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Conversion of Body Muscle Signal to Control a Gripper using Surface Electromyography

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Abstract: **Measuring muscle activation via electric potential, referred to as electromyography (EMG), has traditionally been used for medical research and diagnosis of neuromuscular disorders. However, with the advent of powerful integrated circuits and micro-controllers, the EMG circuits and sensors can find their way into prosthetics, robotics and control systems. Surface electromyography and needle electromyography are two general methods of recording the electrical activities of muscle tissue. In this paper, surface electromyography is used to analyse the human arm muscle nerve signals and convert the obtained nerve signal into mechanical movement in a motor. This kind of bionic control module finds its greatest use in prosthetics. The surface detection of the nerve signals reduces the risk of operation on the amputated part of the patient and gives a proper control to the person in movement of the prosthetic arm/leg. The module has the advantage of being small and simple, and easily manageable when compared to the other available options. Further development in the module can lead to fully developed and human safe prosthetic limbs that are very much alike and do all the functions as the actual human limbs.**

Index Terms: Electromyography, Surface electromyography, Bio electrodes, Bionic Control, non-invasive technique, aphasia

I. INTRODUCTION

One of the most known breakthroughs in biotechnology is Electromyography. Electromyography (EMG) is an electrodiagnostic medicine technique for evaluating and recording the electrical activity produced by skeletal muscles. The EMG is performed using an instrument called an electromyograph to produce a record called "electromyogram". It measures muscle response or electrical activity in response to a nerve's stimulation of the muscle. In this paper, an EMG signal is used to substitute for mechanical joysticks and keyboards. It is targeted for use in noisy environments and may be helpful for people without vocal chords and people with aphasia. The EMG has also been used as a control signal for computers and other devices. An interface device based on an EMG Switch can be used to control moving objects, such as mobile robots or an electric wheelchair. The EMG can be used to sense isometric muscular activity where no movement is produced. This enables definition of a class of subtle motionless gestures to control interfaces without being noticed and without disrupting the surrounding environment. These signals can be used to control a prosthesis or as a control signal for an electronic device such as a mobile phone.

The surface electromyography (sEMG) is an EMG signal that collects the electrical signals of muscle activity by placing the electrode on the surface of the skin. Detection of sEMG signals is useful to improve the essential methodologies in many applications. Such applications are becoming increasingly in demand, such as biomedical engineering, robotics arm and automation control systems.

The measurements and precise representations of the sEMG signals depend on the characteristics of the electrodes and their relationship with their skin of the forearm or shoulder and are affected by the amplifier design and the transition of the sEMG signals from analog to digital format. A raw sEMG signal has maximum voltage of (0-2) mV, and a range of frequency approximately between (0-1000)Hz.

Two main types of electrodes acquire signals of the EMG; they are needle electrode (inside the skin) and surface electrode, with no significant variance between them. There are two types of surface electrodes are gelled and dry sEMG electrodes. Gelled sEMG electrodes contain a gelled electrolytic material as an interface between electrodes and the skin. The dry electrodes like bar or pin do not require a gel for interfacing and possible to be form of an array.

In this paper, for the recognition of movement, a servo motor is used which produces a mechanical output. A servo motor is a rotary actuator or linear actuator that allows the precise control of angular or linear position, velocity and acceleration. It is often used to refer to a motor suitable for use in a closed loop control system. It is closed-loop servomechanism that uses position feedback to control its motion and final position. Servo motors are used in applications such as robotics, CNC machinery or automated manufacturing.

II. PROTOTYPE CONSTRUCTION

A. Objective

The objective of this paper is to develop a simple working prototype where the concept of surface electromyography is used to analyse the signals generated by the motor neurons and convert the signal into a mechanical movement in a servo motor. Motor neurons are the neurons which have its cell body located in the spinal cord (motor cortex) and its axon project to the muscles and glands.

And it is also to look for the different applications and future scope of the surface electromyographic modules that will help reduce risks and contribute to the health and well being of the society.

B. Block diagram

The Arduino Uno is the most common version of Arduino family. The Arduino Uno is a micro controller board based on the ATmega328.It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16

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MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button.

Figure 1 shows the block diagram of Bionic Control.

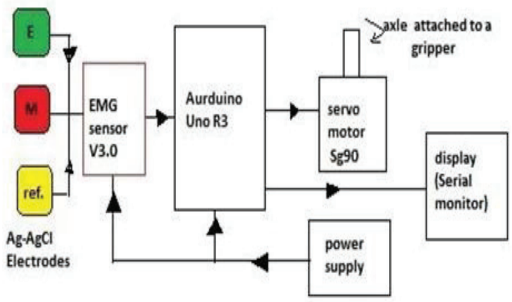

Figure 1. Block diagram of Bionic Control Using Electromyography

The signals from human body are detected by an EMG sensor. There are three electrodes used to sense the signals from different parts of the arm. The Arduino helps to obtain the signal and transfer to a microcontroller. The signal from the microcontroller is used to drive a motor. The whole set up uses a power supply for its functioning. The digital display is also obtained on a monitor. It is an Easy-to-use controller that detects muscle activity.

