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A Study on Electromyography Signal as a Controller

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Abstract— Human computer interaction (HCI) is the study of interfaces between human and computer. When an input keyboard is pressed the output is displayed in the monitor is a simple example of human and computer interaction. World Wide Web is yet another example of HCI. HCI is everywhere and has become an important aspect in human life. HCI have many subfields and one among them is the study of biosignals. Signals that are generated from living body during muscle contraction, eye movement, brain signal are biosignals and these signals have potential for developing an interface for human computer interaction. There are many such bio electric signals which can be made to use for developing interface and that can be done by acquiring these signals which will form a linkage with the computer technique. These types of signals are brain signal called Electroencephalogram (EEG), heart signal Electrocardiogram (ECG), eye movement signal Electrooculogram (EOG) and muscle signalElectromyogram (EMG). The paper focuses on the study of muscle signal controller as HCI, EMG signals are captured during contraction of a skeletal muscle. The signal is then amplified and converted into usable signals that will be fed as an input to computer and can be used for controlling certain devices.

Keywords- EMG, HCI, Voluntary Muscles, Differential Amplifier, Basic Stamp, Boe-bot

I. BACKGROUND

HCI in the start was known as man-machine interaction, its growth began since 1980s and is expanded since then. HCI focuses on the implementation of a design so a system that is easy to understand, simple in design and create a reciprocatively interface between human and computer. There are two important aspects in HCI, understanding human behavior as its factors like human needs, limits, cognition affects system input and output. Second is understanding the level of system which gives responses when given a task. Designing a system which is simple, efficient, easy to use and making people understand the advantages of computation-based devices is important [11]. HCI is popular among a wide range of people as its computer system can also be used for communication between machines and for specially-abled people. These are physically challenged groups of people who need support to perform work. They cannot directly communicate with the computer unless helped but with the emerging trend of the use of HCI, this group of people can now communicate with the interface directly. Researchers develop new approaches understanding the types of users needs and limits and design a system that makes communication easy and fun [20]. Understanding user's goal and minimizing the gap between man and machine is what HCI is aiming for. Examples of HCI techniques that are popular are gesture recognition, image processing, virtual reality, multi-touch technology, google voice search app, smart watch and many more. The success of HCI is not only from a single source, but it has multiple sources that contribute to its study and development.

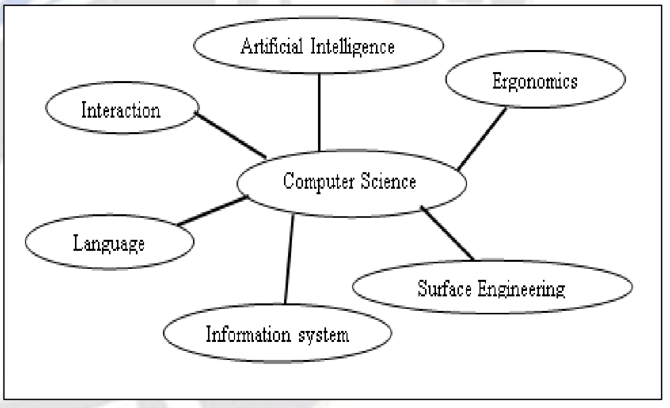

Figure 1. Shows Multidisciplinary Nature of HCI.

EMG is for measuring, recording and estimating the bio electrical potential signals generated by muscles during contraction or movement. The record of the signal produced is called electromyogram and is performed using electromyography [20]. The electric potential difference generated during movement of a muscle are used for EMG based system. EMG HCI technique captures the input from human body muscle signal which is an input to the computer and can be processed for control system like virtual joysticks, motor control system etc. [17]. The main purpose of EMG in biomedical field is to identify the strength of muscle signal, muscle movement and certain disabilities. Hence, making EMG as a potential source for developing HCI based system for motor disabled group of people. EMG signal can be obtained in the form of

