PROSTHETIC ARM USING BIO-MEDICAL SIGNALS

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Abstract—**Amputee and Archeiropody patients often use an artificial hand or other types of prosthetics to regain part of the lost functions. However, the advanced robotic prosthesis is economically out of reach of many patients. In this project, we have described a low cost system that operates from the low dimensional surface EMG/EEG signal derived from the arm of the human body to control a robotic arm. In this paper, we report the results of applying advance signal processing and machine learning to bio-medical signals waves, where each frequencies of the neurons and its combination is mapped to a robotic arm as a form of prosthetic arm with movements similar to a human arm**

Keywords—EMG; EEG;

I. Introduction

This project "Prosthetic arm using Bio-Medical Signals" is project based on a biofeedback mechanical arm that uses a low dimensional input derived from EMG (electromyography) data. The work involves creating a system that allows signals recorded directly from a human body to allow control of a part of a robotic arm.

A robotic arm is controlled using the EMG signal acquired from the electrodes attached to the human arm. The EMG signals are acquired from three different muscle groups of the upper forearm. Considering the EMG signal be very noisy and of the order of micro volts, appropriate filters and amplifiers can be used to provide a valid data. The signals recorded directly from a human body is amplified and filtered to allow control of a portion of a robot arm. The purposed system is designed to use these low dimensional data and map specific patterns to resulting actions of a robot arm. The system can be used as a Bio-Robotic arm for Archeiropody patients (congenital defect, meaning you are born with this condition), amputation (traumatic or surgical condition for removal of body parts). Industrial purpose such equipment movement in normal as well as shied areas, Military purpose for bomb defusing and so-on.

Currently, successful autonomous completion of complex, high-level strategies by a robot relies heavily on human input for control. [1] The unpredictability and density of information provided by the environment surrounding a robot, combined with inaccuracies in sensor measurements make these tasks difficult for a robot to complete. Human brain and human body, on the other hand, are capable of processing large amounts of information and are better at making rational decisions based on these data than current autonomous systems [5].

In some cases, robotic motions and behaviors can be pre-recorded so that the operator only needs to satisfy a simple condition to trigger playback of the action. While this might work in static cases but in dynamic cases, situations may arise where a pre-determined movement may not be appropriate or possible. In such cases, a human to robot relationship needs to be established for better outcomes rather than an autonomous system [3].

Generally, prosthetic arm is not capable of functioning like a human arm. External movement from another or same user needs to be applied. A Prosthetic arm is incapable of movement, placement and pointing objects. Similarly, successful autonomous completion of complex, high-level strategies by a robot relies heavily on external human input for control. In order for robots to do all but the simplest of tasks, such as obstacle avoidance or color segmentation, human intervention and guidance play a major role. Even tasks as simple as moving through a doorway can be surprisingly tough for an autonomous robot.

Our system uses the combination of both Frequency Domain (Power Spectral Density Profile) and Time Frequency Representation (FFT, SFT, Wavelet Transformation) to extract the appropriate signal waves[Delta(0.1-3Hz), Theta(4-7Hz), Alpha(7-13Hz), Beta(14-30Hz), Gamma(30-00Hz), μ waves(>100Hz) and further amplifies and filtered (Sailen Key Band Pass filter) followed by sampling (ADC>4, Frequency > 6 KHz) and analysis. The raw data is converted to feedback signal which incorporated with the motor rotation for the movement of the arm [4].

II. Related works

A robotic arm is a type of mechanical arm, usually programmable, with similar functions to a human arm; the arm may be the sum total of the mechanism or may be part of a more complex robot. The links of such a manipulator are connected by joints allowing either rotational motion (such as in an articulated robot) or translational (linear) displacement. The first prototype, Unimate, was produced in 1961 and installed in GM's factory for die casting handling and spot welding. It cost $65,000 to produce yet was sold for $18,000. After that, GM installed 66 more Unimates and Ford became interested as well. The industrial robot future was certain to be bright with all of the automotive interest and investment. The Stanford Arm was one of the first electronically powered, computer-controlled arms. The Stanford Arm was followed by the Silver Arm in 1974[2].

Similarly, Electromyography (EMG) is a diagnostic procedure to assess the health of muscles and the nerve cells that control those (motor neurons). An EMG uses tiny devices called electrodes to transmit or detect electrical signals. The introduction of the first commercially available electromyography (EMG) system was from 1950. From 1950 to 1973 was the era of the analog EMG systems: EMG signals were recorded, and subsequent analyses were carried out manually on film or paper. From 1973 to 1982, the first modular digital EMG systems were introduced. Dedicated analysis modules were introduced, but detailed analysis was still done on paper. In 1982, the first system controlled by a microprocessor was introduced. From 1982 to 1993, many new ways of analyzing EMG signals and basic reporting features were implemented in the EMG systems. Since 1993, personal computer technology has been used in EMG systems. [6].

