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Multiple Hand Gesture Recognition using Surface EMG Signals

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ABSTRACT

Significance of robotics in serving the human being is increasing day by day. A large number of impairments and disabilities in human body force the researchers to think on the necessity of simple and natural human-machine control interface. The idea of the project is the acquisition of SEMG (Surface Electromyographic) signals from the forearm and to recognize the various hand gestures. The resulting classification is then used to control a two degree of freedom (DOF) robotic gripper.

Muscular activity is sensed by placing the EMG sensors/electrodes on the skin. The acquired signal from these electrodes is very small in amplitude and corrupted by different artifacts due to positioning and pasting of electrodes, transmission line and crosstalk with other biological signals. Pre-amplification is required to boost up the signal and then filtration is required to get the desired usable band of frequency. After that artifact-free EMG signal is further amplified, which can be fed to the control circuitry (microcontroller) to control the Hobby Servo motor of the robotic gripper hand. All the process is implemented for the real time scenario.

Keywords: Human-machine control interface, SEMG (Surface Electromyographic) signals, classification, degree of freedom (DOF), crosstalk biological signals.

1 Introduction

Electromyographic (EMG) signals provide a very useful means of control of robotic prosthetics. Research in the field of biomedical engineering, wearable robotics supported by electro mechanics, has led to the creation of advanced and accurate active prosthetics. The foremost problem encountered while dealing with physiological signals is isolating the desired signal from that of its like counterparts. When measuring motor unit action potentials, it can be hard to assure that the acquired signal is that of the muscle under examination [3].

Once obtained the EMG signal can be used for several applications. In applications such as determining muscle fatigue, the frequency spectrum of the signal possesses the desired information, whereas, for control applications the overall energy of the signal provides the preferred control parameter. The goal for this paper is to use EMG signals obtained from the forearm to control a mechanical gripper which not only focus on obtaining an accurate signal from the muscle, but also creating an easily controllable servo mechanism that will provide user feedback. For gripping tasks, a drawback for the user can be

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their inability to identify grip strength. The goal of this paper is to provide the user with a vibration sensation to indicate gripper strength, while allowing the user to vary this strength accordingly [1] & [2].

The objectives of this paper are to give the user motor control and sensory feedback information using a simple non-invasive interface method. A non-invasive method allows the user to wear the bionic hand only when they feel it's appropriate. The ease of use comes with the control system we have used, that how to control robotic gripper. Flexion and extension of the users' muscles must be recorded and sent to the electrical system which gives the output and direction on how to flex or extend the mechanical joints to the specified hand position. The last objective of this paper is to develop some sensory feedback to the user so that they have an idea of how much pressure the hand is on an object.

It is important for a user to have this sensory information because it allows them to go beyond simple interaction with the physical world, but to understand their own interaction and the ability to make adjustments. The Objectives for the paper are defined as the ability to control the robotic gripper using electromyography, the ability of the robotic hand to perform up to a maximum of five hand positions that will assist the user in easing daily actions and the ability to display sensory feedback information to the user. The bock diagram is shown in figure 1.

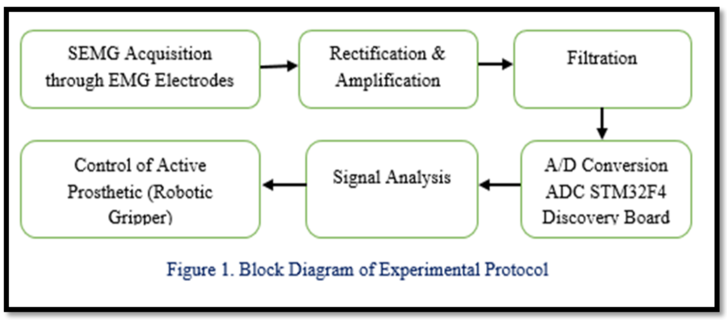


Figure 1. Block Diagram of Experimental Protocol

Figure 1. Block Diagram and Experimental Protocol

First of all muscular activity is sensed by placing the EMG sensors/electrodes on the skin [4]. The acquired signal from these electrodes is very small in amplitude and corrupted by different artifacts. Pre-amplification is required to boost up the signal and then filtration is required to get the desired usable band of frequency. After doing all this, the artifact-free EMG signal is further amplified up to some volts which is fed to STM32F4 discovery board to control the Hobby Servo motor of the robotic hand gripper for practicing different hand gestures. Different gestures are as shown in figure 2. The STM32F4 discovery board is based on the high-performance ARM® Cortex™-M4 32-bit RISC core operating at a frequency of up to 168 MHz The Cortex-M4 core features a Floating point unit (FPU) single precision which supports all ARM single precision data-processing instructions and data types [11].