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graphs or numerical values that helps researchers to identify whether the activation level of muscle is normal or not. In order to acquire the bioelectric signal electrodes are used. There are numbers of electrode, but mainly used are:

i. Dry electrode or surface electrodes are the electrodes which is directly placed on the skin and it records muscle activity from the surface during contraction or movement of a muscle. It requires more than one electrode to record the potential difference between the two electrodes.

ii. Inserted electrode or needle electrode are the electrodes that are to be inserted inside the human body. The need for medical help and uses electrolytic gel for chemical interface. Needle and fine wire electrode are the examples. Needle electrodes are used in medical areas and fine wire is planted in the skeletal muscle.

These electrodes that record the data of a muscle signal will diagnose motor control disorder and many other neuromuscular diseases.

The design, operation, construction, theory and function of a robot is a part of Robotics. Boe-bot is used for this experiment which is controlled by basic stamp programmable microcontroller. Boe-bot has batteries, two geared motors, control electronics, two plastic wheeles and a gripper [9]. Basic stamp and the boe-bot can perform four activities:

1. Sensors for detecting around.
2. Decision making capability based on what is sensed.
3. Motion control (by operating the motors use of gripper is performed)
4. Information exchange with appropriate devices.

The control command ie, EMG signal is passed through the Universal Synchronous Asynchronous Receiver Transmitter (USART) which then will transmit the signal to boebot using wire communication, which in turn guides the model to perform certain task.

The rest of the paper follows the following section related works describes all the work regarding the acquisition and implementation of EMG signal based for human computer interface to provide output command to certain devices, also the classification techniques to analyze the signal. There are numbers of classification techniques like support vector machine (SVM), neural networks, etc., System architecture gives the overview of the system, all the phases of acquisition, conditioning, processing, interfacing, and use of boebot. Design and implementation discuss the position of electrodes, designing of the circuit for EMG acquisition and also digital output of the signal acquired. Arm control mechanism shows how the servo motor is used to control the gripper of the robot; its rotation is also described. PC interfacing section gives the knowledge of the circuit and the boebot is interfaced using microcontroller. Result section provides some of the figure of acquiring EMG signal and also the controlling of the boebot gripper. The paper only focuses on acquiring EMG signal, measuring, filtering, amplifying and finally using this signal as an input to a robot and perform a task of opening and closing gripper.

II. Related Works

Since the development of biosignal processing, a large number of research are carried out in the field of EMG signal and have made an attempt to control devices like robots.

In 1996Yasuharu Koike et.al, [1] worked on developing an interface that learns motion capability of a robotic arm by employing forward dynamics model of the human arm. The use of machine learning Artificial Neural Network (ANN) made the model a complete human interface which records physiological EMG signals from arm movement. Similarly, in 2000 Alsayegh et.al, [3] 12 arm gestures are recognized by using EMG signal. Researchers used the source EMG signal from arm muscle biceps brachii, anterior deltoid, medial deltoid. The model used Bayes theorem which classifies different arm gestures.

Researchers did not only studied gesture recognition or controlling motor by the use of EMG signal but have done tremendous work by developing a model that can be used by group of people with motor disabilities. Using arm muscle many has acquired a means to communicate with computer in 2004 Jong sung kim et.al, [4] 6 motions were predefined for developing EMG mouse system as a computer command control. In 2005 Inhyuk Moon et.al, [5] developed an interface using EMG signal for the user with motor disabilities caused by C4 and C5 spinal cord injury. EMG signal acquisition is taken from elevation movement from both shoulder and the signal is taken as an input to wheelchair which performs a task like moving forward, backward, stop and start. The following year more research based on EMG signal focusing people suffering from motor disabilities was presented. In 2006 Ki-Hong Kim et.al, [6] developed an assistive system with the use of EMG signal acquired from the contraction of face muscle.