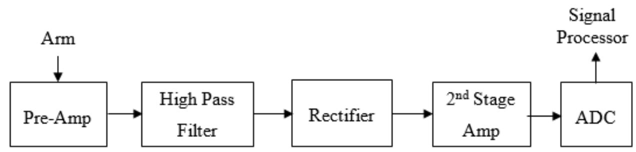
The history of EEG is detailed by Barbara E. Swartz in Electroencephalography and Clinical Neurophysiology. In 1912, Ukrainian physiologist Vladimir Vladimirovich Pravdich-Neminsky published the first animal EEG and the evoked potential of the mammalian (dog). Research on BCIs began in the 1970s at the University of California, Los Angeles (UCLA) under a grant from the National Science Foundation, followed by a contract from DARPA. The papers published after this research also mark the first appearance of the expression brain–computer interface in scientific literature. By 2014 Ohio Doctors were able to control the body parts by inserting electrode and microchips into the brain (based on Artificial Neural Network) [5].

The year 1998 marked a significant development in the field of brain mapping when researcher Philip Kennedy implanted the first brain computer interface object into a human being. However, the BCI object was of limited function. The only benefit from this development was the use of a wireless di-electrode. John Donoghue and his team of Brown University researchers formed a public traded company, Cyberkinetics, in 2001. The goal was to commercially design a brain computer interface, the so-called BrainGate that uses the series of wavelet of transformation with variation of sine and cosine waves for faster frequency response which introduce Neural Monitoring System. Neural Monitoring System enabled them to identify micro-seizure activity prior to epileptic seizures among patients. June 2004 marked a significant development in the field when Matthew Nagle became the first human to be implanted with a BCI, Cyberkinetics's BrainGate [6].

In December 2004, Jonathan Wolpaw and researchers at New York State Department of Health's Wadsworth Center came up with a research report that demonstrated the ability to control a computer using a BCI. In the study, patients were asked to wear a cap that contained electrodes to capture EEG signals from the motor cortex – part of the cerebrum governing movement. A number of developments have been taking place in the field. By 2050, it is having been suggested that BCI could become a magic wand, helping men control objects with their mind. The day isn't far off when man may be able to guide an outside object with their thoughts in order to consistently execute both natural and complex motions of everyday life and could get error rate up to 0.001% [6].

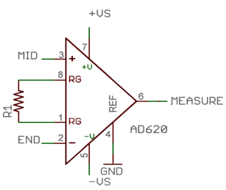
III. Spectral Techniques Analysis USING SFT

It is performed between two Spectral F-Tests (SFT) used in an incremental analysis of EEG records containing four different classes of Steady-State Visual Evoked Potentials (SSVEP). The EEG data acquisition and processing is done by feature extraction and classification of features at different frequency levels for Beta, Alpha, Theta and Delta waves. Similarly, for EMG Waves each peak response is calculated by creating a series of widows and combine to regenerate the signals. The Principal Component Analysis(PCA), and the Wavelet Transform(WT) can be used for dimensionality reduction and feature extraction. The Artificial Neural Network (ANN) which is a computationally powerful model, is used as the classifier[7].



A. Pre-Amplification

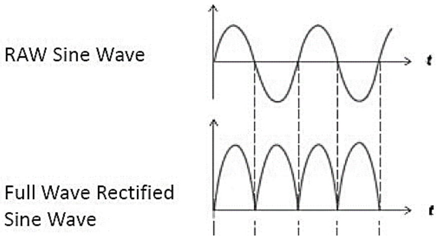
The amplitude of the single ranges from 0.5 millivolt to 5 microvolts. Similarly, the frequency of EMG/EEG varies between 0.01Hz to 2000Hz with practical usable frequency from 20Hz to 500Hz. The EMG signal amplifications consists of two stages. The pre-amplification is done by using a differential amplifier, AD620N, with a gain of 200. The differential amplifier rejects the common mode signal and amplifies only the potential difference between the two electrodes [7].



B. Filtration and Rectification

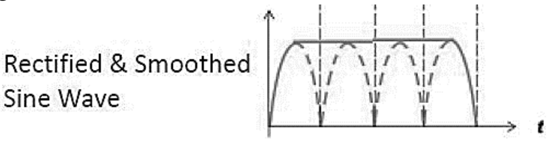
Generally, the frequency of EEG/EMG varies between 10Hz to 2000Hz. The Filtration of signal is generally done by using a fourth order Sallen key band pass circuit constructed by using a 2^{nd} order Sallen Key High pass filter cascade with other 2^{nd} order Sallen Key Low pass filter both with unity gain that filters out the frequency range between 20Hz to 1 KHz which also filters out low dimensional noise at 10Hz.

The filtered signal is passed through a Rectifier circuit consisting of two Zener diodes and an operational amplifier. Each diode conducts the signal to the inverting and non-inverting terminal of the op-amp respectively and the op-amp inverts the negative signal rectifying the filtered signal.



C. *Smoothing and 2nd Stage Amplification*

The rectified signal is passed through a simple Low pass RC filter to smoothen the signal and then amplified using an inverting amplifier with adjustable gain ranging from 1 to 10 times to compensate for the amplitude loss in previous stages.



IV. Experimental evalutaions

The filtered signal was rectified and further smoothen for better analysis using a basic non inverting terminal low pass filter.