C. Circuit connections

The implementation of the process has different levels or stages. The first stage is sensing or getting the input variable to be measured and processed, then the signal is conditioned by a signal conditioning circuit that contains amplifiers, rectifiers, filters and the smootheners, a signal processing [1] happens were the signal is analyzed and then manipulated and finally an output is shown in terms of mechanical movement. Figure 2 shows the circuit connections to be taken from a human arm.

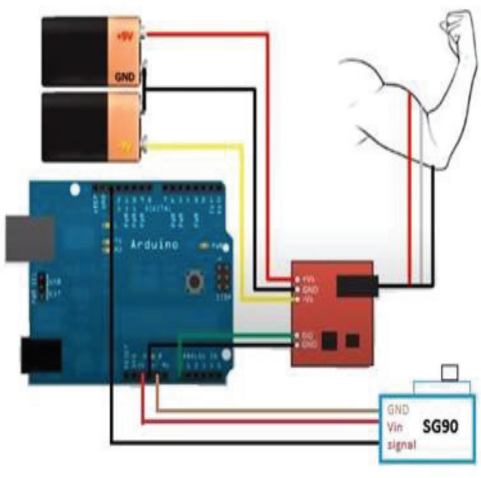

Figure 2. Circuit connections taken from an arm

The flow chart shown in figure 3 shows the stages of the signal processing done in the system.

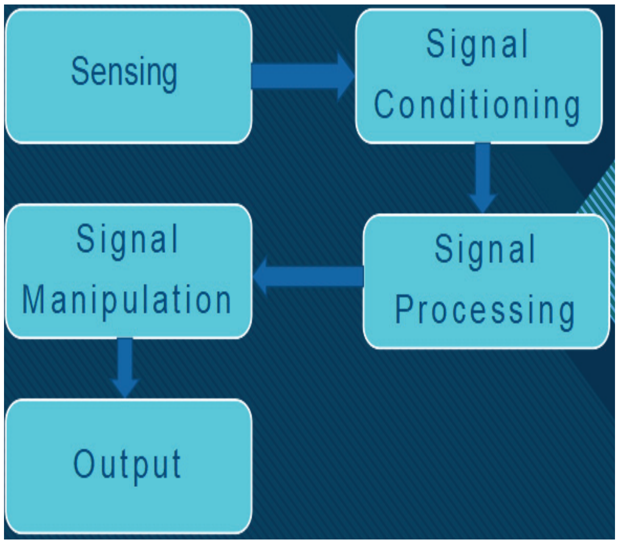

Figure 3. Flow chart of signal processing

D. Sensing or Signal acquisition

Surface EMG electrodes provide non-invasive technique for measurement and detection of EMG signal. The theory behind these electrodes is that they form a chemical equilibrium between the detecting surface and the skin of the body through electrolytic conduction, so that current can flow into the electrode. The sensors used in the circuit are the Ag-AgCl electrodes because they are more suitable for signal acquisition in Surface Electromyography. The human body is electrically neutral; it has the same number of positive and negative charges. But in the resting state, the nerve cell membrane is polarized due to differences in the concentrations and ionic composition across the plasma membrane. A potential difference exists between the intra-cellular and extra-cellular fluids of the cell. In response to a stimulus from the neuron, a muscle fiber depolarizes as the signal propagates along its surface and the fiber twitches. This depolarization, accompanied by a movement of ions, generates an electric field near each muscle fiber. An EMG signal is the train of Motor Unit Action Potential (MUAP) showing the muscle response to neural stimulation. There are three electrodes that sense and generate an electrical disturbance is the circuit, the mid muscle electrode, the end muscle electrode, and the reference electrode. The reference electrode is placed on an electrically neutral muscle and the other two electrodes are placed on the detection surface. Figure 4 shows the different types of electrodes used in this prototype.