Another hand gestures and actions identification was done in 2006 Ganesh R Naik et.al, [7] by the use of ICA (Independent Component Analysis). With the development of a system that could identify gestures and actions successfully in 2008 JonghwaKim et.al, [10] modified a remote-control car that is instead of using remote control unit, user’s hand sign is used as different hand sign gives different range of electrical input. Classification of control of remote-control car is done by combining K nearest neighbor (KNN) and Bayes theorem.

Another artificial prosthesis control system was proposed based on forearm EMG in 2009 Jun-RuRen et.al, [12]. In the same year Ahsan et.al, [13] studied on classification of various EMG signal that can improve interface for specially-abled people. People with severe disability is impossible for them to communicate with computers one of the works of Armando Barreto et.al, [14] in 2010 proposed an EMG system for people suffering from neck down disability to interact with computers and also to communicate using graphics point and click with the people. The EMG signal acquired is from face muscle movement.

In 2011 surface EMG became popular for interfacing Ishii et.al, [15] studied about arm and hand gesture using surface Electromyogram.In 2012 Takeshi Tsujimura et.al, [16] researchers employed EMG signal from forearm using hand sign. It classifies that if fingers are moved specific muscle of forearm also works. In 2015 Ahmed Mehaoua et.al, [21] designed an easy and efficient EMG based HCI model that control multimedia player which allows commands like start, stop with the use of EMG forearm signal. In 2018 [23] Shin et.al,developed a real time HCI interface using hand gestures for multiple-DoF robotic arm, the use of EMG signal for interfacing with output devices like robot, media player, computers has made a real system as the inputs are from user itself.

In 2019 Qi, Jinxian, et.al, [29] designed a system that could recognize nine different pattern using sEMG signal as an input and has classified nine different classes of wrist movement, finger movement and palm open close. People suffering from many disabilities is one of the reason of advancement of the

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study of biosignals in HCI area in 2020 [32] Alibhai et.al.,studied on developing assistive technologies which could help people in need. With the growing demand researchers have developed smart wheelchairs using EMG signal from forearm which controls the wheelchair.

III. System Architecture

The paper focuses on creating a system for acquiring and processing the EMG signal for HCI application focusing on performing some command. Figure.2 describes the various stages of the system.

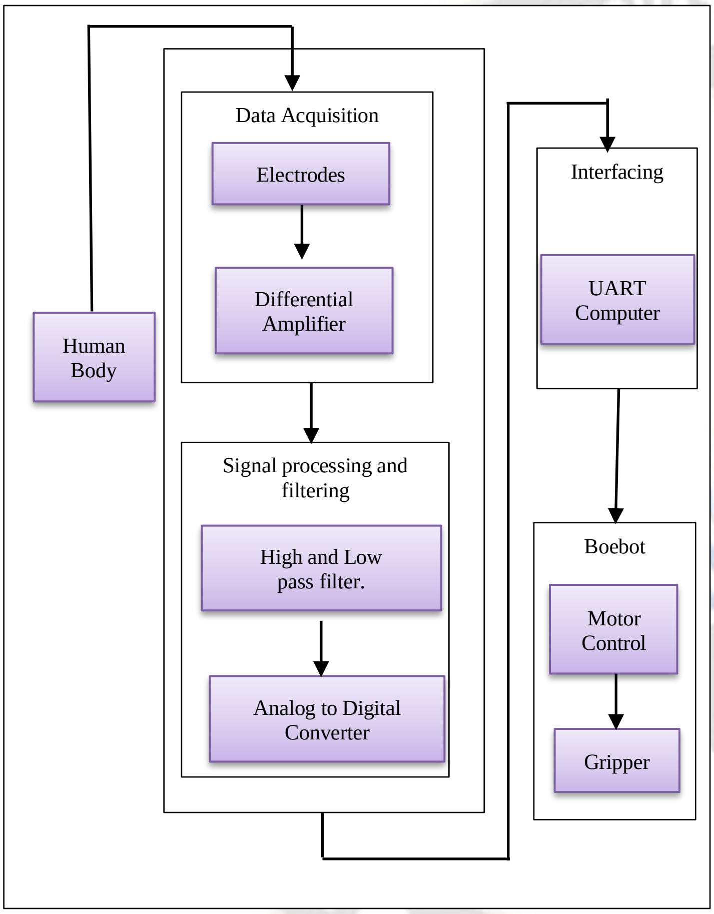

Figure 2. System Overview Block Diagram

A. *Design Strategy*

First, The methods used for completing all the phases are as follows:

