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Real Time Control of Robotic arm Using Electromyogram (EMG) Signals

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Abstract— ***Nowadays, the rate of disabled and the people who find difficulties in using their limbs due to age are increasing. A human-assisting robot is a better option for them to overcome this problem. An Electromygraphy (EMG) is a physiological signal that is produced due to the electrical activity when muscle contracts. These signals can be used as control signals for serving the robot. In this paper, a robotic arm is controlled using the EMG signals acquired from the forearm of the user. The proposed interface can be used to control a pick and place robotic arm in real time. EMG signals are acquired from the forearm of the user with the help of surface electrodes attached to the user's skin, which avoids bulky interface sensors. Moreover, it is found as the proposed system is robust to muscle fatigue or adjustments of contraction level.***

Keywords— ***Electromyographic (EMG) signals, Robotic arm, Root Mean Square (RMS) value, variance, LabVIEW***

I. Introduction

As we know robots find useful in many fields. The human-robot interface has been proposed in several studies earlier. Most of the previous work proposes complex mechanisms where the user should be trained to map his/her action to the motion desired for the robot. In this paper, a new means of control interface is proposed, in which the user performs natural motions with his/her hand. Surface electrodes which are placed on the user's skin record the Electromyography (EMG) activity of the muscles of the forearm. The recorded muscle activity was processed such that they can be used to control the robot arm. Here we use a pick and place edge robotic arm which moves according to the arm movements.

EMG signals have often been used as control interfaces for robotic devices specially robotic arms. However, since the musculoskeletal system is very complex and the EMG signals are non-stationary signals, only discrete control has been realized. While going through the earlier studies, some developed an upper-arm EMG-based robot control system using the adaptive neuro-fuzzy inference system (ANFIS) to realize the fuzzy system[1].Others explained the hand-arm robotic system using haptic technology[3],consists. of data Glove with flex sensors and Micro-Electro Mechanical System (MEMS). Another was a prosthetic finger system based on the EMG signals and uses the Hilbert transform two EMG patterns[5].In [6], robotic arm with four degrees of freedom is designed in which servomotors are used. Here the input is given using arm made of polycarbonate fitted with potentiometers with a certain angle of rotation. Artemiadis and Kyriakopoulos [7] proposed an EMG-based position and force control scheme for robot arm which had training and real time phases. In this paper, real time control of robotic arm using surface EMG signals are proposed. For simplicity only two movements are taken into consideration; flexion and extension. The signals are taken from the forearm of the user and processed to serve as control signals for the robotic arm. At first a training process was done by collecting EMG signals from the forearm of different persons who are having similar features (height, weight etc). After processing these signals calculated the range. In the next step robotic arm was controlled by the EMG signals in real time.

II. METHODOLOGY

A. Problem Definition

There is no doubt that the EMG signals are non stationary signals which are complex. However, they can be used for interfacing the human with the robotic devices. In this paper, a human-robotic interface is proposed using the EMG signals. The EMG signals from the forearm is used for controlling the pick and place robotic arm. For simplifying the work only two movements are considered, that is, flexion and extension. An EMG signal represents the electrical activity of the muscle due to the potential difference when the electrode is placed as the muscle is contracted. The amplitude of the electrical signal generated by the muscle activation will depend upon the force applied to move the joint, the velocity of muscle contraction and the angle of muscle pull when it contracts. Fig.1 represents the proposed model for the robotic arm control. Here, a robotic arm is controlled using the EMG signals in real time. For accomplishing this task,as in Fig.1,the initial step is to acquire the EMG signals from the fore arm of a person. For this purpose, surface electrodes are used. EMG signals are collected from different persons. They are asked to do the two motions, flexion and extension, each for a time duration of 10seconds and about 10 samples are taken. These signals are then processed in the LabVIEW software. The corresponding digital values are given to the robotic arm and thus it can be controlled in real time. In order to control the robotic arm it is necessary to extract the features of the signal. The features can be Root MeanSquare value

(RMS),Mean Absolute Value(MAV),Variance etc. Here we are extracting the RMS and Variance values of the signal to obtain the control signals.