Figure 2. Different Hand Gestures

2 Surface EMG Signal Detection and Pre Amplification Circuitry

The EMG signal is the electrical manifestation of the neuromuscular activation which represents the current generated by the ionic flow across the membrane of the muscle fibers that propagates through the intervening tissues to reach the detection surface of an electrode located in the environment. The EMG measures the amount of electrical discharge in the muscle fibers and therefore it quantifies muscle contraction and relaxation. This electrical discharge is translated into auditory and visual displays and the person can begin to notice and bring about changes in muscle tension which he/she was previously unable to do. An EMG is the summation of action potentials from the muscle fibers under the electrodes placed on the skin [5] & [1].

The EMG signal is recorded by using an electrode placed on the muscle. The quality of an EMG signal measurement strongly depends on a proper skin preparation and electrode positioning. This is needed to improve the adhesion of the electrodes, especially under humid conditions or for sweaty skin types and/or dynamic movement conditions. Special abrasive and conductive cleaning pastes/gels are available which remove dead skin cells and clean the skin from dirt and sweat. The electrodes we have used are pre gelled surface electrodes.

2.1 Pre Amplification and Body Reference Circuit

Since the EMG signal is low in amplitude with respect to other ambient signals on the surface of the skin, it is necessary and convenient to detect it with a differential configuration. That is, two detection surfaces are used and the two detected signals are subtracted prior to being amplified. In this differential configuration, the shape and area of the detection surfaces and the distance between the detection surfaces are important factors because they affect the amplitude and the frequency content of the signal. That is why two channel data is acquired.

The differential arrangement acts as a comb band-pass filter to the electrical signal seen by the detection surfaces. (In actuality, if the inter-detection surface spacing is set so as not to alias the EMG signal, the spectrum of the EMG signal should fit in the low end of the band-pass filter. Thus for practical purposes, the differential electrode behaves as a high-pass filter.) The distribution of the frequencies in the spectrum as well as the bandwidth is affected by the distance between the detection surfaces [].

At least one neutral reference electrode per subject has to be positioned. Typically an electrically unaffected but nearby area is selected, such as joints, bony area, frontal head etc. we did prepare the skin for the reference electrode too and use electrode diameters of at least 1 cm. The EMG signal is recorded by using an electrode placed on the muscle. The electrical activity measured by each muscle electrode and the ground electrode are sent to an amplifier. The pre amplifier circuitry is as follows.

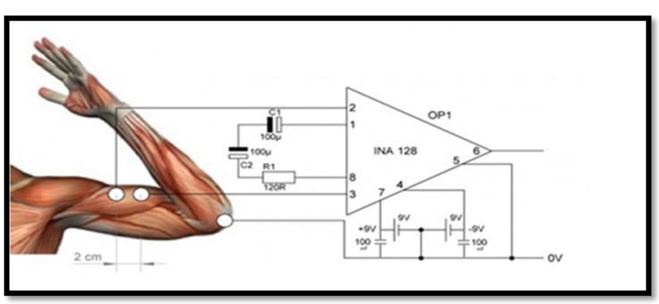


Figure 3. Pre Amplification and Body Reference Circuitry for surface EMG Signal

As explained earlier, EMG signal is so small that it is not suitable for further processing. While the amplitude of the signal is between 0 to 10 millivolts (peak-to-peak), or 0 to 1.5 millivolts (rms), the usable frequency of an EMG signal is ranging between 0-500 Hz. At this state, we need a huge gain to boost the EMG signal without changing phase or frequency of the signal so the gain is set to 500. To get the right level of the input signal, we need a body reference circuit which works as a feedback from the inputs. Whenever the body temperature changes or signal changes due to noise introduced by the body, this body reference will help in maintaining the correct level of signal. In each input channel, there is one body reference feedback [9] & [10].

