robotics. EMG signals are subject to noise, including crosstalk, motion artifacts, ambient noise, and intrinsic noise. Electromyography preparation requires careful selection of muscle groups, electrode placement, and environment quality, all of which impact the signal output. The goal of this study is to create an EMG-based robotic arm control system that can be used to help the elderly, individuals with impairments, and those who operate in dangerous places. Initially, a literature review on current human-robot interaction approaches and analysis of the kinematics of a 5 DOF robotic arm has been conducted. Then, utilizing Electromyogram (EMG) data obtained from the muscles of the elbow, a way for controlling a 5 DOF robotic arm is provided. Two accelerometers are utilized to record the human arm's gesture and posture, this information is then communicated to the robotic arm as an input. In the experiments, wrist rotation, left, right, up, and down movements were used to establish controlled motion of a 5 DOF robotic arm. The project's goal has been met with the successful development of an EMG-controlled robotic arm. The robotic arm may yet be improved by including Implementing a wireless sensor network with multiple channels.

Keywords : Electromyography, EMG signal, muscle, robotic arm

I. INTRODUCTION

Electromyography (EMG) has existed widely employed in biological, therapeutic, and contemporary human-computer interface applications. EMG is a technique for assessing electrical activity in muscles. An EMG [1] is essentially the total of all action potentials collected from muscle fiber electrodes. The motor units, which are composed of muscle fibers, exhibit electrical behavior when muscles contract. EMG signal capture would aid in giving important Information derived from the Motor Unit Action Potential (MUAP) for the use of contemporary technologies. Myoelectric signals are the electrical characteristics of the muscles.

Myoelectric signals are often utilised to operate assistive equipment including robotic arms, exoskeletons, and prosthetics. EMG is often utilised because it delivers a simple and natural experience while manipulating gadgets. Affording to [2] over 150,000 Malaysians need prosthetic or orthotic expedients. Prostheses are commonly the technique is used in America and Russia, resulting in the amputation of approximately 1.7 million people. The capture of EMG signals is critical in the creation of an EMG-based device. Electrodes are used to detect EMG signals, which may be gathered in two ways: invasive or non-invasive.

Pre-processing, feature selection, and classification are three critical processes [3] for effective EMG signal categorization. Noise, distortion, and artefacts produce disruption in the sample, lowering the signal's quality. An electromyography (EMG) measures the response of a muscle to a nerve stimulus. Neuromuscular disorders can be detected with the help of this test. In addition to dexterous manipulation, robot hands are being developed for use in human contexts, as a means of investigating human cognition, and as a research tool for research purposes.

It has been suggested that even for robotic hands, which have more than 20 degrees of freedom, there is a need to develop a mechanical solution that might minimise control complexity while maintaining grasping and gripping capabilities. Today, medical robots are widely used in surgery, particularly in the precise operation of surgical tools through tiny incisions using robots, computers, and software.

II. RELATED WORKS

Specifically, the articulation of the human hand and the movement of the human body as a whole are examined of a significant amount of research and study. The areas of study are also rather varied; the majority of the research has been conducted in the realm of computer graphics with the goal of producing lifelike automated hand language detection, avatar animation, and automatic drawing utilizing virtual motion [4]. The collection of motion information may be divided into two categories: contact and noncontact, depending on the kind of sensor device that was employed. The information may be categorized as comprehensive or partial based on whether or not it tracks the whole of the hand or only some of the distinctive characteristics.

When compared to the other touch methods, it seems that the statistics glove, when paired with visual input indicating the location of a hand-held object, produces the best results. The angle of motion between neighbouring moveable links of the hand is detected by the data gloves. The following are some drawbacks associated with the data gloves: If the locations of the hand are to be determined, the system must either make an educated guess or do an a priori measurement of the lengths among the finger joints [5].

The bending of the hand causes minute cuts in the fiber, which allows light to escape. Each individual user is required to recalibrate the device. Joints of freedom include five metacarpo-phalangeal bones, one interphalangeal joint in the thumb, and four proximal interphalangeal bones in the other fingers [6]. In part, this is due to the difficulty of designing an exoskeleton that can adapt to hand deformations while still maintaining precision in the measurement of particular joint movements. Exoskeletons are often used to detect and track the motion of a small number of degrees of freedom.