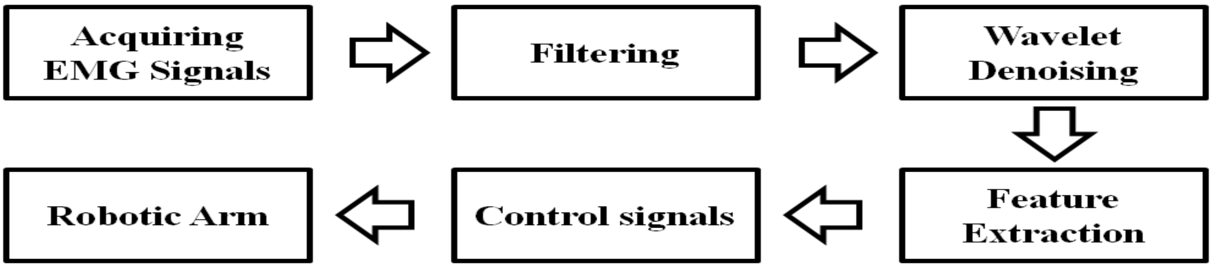

Fig.1 Proposed system model for the robotic arm control

B. Filtering

Raw EMG signal ranges from 20Hz to 500Hz. So inorder to acquire those signals we use a Butterworth band pass filter with cut-off frequencies ranging from 20Hz to 500Hz with order 6. There are so many artifacts which affects the EMG signals adversely. The most common artifact is the line interference. It comes from the power line. Inorder to remove this interference we use a notch filter with cut-off frequencies 49Hz to 52Hz.

C. Wavelet Denoising

Denoising is used to remove the noise signals from the useful information. The wavelet transform is used to construct time-frequency representation of the signals. Here we use Discrete Wavelet Transform for denoising the signals. A wavelet can be described as a small wave which oscillates and decays in the time domain. Wavelet transform consists of two functions: scaling function which has the scaling index k and the time translation function with time translation index j. Among the different transform types the Daubechies transform found appropriate in denoising. Denoising consists of mainly three steps: decomposition, thresholding, signal reconstruction.

In decomposition, the noisy signals are decomposed to four levels using Daubechies wavelet(db02). In thresholding, we use soft thresholding. The soft thresholding zeroes out all the values smaller than the threshold value and subtracts the threshold from the values greater than the threshold. Let the wavelet coefficients are represented as Tj,k. If the threshold can be represented as t, then the thresholding can be represented as,

$$D(T_{j,k}) = \begin{cases} 1 & \text{for } T_{j,k} \geq t \\ 0 & \text{otherwise} \end{cases}$$

D. Root Mean Square (RMS) value

The RMS value can be defined as the statistical measure of the magnitude of a varying quantity, here, the EMG signals. It is the square root of the arithmetic mean of the squares of the set of values. This will help to find the digital values required for the robotic arm control. The RMS value is calculated for the samples taken from different persons. Then the range of the value is computed. Let Xn represent the samples then RMS is given by ,

$$\text{RMS} = \sqrt{\frac{1}{N}\sum_{n=0}^{N-1} Xn}\ \hat{}\ 2$$

E. Variance

Variance specifies the inequalities between the samples. It represents the contraction levels in the signals. It is usually represented as,

$$\text{Variance} = \frac{1}{N-1}\sum_{n=0}^{N-1} Xn\hat{}2$$

F. Overview

For accomplishing the task of human-robot interface, the initial step is to acquire the EMG signals from the fore arm of a person. For this purpose, surface electrodes are used. These surface electrodes are attached to the fore arm and thereby extracting the signals using Biokit. It filters and amplifies the EMG signals. We can acquire these signals using the National Instruments USB-6008 DAQ. After acquiring EMG signals ,it should be processed. For this LabVIEW software is used. After converting it to digital values it should be given to the robotic arm. Here, USB-DAQ is used to give the digital values corresponding to the EMG signals to the driver circuit. The driver circuit is made of L293D.The robotic arm consists of five motors. Each motor can be driven using the driver circuit by giving the digital values. Thus according to the movement of human arm the robotic arm is controlled virtually in real time.Fig.2 represents the block diagram of the system.

Fig.2 Block Diagram of the EMG-based robotic arm control

III.EXPERIMENTS

The EMG signals are collected using surface electrodes. Surface electrodes are, as their name implies, attached to the surface of a person's skin of the fore arm. This is normally accomplished by a self-adhering disposable patch to which an electrode wire is attached,or using conductive gel, and a conductive metal electrode. The electrodes are connected to the Biokit. It has an amplifier which amplifies the EMG signals. The USB-DAQ is used to acquire the EMG signals from the Biokit. The LabVIEW software is used to process these acquired signals. The processed values of the signals, which are digital in nature are taken from the digital pins of the of the USB-DAQ. These digital values are given to the driver circuit made of L293D which drives the DC motors of the the robotic arm and thereby moving the robot. The experimental setup is shown in Fig.3.