- Acquisition: In this process the type of electrode used for acquiring EMG signal from the human body are identified and the signal is amplified to get a better signal. For amplification, differential amplifier is used so that it amplifies the differential value.
- Signal processing: The main processing of signal is done in this phase. Filter of unwanted signal is also done in signal processing. Two filters are used a high pass and a low pass filter which are connected in series and effectively produce band pass filter.
- Interfacing: The signal is then taken as input and is fed in the PC for interfacing using arduino, and then the output is passed into Boe-Bot to perform a task.
- Boe-bot: It is an output system that is controlled by the input given to the system from the muscle of the user. The signal produced in the muscles of the user helps in controlling the manipulator which is attached to a boe-bot robot.

IV. Design And Implementation

Designing deals with the creation of the circuit which performs the function of signal conditioning unit. Two main issues are to be considered when the detection and recording of EMG signal takes place. First is noise in the signal and the second is distortion of signal. Amplitude of the acquired signal is important which ranges from 0 to 10 millivolts and the frequency is between 0 to 500 Hz, however, the usable energy of EMG signal is between 50 to 150 Hz [23].

A. *Signal Acquisition*

1) Position of Electrode: To For the placement of electrodes three muscle area of forearm is used. For this a surface clip electrode are used and are placed in muscle to acquire EMG signal. Figure 3. shows the positioning of electrodes. The recorded EMG signals depends on and are affected by numbers of factors such as types of electrodes, placement of electrodes, distance between the electrodes, number of electrodes used, shape and size of the electrodes and noise. A reusable surface electrode is taken and proper contact with skin is necessary in order to get signal with low noise ratio.

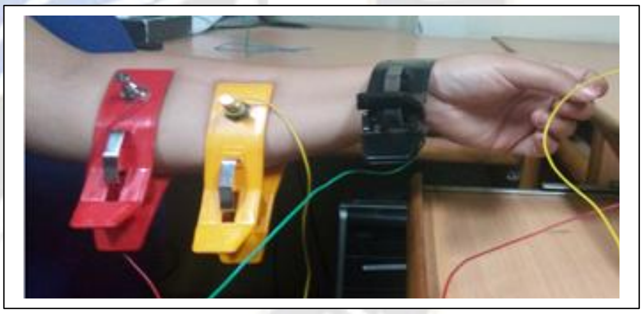

Figure 3. Electrode placed in forearm.

a) Signal Transfer: Highlight The signal acquired by the electrodes is minute signal and it is fed as an input to differential amplifier in order to amplify the signal to match the requirement of the system. The differential amplifier used is INA106 [39] with the precision gain of 10 which has a high input impedance and high common mode rejection ratio (CMRR) to reject unwanted signals. The circuit is designed as Unity Gain Differential Amplifier and the voltage gain of the amplifier is 1, as the resistors R1 and R2 are of same value. The output expression is:

$$V_{out} = V2 - V1 \quad (1)$$

b) Signal Amplifier: A minute signal which has noise signal is measured in signal acquisition phase and in order to make this signal into usable signal it has to be amplified. Thus, the output signal of differential amplifier is fed as an input to the operational amplifier TL072 [40]. In this phase the signal is amplified and inverted to fix the required gain for which two

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feedback loops is used. Capacitor is integrated to remove DC offset error.

Inverting amplifier is:

$$G = -R4/R3 \quad (2)$$

Where, R3 is input and R4 is feedback loop.