Magnetic trackers are likewise imperfect tracking systems; in order to provide a fuller image of the user's mobility, additional sensors need be strategically positioned in various parts of the finger. Touch systems are generally considered to be more intrusive, costly, requiring cable links, are not transferrable [7]. The automated recognition of the grip and the hand position from an image is one of the most significant challenges faced by vision-based systems. These systems have a limited field of view. Strategies such as employing color information, information about motion, and information about edges have been introduced so that the interesting characteristics of the hand may be distinguished from one another.

The problem of occlusion gets more difficult to solve when just one camera is used. Some researchers choose to utilize colored gloves as a solution to this problem. Others begin by locating by viewing the hands from a non-occlusive perspective, the movements of the hands can be tracked that spot, supposing that the changes between frames are rather minor [8]. A hybrid method that combines the two ways involves examining an articulated three-dimensional model and comparing it to the image while varying the joint angles to a predetermined range of values.

From the above literature review, it could be understood that the published information on EMG using 4-degrees of freedom. The previously proposed works on the field are taken and analyzed to propose better future work. The existing systems proposed by different authors with several disadvantages which acts as a base for the proposal. Thus, the literature review gives more importance and very recent reviews among the research, indicating the high priority of research towards this area.

III. PROPOSED METHODOLOGY

To determine hand motion, we suggest the technology that uses non-contact methods, which consists of numerous cameras capturing hand motion as shown in fig 1. Using the image of the hand, we identify the different hand links and feed that information into our model of the human hand.

Figure 1. A 5 DOF robotic arm

This model is made up of links and joints. In our model, the types and orientations of joints in several of the models are unclear. Through the use of kinematic synthesis, these joint positions and orientations can be customized to match the real geometry of the subject, thereby enhancing the accuracy of the model and the motion angles. The hand model should be modified in order to reflect the hand geometry captured during the capture, as well as monitor the angle at each joint, tailored to the more exact identification of hand motion. Figure 2 depicts the general design of the suggested system.

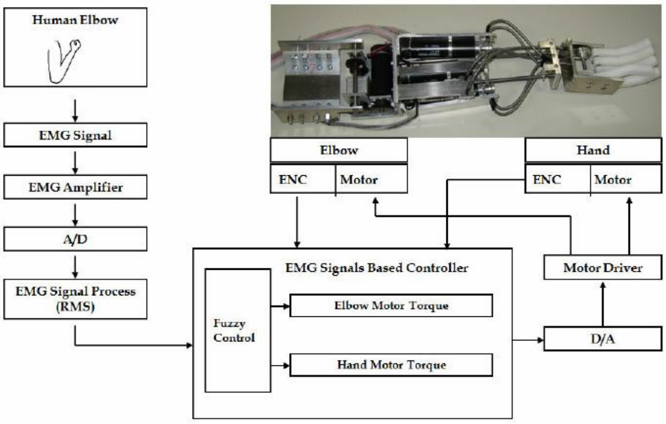

Figure 2. Overall architecture of proposed system

i. Arduino Nano

It is a breadboard-friendly ATmega328P board that is compact, comprehensive and based on an ATmega328P microcontroller. In addition to 30 male I/O headers, the Arduino Nano is equipped with an Integrated Development Environment (IDE) that is shared by all Arduino boards and is accessible online and offline. There are two ways to power the board: via a type-B mini-USB connection or by a 9 volt battery.

ii. MICROCONTROLLER - ATmega328

Atmel has developed the ATmega328 microcontroller as part of its megaAVR family of microcontrollers. Based on Harvard architecture, the processor consists of an 8-bit RISC processor. AVR 8-bit RISC microcontrollers include 32 KB ISP flash memory with read/write capabilities, 1 KB EEPROM, 2 KB SRAM, 23 different I/O lines, 32 programmable working registers, 3 counters and timers with compare modes, programmable interrupts, a byte-oriented 2-wire serial interface, SPI serial port, and a 6-channel 10-bit A/D converter.

iii. AVR microcontrollers

Atmel has been producing AVR microcontrollers since 1996, which Microchip Technology acquired in 2016. Microcontrollers based on the Harvard architecture are 8-bit RISC RISC single-chip devices. On-chip flash memory was used in the AVR family of microcontrollers for programme storage, rather than ROMs, EPROMs, or EEPROMs, which were common at the time.

iv. EMG Electrodes

A technique known as electromyography (EMG) measures a muscle's response or electrical activity after being stimulated by nerves. Neuromuscular disorders can be detected with the help of this test. The test involves the introduction of one or more tiny needles into the muscle through the skin.

v. Robotic arm

This robotic arm has five degrees of freedom (DOF) and operates by mapping microcontroller input values that are generated when muscles contract, resulting in an amount of force being generated by the microcontroller. Servo motors are attached to each DOF in the robotic arm, and these servo motors are responsible for actuating the robotic arm.

vi. Servo motors

An Arduino uno microcontroller controls the operation of a servo motor. A variety of servo motors are mounted on the robotic arm in order to enable movements such as up, down, opening, and closing. Servo motors offer a closed loop mechanism that reduces faults in the system.