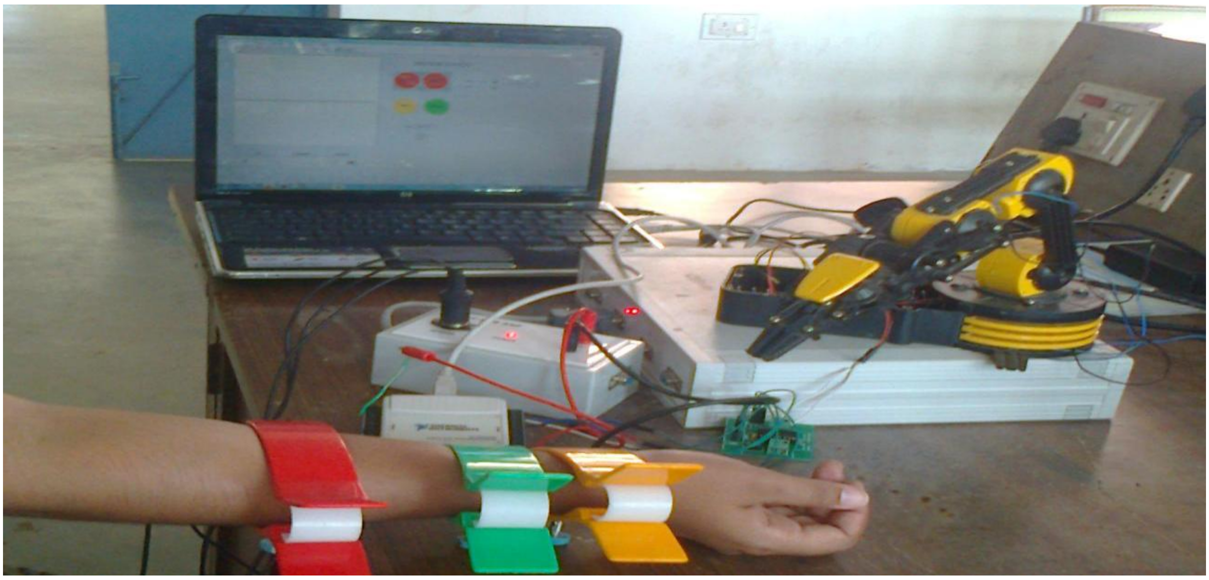

Fig.3 Experimental setup of the proposed system

A. Hardware

The Biokit is used to collect the EMG signals from the fore arm of the human. It consists of disk electrodes and an amplifier. The surface electrodes are used to detect EMG signals. The electrodes can be attached to the fore arm after applying the surgical electrode gel to the particular positions. One electrode act as the ground which is attached near to the wrist, and the other two electrodes detect the voltages, one at the fore arm and the other near to the elbow. The amplifier amplifies these signals.

NI USB-DAQ is a low-cost portable data acquisition (DAQ) device is used to measure and analyze real-world signals. Here the USB-DAQ is used to acquire the EMG signals as well as for giving control signals. The L293D driver circuit can drive two DC motors (Motor A & B) or one stepper motor. The voltage at which the required motors should be driven should be provided to the board through the connector marked Power Input. Alternatively, the power input can also be supplied to the header pins marked Alternate Power Supply. The two DC motors to be driven should be connected to Motor A and B terminals. To drive a motor, the Enable pin (En x) should be provided a logic high (5V). The direction of the motors is controlled by the other two input pins. The values for these input pins are given by the microcontroller. OWI-535 EDGE robotic arm is a pick and place arm. It uses DC motors for the movement. It consists of five motors. Each one for gripper, wrist motion, elbow motion, base motion and for base rotation respectively. The features of them are as follows: The gripper can open and close, the wrist provides a motion of 120 degrees, the elbow range is of 300 degrees,the base rotation is of 270 degrees, and the base motion is of 180 degrees. In our system we are considering only two motions. Each motor is controlled by the digital signal provided by the control via the driver circuit.

B. Software

LabVIEW is a graphical programming language that uses icons instead of lines of text to create applications. LabVIEW can be defined as dataflow programming, where the execution is determined by the flow of data. In LabVIEW, we build a user interface with a set of objects and tools. The user interface is called as the front panel. We then add code using graphical representations of functions to control the objects in the front panel . The block diagram contains the code for front panel. In some ways, the block diagram is similar to a flowchart.

The processing of the acquired signals is done in the LabVIEW software. The signals acquire are in time domain. These signals are converted to frequency domain. The feature extraction, that is, the RMS value and variance are computed in the LabVIEW. By comparing those values, digital values corresponding to the EMG signals for the flexion and extension are produced. These digital values are used for interfacing the robotic arm with the human arm.