The amplifier eliminates random voltages caused by electrical noise by subtracting the signal from the ground electrode from the muscle electrode, producing the raw EMG. Noise is being eliminated in LabVIEW software by using moving average filter [5] & [6] and finally a noise free signal is obtained. This can be made pretty clear by seeing the difference between Raw and Filtered EMG signal of open and close gesture as well as wrist movement gesture respectively in the figures shown below.

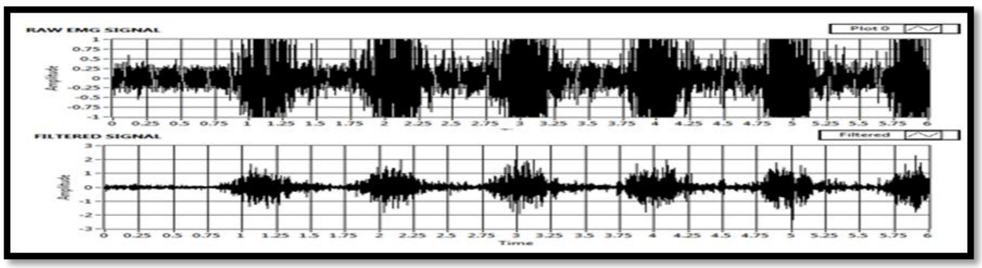


Figure 4. Samples of Hand Open and Close

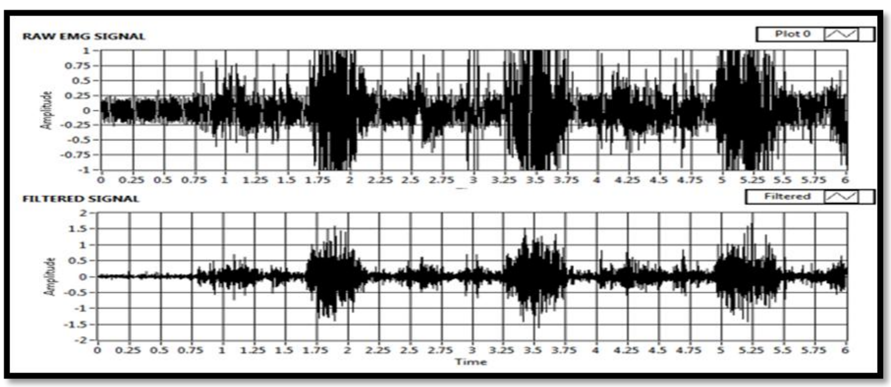


Figure 5. Samples of Wrist Movement

3 Filtration and Rectification

The high pass filter is applied at the Gain resister, so that they help to prevent noise that has been amplified by the amplifier. The filter also helped to sink any DC current that could cause bias for the signal. As described earlier, the usable frequency of the signal lies between 20 to 500Hertz. Majority is concentrated in 50 – 150 Hz. So, we used a High pass filter to remove the low frequency components in the signal and distortions occurred due to electricity wires and mobile phone signals that may affect our required signal.

In the amplifier section we have gain and bias adjustment circuit. The amplifier and bias adjustment provide an ability to adjust or correct the output signals in some circumstances. For example, the amplitude of amplified signal from the preamplifier is not high enough for the control circuitry or the amplified signal still has a bias or offset. Therefore, these problems can be resolved by using of the gain and bias adjustment.

There is a limitation of the gain and the bias adjustment. The amplifier in our EMG device can amplify about 1 to 1000 times. The bias adjustment can adjust the signal up or down by the level of positive nine volts, or negative nine volts. However, by the nature of op-amp, the output from the op-amp cannot be more or less than the power supply voltage. The output of the pre amplification and reference body circuit, for both channels goes to rectification circuit. Rectification is done to convert AC signal into a DC signal. Since the diode has unidirectional property hence suitable for rectifier. The schematic diagram for the rectification circuit made on Proteus Software can be seen in the figure below.