An identical robotic arm is made up of two servos, one which controls the arm's base using the X1 value returned by accelerometer 1, and the other which controls the arm's shoulder using the Y1 value returned by accelerometer 1. A similar arrangement is used for controlling the servos 3 and 4 of the arm's elbow and wrist, respectively. Finally, the value supplied by the muscle sensor controls servo 5, the gripper. As a result, the servo motors operate in accordance with the values provided by the accelerometer and muscle sensor. As shown in Figure 3, the 5 DOF Robotic Arm has a kinematic scheme.

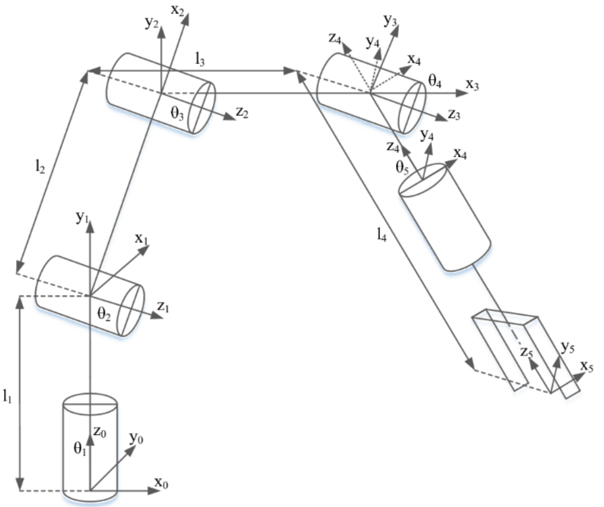

Figure 3. Kinematic scheme of the 5 DOF robotic arm

Analytical Analysis for Forward and Inverse Kinematics

Any robotic system's kinematic analysis is done in two ways: Inverse kinematics and forward kinematics. Forward Kinematics describes the process of determining a robotic manipulator's position and orientation based on joint variables. The forward kinematics of multi-DOF robotic manipulators is a simple job owing to the accessibility of Denavit-Hartenberg convention.

$$a(s) = f(\theta(s))$$

A robotic manipulator's end-effector is positioned and oriented to meet a specified requirement through the use of inverse kinematics, as shown in equation (2).

$$\theta(s) = f'(a(s))$$

Calculating inverse kinematic solutions is more difficult than forward kinematics as the governing equation is nonlinear and time-varying; there is no feasible unique solution. There are three distinct ways to generate the inverse kinematics of a multi-DOF robotic manipulator: algebraic, geometric, and iterative. Kinematic analysis of a robotic manipulator with 5 degrees of freedom was accomplished utilising an algebraic technique in this research. The forward kinematic equations were obtained using the Denavit-Hartenberg convention, as shown in Tab. 1.

Joint	θ_i (°)	α_i (°)	a_i	d_i
1	θ_1	-90	0	L_0
2	θ_2	0	L_1	0
3	θ_3	0	L_2	0
4	θ_4 - 90	-90	0	0
5	θ_5	0	0	L_3

A closed solution was used to derive an inverse kinematic solution is provided for the entire 5-DOF robotic manipulator; equations are provided below for the general joint angles:

$$\theta 1 = xtan2(py, px)$$

$$\theta 2 = xtan2\,(L0 - pz \,/\, pxC1 + pyS1)$$

$$\theta 3 = atan2(S3\,, C3)$$

$$\begin{aligned}\theta 4 = atan2\,((&axC1S23 + ayS1S23 \\ &+ azC23), (azS23 - axC1C23 \\ &- ayS1C23))\end{aligned}$$

$$\theta 5 = atan2\,((nyC1 - nxS1), (oyC1 - oxS1))$$

According to the rotations of links 1, 2, and 3, the aforementioned a value of 1 is obtained by the inverse kinematic solution, whereas two values of 2 and 3 are obtained by the same process.According to wrist rotations, there are two solutions for 4 and one solution for 5. The found solutions show that a variety of numerous solutions are feasible.