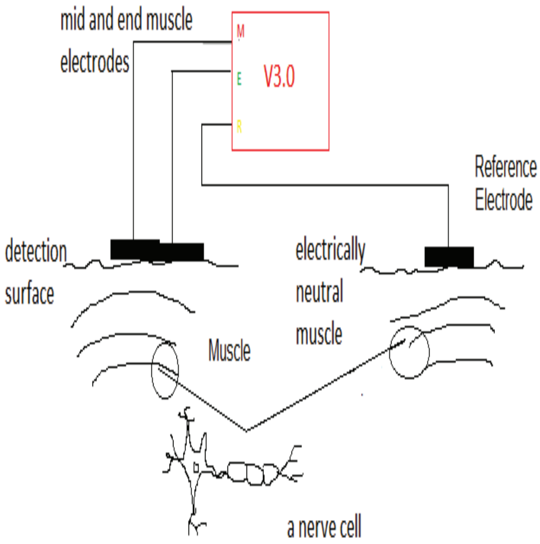

Figure 4. Types of electrodes used in the prototype

Electrode-skin impedance plays a major role in biological signal quality. High electrode-skin impedance influences negatively biological signal quality since it is associated with low signal-to-noise ratio. High electrode-skin impedance causes poor detection of biopotentials at the electrodes sites because it forms a strong barrier for the biopotentials to cross it. It could be linked with low mobility of ions across the highly resistant skin layer (stratum corneum) that is in contact with electrodes and low electron/ion exchange at electrodes sites. Thus, that could cause weak conductivity between the electrodes and the skin and would reduce the biological signal amplitude (low signal to noise ratio). A mismatch in impedance between the electrodes at the skin surface during recording a biological signal would reduce the common mode rejection ratio of the recording system, increase common mode interference (e.g., power line noise) and decrease the signal-to-noise ratio. Electrode-skin impedance varies from one person to another and from one part of the body to another. For example, when Rosell et. al. measured the electrode-skin impedance at different parts of the body for ten subjects using Ag/AgCl electrodes, they found a high electrode-skin impedance of around 1 MΩ at 1 Hz at the leg site, and around 100 kΩ at the forehead site. Non-polarizable electrodes are likely to have lower electrode-skin impedances in comparison to polarizable electrodes.

D. *EMG signal detection*

Precise detection of discrete events in the sEMG (like the phase change in the activity pattern associated with the initiation of the rapid motor response) is an important issue in the analysis of the motor system. Several methods have been proposed for detecting the on and off timing of the muscle.

The most common method for resolving motor-related events from signals of the EMG consists of visual inspection by trained observers. The “single-threshold method,” which compares the signal of the EMG with a fixed threshold, is the most intuitive and common computer-based method of time-locating the onset of muscle contraction activity. This technique is based on the comparison of the rectified raw signals and an amplitude threshold whose value depends on the mean power of the background noise. The method can be useful in overcoming some of the problems related to visual inspection.

E. *Signal conditioning and manipulation*

The electrical design considerations [2] in order to synthesize the best possible EMG signal from the muscles of the human body are in thorough detail. There are many concerns regarding the proper detection of the EMG signal. Once the electrode is properly placed and the signal is extracted, noise plays a major role in hampering the recording of the EMG signal [3]. For this purpose, the signal must be properly filtered, even after differential amplification. The noise frequencies contaminating the raw EMG signal can be high as well as low. Low frequency noise can be caused from amplifier DC offsets, sensor drift on skin and temperature fluctuations and can be removed using a high pass filter. High frequency noise can be caused from nerve conduction and high frequency interference from radio broadcasts, computers, cellular phones etc., and can be deleted using a low pass filter [4]. The signal processing is the most important process or stage as it determines or has direct impact on the output of the module of the project. The processing includes conversion, analysis and control of the signal or variable. The input signal for the module is an analog signal and output generated is of digital in nature. The controller used for the signal processing in the module is arduino UNO R3 board. It also adds as a DAC element for the circuit. The AT mega328 is the micro controller that is used for the module. It contains the program instructions that are used for analyzing the EMG signal. The analysis is done using the threshold method where a threshold value is declared for the signal and a set of different functions are carried out according to the magnitude of signal in comparison to the threshold value. The software that is used for the programming instructions is the Arduino IDE version 1.8.13.

The process signal is manipulated [5] accordingly and the output is obtained. Signal manipulation is done by using the threshold method to actually manipulate the signal and convert it into a mechanical movement in the servo motor that will lead to the opening and closing of the gripper that is attached to the servo motor. Filters are used to remove the noise signals [6].

The actual value for a set point that can be used for muscle movement in arms for a general person is about 150-300 analogue units this threshold value can differ from person to person as the amount of fat and muscle twitching or fibre twitching is not the same in all of the people. in this particular module programming the set point for each muscle movement is set to 200 analogue units out of 1024 and login it's so when the signal is above 200 units, A 5V volt signal is generated by controller making the servo motor axle rotate by 90 degrees does opening the gripper and when the signal falls below 200 units the gripper reflexively closes as the angle axle of the motor rotates backwards to zero degrees. The grippers opening and closing movement can be taken as a mechanical output for the system and the servo motors actuator acts as a final control element for the system. The output is in the form of a digital signal and is given to the servo motor so the power for the servo motor is obtained from the Arduino UNO board itself. A digital output can also be obtained in the form of the magnitude of the signal, and it can be monitored by the serial monitor tool that is available in the Arduino UNO IDE software.