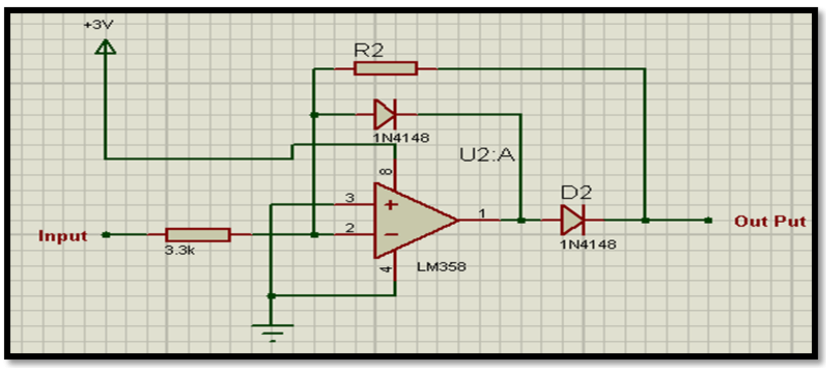


Figure 6. Schematic Diagram of Rectification Circuit

4 The Control Circuitry (Stm32F Discovery Board, Servo Motors and Robotic Gripper Interface)

After acquiring artifact free EMG signal next and most important part of this project is to make use of this signal to control the hobby servo motor of the robotic gripper hand. Servo motors have been around for a long time and are utilized in many applications. They are small in size but pack a big punch and are very energy efficient. These motors are capable of operating remote-controlled or radio-controlled toy cars, robots and airplanes. Servo motors are also used in industrial applications, robotics, in-line manufacturing, pharmaceutics and food services.

Our aim is to control the robotic gripper hand using the Stm32F407VG discovery board. By using the ADC module and controller of the discovery board we controlled the hobby servo motors to actuate the robotic gripper hand.

4.1 Analog to Digital Converter Module (ADC)

The 12-bit ADC is a successive approximation analog-to-digital converter. It has up to 19 multiplexed channels allowing it to measure signals from 16 external sources, two internal sources. The A/D conversion of the channels can be performed in single, continuous, scan or discontinuous mode. The result of the ADC is stored into a left or right-aligned 16-bit data register. The analog watchdog feature allows the application to detect if the input voltage goes beyond the user-defined, higher or lower thresholds.

5 Experimental Setup and Results

Experimental setup mainly comprised of a circuit box consisting of pre amplification circuits for both surface EMG channels, rectification circuit, servo motors circuit and stm34F discover board interface and a robotic gripper. The complete experimental setup is as shown in the figure below.

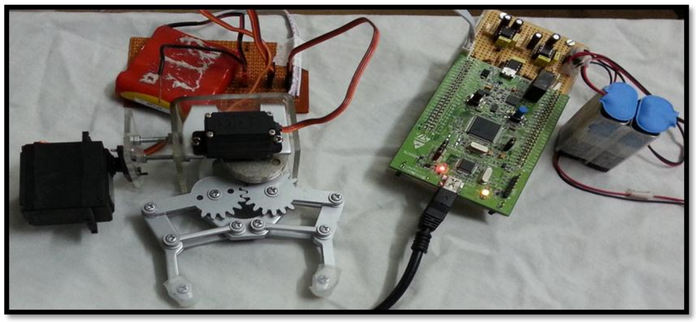


Figure 7. Experimental Setup

We have divided the main circuit in 5 sections. In the following circuit we have three connectors as mentioned in the figure a, b and c. First one “a” is for first channel labeled as section “2”. Second one “b” is for second channel labeled as section “3”. The section 1 is the button for ON/OFF purpose connected with the battery. Section 4 is the rectifier circuit. Section 5 is the STM32F4xx discovery board. Connector “C” is used to connect the Robotic Gripper with the Control circuitry.