Here, the calculated Gain using above formula will be G= –150/10= –15. This gain will again be fed as an input to the second feedback loop where,

$$G = -R6/R5 \quad (3)$$

Therefore, the final gain obtained through signal conditioning- amplification will be G= –453/150 = –3 (approx.)

c) Signal Retfication: Highlight In This phase an active full wave rectifier is used which turns the negative part of the signal and switches into positive making the signal entirely into positive voltage region. Operational Amplifier is used with zener diodes for signal rectification. Low pass filter is used to remove unwanted noise with cut off frequency as (10±200) Hz.

i.e., upper cut off frequency (fn) = 200Hz

$$fn = 1/2\pi RC \quad (4)$$

C2= 0.01μF Then, $1/2\pi RC = 200Hz$

So, $R = 1/2\pi C*200$

$R = 1/2*3.14*0.01*10^{-6}*200$

R= 79.62KΩ= 80KΩ (approx.)

d) Final Signal: Analog signal conversion to digital is done in this phase. The signal is passed to microcontroller to perform operation that is to control motors. An active low pass filter is used to smooth the signal before converting it into digital signal. A potentiometer is added in the circuit to provide required voltage supply for the motor. Figure 4 shows the circuit diagram for signal acquisition.

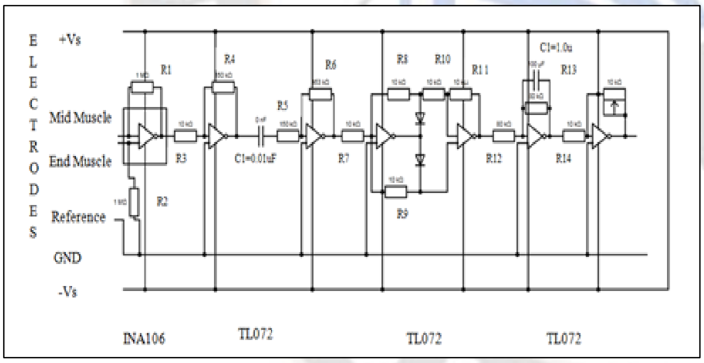

Figure 4. Circuit Diagram for EMG signal acquisition

V. Arm Control Mechanism

The For a control system a boe bot arm is used. The input as EMG signal from forearm is fed as an input to the circuit which then is passed to the controller that is boe bot that shows the controlling capability of the designed system [17]. There are various types of articulated robot powered by Servo motors, Stepper motors, DC motors.

DC motors and stepper motors suffer from imbalance when there is load as it does not have potential feedback systems incorporated in them. But Servo motor has a potential feedback system to correct the imbalance when there is load in the shaft.

A. Servo Mechanism

The servo motor can be rotated from 00 angle to 1800 angle. The servo pulse of 1.5ms will set the servo to 900 position, with the servo pulse of 1.25ms the servo is set to 00 and with the servo pulse of 1.75 the servo is set to 1800. The control of a servo motor is done by basic stamp microcontroller which is shown in Figure 5.

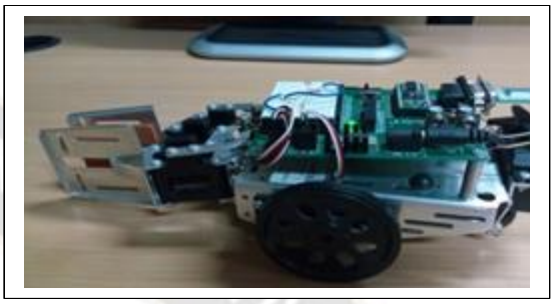

Figure 5. Boe bot with basic stamp microcontroller and servo motor

The actuator arm is set after a pulse is sent to the boe-bot. The servo checks the pulse after some duration to gain for correct information. The gripper of a servo motor is activated when a power supply and an input source EMG is supplied. Control of servo motor is given in Figure 6.