III. Output

The output that is given by this module is the mechanical movement that is the rotation of the axle which will directly lead to the opening and closing of the gripper set up. This mechanical movement is directly proportional to the EMG signal that is picked up by the electrodes from the motor neurons of the skeletal muscle of the arm. The mechanical movement for the opening and closing of the gripper will be in imitation of the opening and closing of an artificial prosthetic limb and it can mostly be related to opening and closing of a fist. The gripper is as shown in figure 5.

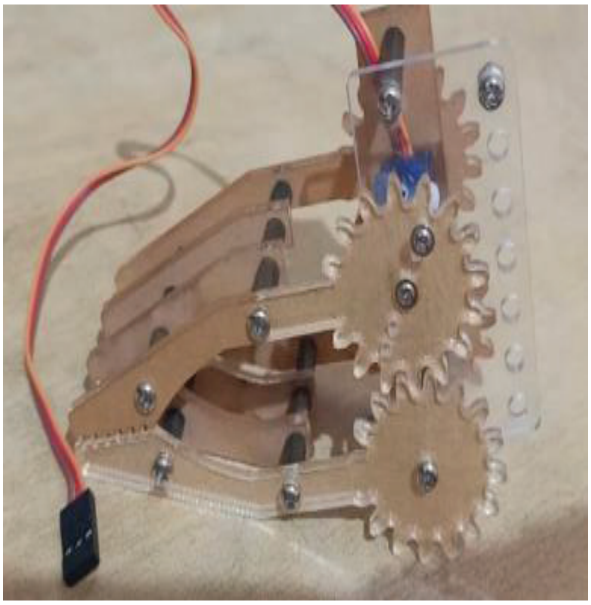

Figure 5. Gripper

A display of magnitude values per every time interval is displayed on the serial monitor tool that is available on the Arduino IDE software and this magnitude of the electric signal will be directly proportional to the EMF that is picked up by the electrodes. The magnitude is in the form of analog units. Any signal that is acquired by the order number can be given a specific magnitude in terms of units. The unit of the output scale can be varied from 0 to 1024 scale. Hence, Surface electrography can prove to be very useful and advantages when compared to other options available in the field in accordance with many factors [7].

IV. Conclusions

A process that uses surface electromyography is advantages because it has the feature of easy and quick attachment and removal. As the sensing part that is to be connected to the process is the surface electrode. Non-Invasive techniques do not need to be injected into the skin or any nerve. It has to be just borne by the person like an accessory and the other part of the prosthetics can be attached to the amputated part using a small operation. There would be no side effects or skin problems involved after the process of attachment as nothing is being injected or put into the body of the person. If the intramuscular electrodes were used instead of such surface electrodes, the body might react with the needle an infection. In this case, the probability is completely zero. There is no chance of the device being infected by the fluid of the body of the amputee. Generally, this happens when there is a little bit of leakage from the body because of infection in inside the body infection can generally occur because of inflammation caused by intramuscular electrodes. This case is called the prosthesis being expelled from the body. A comfortable prosthesis can mean improved mobility and ability. For athletic amputees who use the intramuscular method of electromyography, the movement is more painful and causes discomfort. Using the proposed method, it can help in acceleration to their top speed and it can help them by exerting a little bit less effort. The disadvantages of the module come along with the limitations of the module. The cost of the setup is the main drawback because the accurate real time sensors are of more cost effective and so are the prosthesis. A minimum working process tik arm without sense of touch cost around the around $5,000 and a fully working easy arm with sense of touch goes beyond the cost of $50,000 rupees and the real-time sensors have the market value of around 6000 rupees per sensor making it more costly so for a common man. The electrodes inside the setup need to be replaced every now and then as they might lose their accuracy after some time. For real time use, it is recommended that the person will be using metal surface electrodes instead of Agcl electrodes because the metal electrodes are more real reliable and have a longer life time than the Agcl electrodes. There are also certain number of applications or situations where the patient must use intramuscular sensing methods, in such cases surface electromyography goes out of the picture. There can be noise signals that can interrupt the sensory perception of the amputated limb and this might result in reduced or deficient motor control and the reduced sensory perception. The prosthetic limbs can be heavier and harder to handle for a person and can result in loss of more energy and might result in different leg mass and inertia. The instrument is more sensitive, easily damageable, and prone to Noise and temperature sensitive.

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