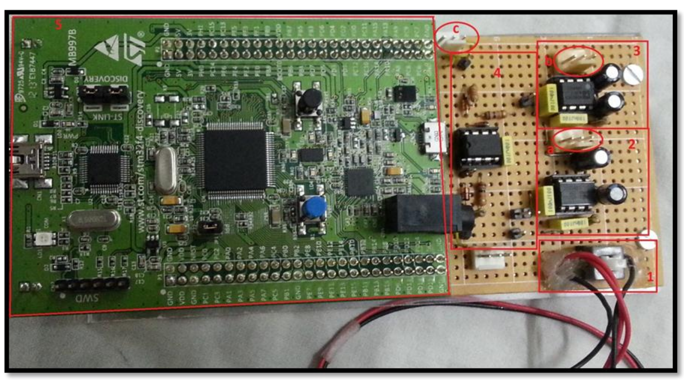
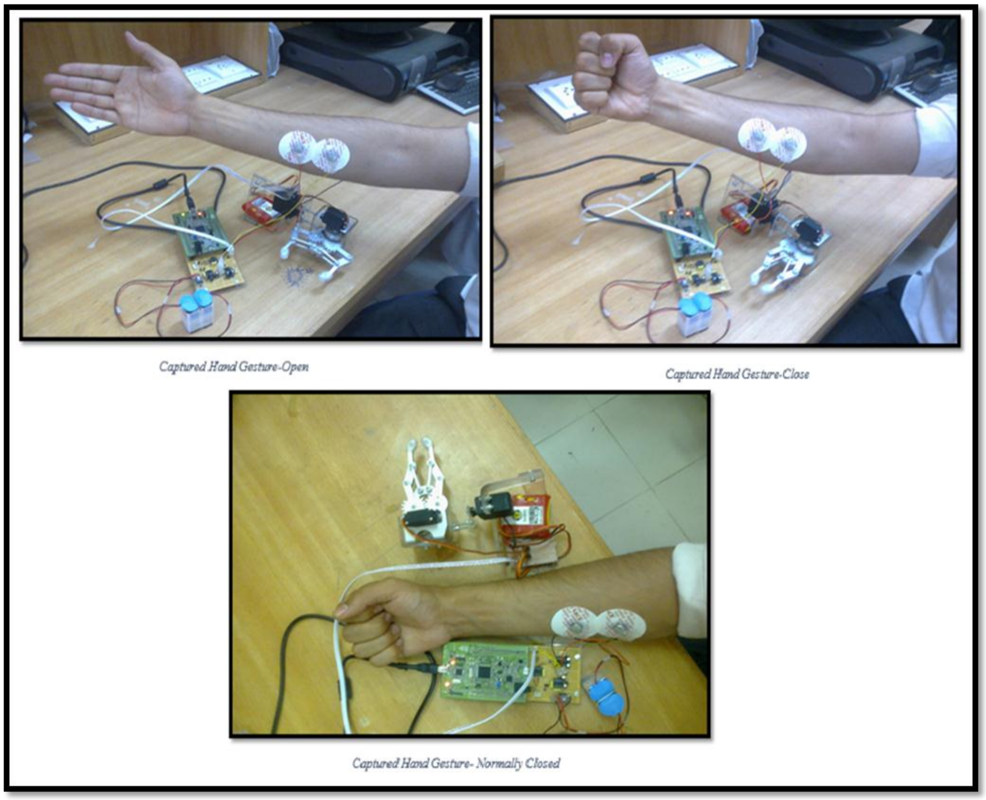


Figure 8. Labeled Sections of Experimental Setup

EMG signals have acquired from SEMG electrodes placed on the right arm of the test subject and it is instructed to perform the hand gestures without creating any flickering of eyes and other muscles contraction. Recorded EMG signals are fed directly to the filtration circuitry where all the undesirable artefacts are removed and signals are amplified according to the readable range of the controller. Once the signals are filtered they are fed to the analogue to digital conversion circuit where recorded continuous EMG signals are digitized and then digitized EMG signals are fed to the STM discovery board controller, where they are analyzed and recognized into multiple hand gesture classes and command signals are generated according to stratified classes to control the motors of robotic gripper [11].

Hand gestures we have detected are as follows and some of them can be seen in the figure below.

- Open
- Close
- Normal
- Normally Close
- Wrist downward movement



Captured Hand Gesture-Open

Captured Hand Gesture-Close

Captured Hand Gesture- Normally Closed

Figure 9. Results of different gestures detected

6 Conclusion

Electromyographic signal contains valuable information regarding the nervous system so the main objective of this study was to give a brief information about EMG signals acquisition, analysis and interfacing methodologies with exoskeleton/robotic gripper. This study clearly differentiated gestures of upper limb (open, close, normally close and wrist downward movement) and interfaced successfully with the robotic gripper using STM32F40xx discovery board controller. While implementing the hardware interface it has been observed that use of other reconfigurable devices like FPGA and PLDs will enhance the results in more efficient way. Future work will comprise of enhancing signal processing techniques and lower limb prosthetics interfacing with SEMG electrodes.

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