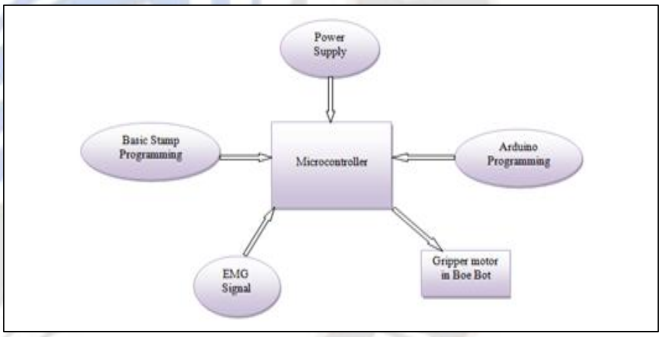

Figure 6. Control of servo motor

VI. PC Interface

The USART module is configured to work in asynchronous mode. The computer transmits the data serially at a baud rate of 9600 with no parity and no flow control. The PIC microcontroller receives the data from the computer and controls the servo.

The stamp controls the servo motor of boebot. The design of a system is that a single pulse movement can perform OPEN movement as well as CLOSE movement in the manipulator. When a single OPEN movement is made, the system identifies it and the manipulator performs a gripper operation. When an EMG signal is fed as an input to the circuit it activates the interface giving the output command to OPEN and when input is released the output command is CLOSE.

VII. Results

The experiment resulted into a successful control of manipulator (servo motor) using the EMG signals shown from figure 7 to 13. Noise of the EMG signals was correctly filtered, and the desired controls were achieved. It is found that the circuit can also verify the activation level of the muscle of individual

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whether it's high or low. The circuit provides the voltage as an input to USART and then it is passed to Basic Stamp which then will implement the program to drive a motor to activate gripper of the boe-bot.

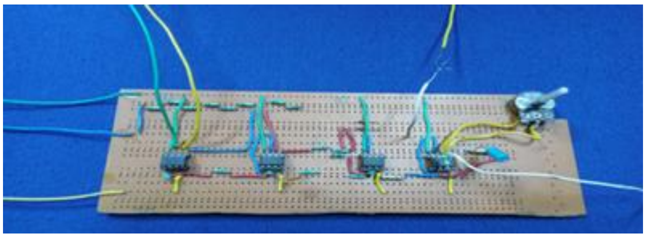

Figure 7. EMG signal circuit diagram

Figure 8. Acquisition of EMG Signal

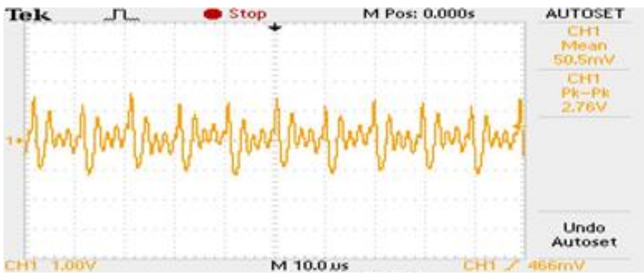

Figure 9. Conditioning of EMG Signal

Figure 10. Rectification of EMG Signal

Figure 11. Final Output of EMG Signal

Figure 12. Position of gripper with no input

Figure 13. Gripper activated with input.

VIII. CONCLUSION

The work presented in this paper is to show the mechanism of EMG based system where the input is taken from forearm by clenching a wrist. Three electrodes are taken for the experiment to acquire signal this signal is then processed to make a useful signal that can be used for HCI and to control some output command. The acquired EMG signal is set to 0V to 5V using potentiometer. The final signal is fed as an input to parallax basic stamp microcontroller that is mounted on top of boe-bot which then with the input signal will open a gripper of a boe-bot and close when no signal is passed. The device can be made more flexible and accurate to control device for the use of HCI. Using EMG signal multiple applications can be controlled at once and analysis of signal can be done.

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