C. Results

The EMG signals were collected by attaching the electrodes to the forearm . The movements taken under consideration were flexion and extension. Four persons with similar height and weight were considered for this purpose. After collecting the EMG signals they were filtered using bandpass filter as well as by notch filter inorder to remove the artifacts present in the signals and to get the required range where useful information is present.

The wavelet denoising was done inorder to remove the noise in the signals. After denoising we extracted the two features of the EMG signals that is, the RMS and Variance. We were able to find the range in which the movements can be distinguished as flexion or extension. In Fig.4 and Fig.5 the front panel of the system is shown.

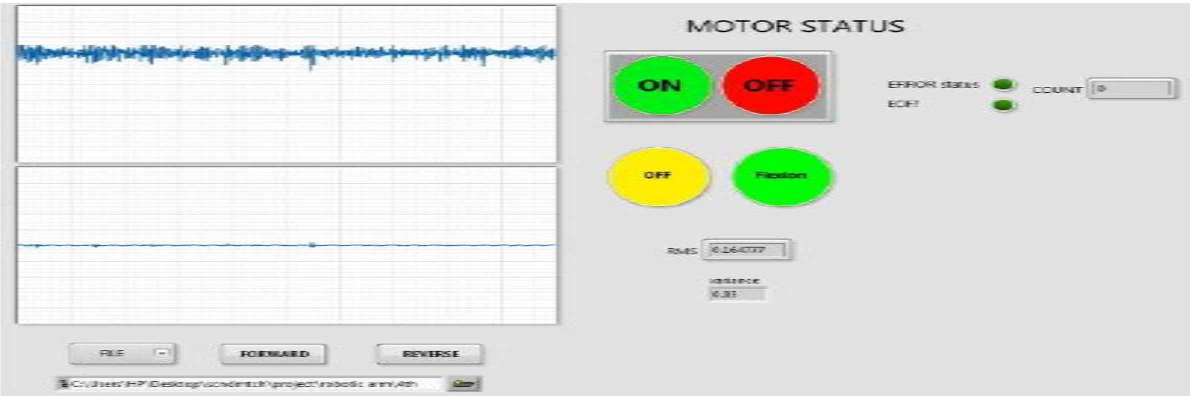

Fig.4 Front panel for flexion

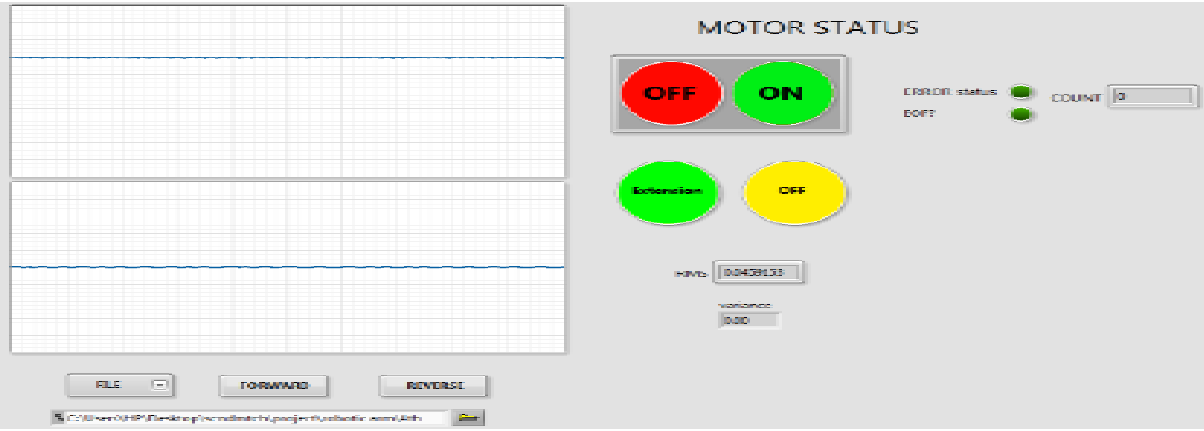

Fig.5 Front panel for extension

IV. CONCLUSIONS

Here, we were able to control the robotic arm using the EMG signals acquired from the fore arm of the person. By extracting the required features from the signals the arm is controlled. The EMG signals were acquired from the fore arm for the movements flexion and extension of different persons. This was done by attaching surface electrodes to the fore arm with the help of the through NI USB-DAQ. The samples were taken and features like RMS and Variance were extracted. These features were used to produce the control signals. The OWI-535 EDGE robotic arm was controlled by giving digital values from the NI USB-DAQ through the L293D driver circuit. The programming was done in the LabVIEW. In future, instead of using DAQ we can use a microcontroller for giving the control signals to the driver circuit and thereby the robotic arm can be controlled.

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