IV. RESULTS AND DISCUSSIONS

To determine the optimal gesture for controlling the robotic arm, we analyzed the EMG signal generated by several different types of gestures. Additionally, this experiment partially achieves the project's goal of analyzing the functional performance of the robotic arm through the analysis of the EMG signals acquired from the forearm. The nine hand gestures in this exam are: extending, flexion, flexing, grasping, wrist extension, thumb extension, index finger extension, middle finger extension, ring finger extension, little finger extension.

The movements are used to generate EMG signal values (bits), which are then captured by the serial monitor. For each gesture, 20 samples are collected. The EMG signal graph is displayed and categorised.

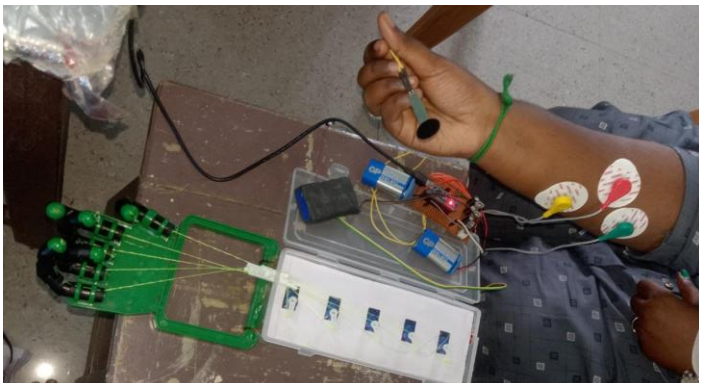

Figure 4. Output Setup

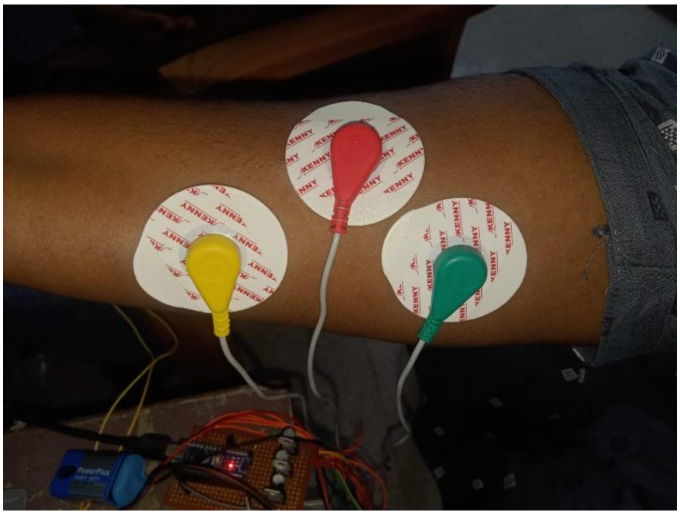

Figure 5. EMG electrodes

Figure 6. Robotic arm with 5servo motors

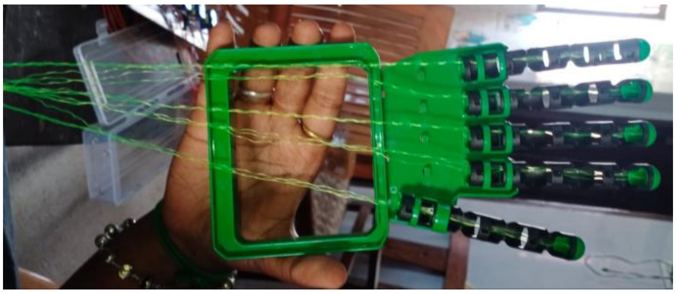

Figure 7. Robot hand

V. CONCLUSION

Using various gestures to control the robotic arm, the EMG signal is identified and the optimal gesture is determined. As a result, this experiment helps partially achieve the project's goal of analyzing the forearm EMG signal to determine the functioning of the robotic arm. It includes nine hand gestures, including thumb flexing, index finger flexing, middle finger flexing, ring finger flexing, little finger flexing, wrist extension, wrist flexion, and grasping. Serial monitors capture the value(bits) of the EMG signals generated by the motions.For each gesture, 20 samples are collected. The EMG signal graph is displayed and categorised.

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Cite this article as :

Dr. N. Radha, V. Kanimozhi, A. Pavithra, Athulya Paloran, "Design And Construction of 5-Dof EMG Based Robotic Arm System", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 10 Issue 2, pp. 440-445, March-April 2023.
Journal URL : https://ijsrset.com/IJSRSET2310273