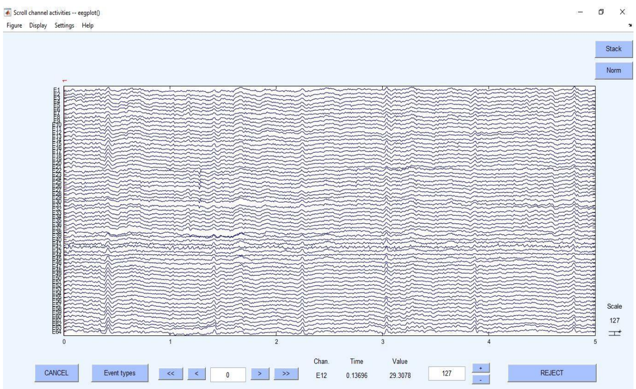


Fig: 6000 Samples of EEG at interval of 10 sec

The signal was extracted from the various point of brain and forearms and was filter to associate frequencies.

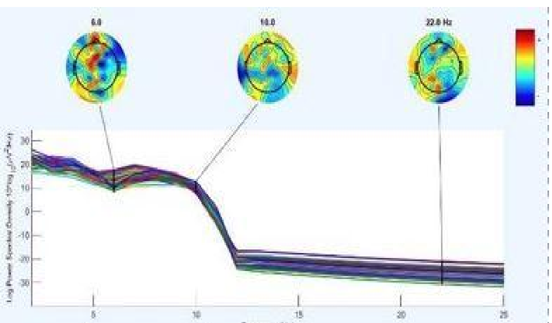


Fig: Power Spectral Response (Series of Wavelets)

Response was calucalte using series of fourier transformation to evaluate its power and energy levels.

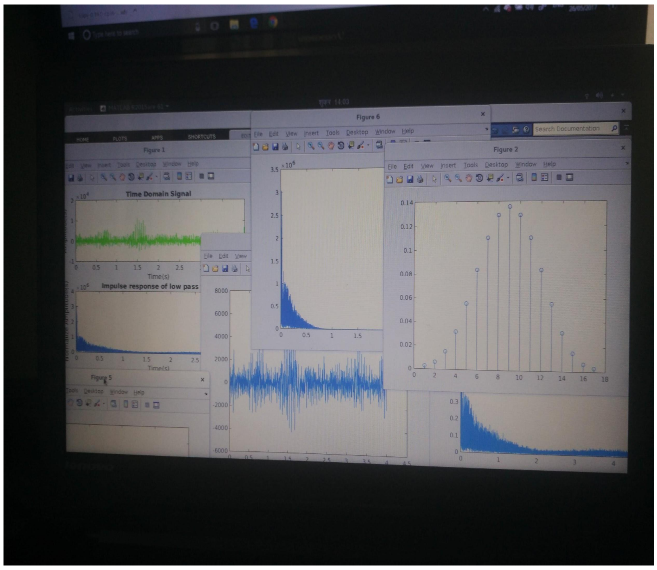
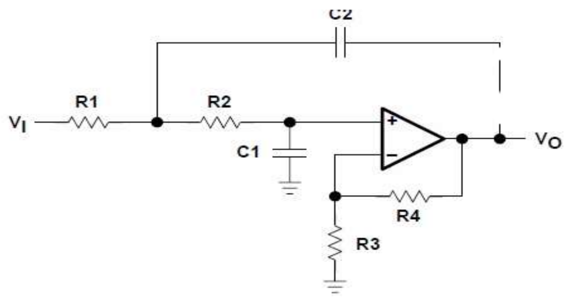


Fig: Time Frequency representation using Mat lab

First the raw signal was quantized to 255 level to find the appropriate frequency response. Similarly, its time domain signal was multiplied with a unit impulse response to find the respective peak and was compared to frequency response. The factor deviation was calculated. And impulse response was tuned based to the factor. The whole process was repeated until the error response become less than 10%.

A. *Equations*



$$H(f) = \frac{\frac{R3+R4}{R3}}{(j2\pi f)^2(R1R2C1C2) + j2\pi f\left(R1C1 + R2C1 + R1C2\left(-\frac{R4}{R3}\right)\right) + 1}$$

Fig: Filter Response Transfer Function

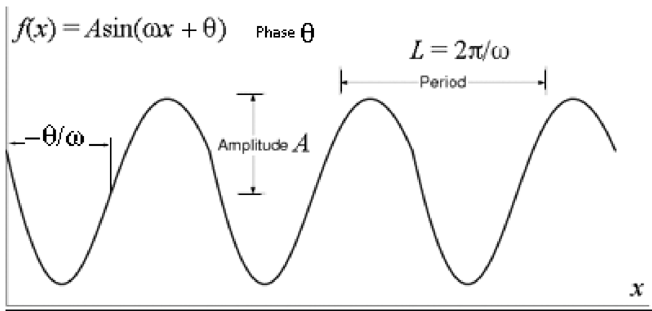


Fig: Spatial Fourier Transformation

V. Error Analysis and Discusions

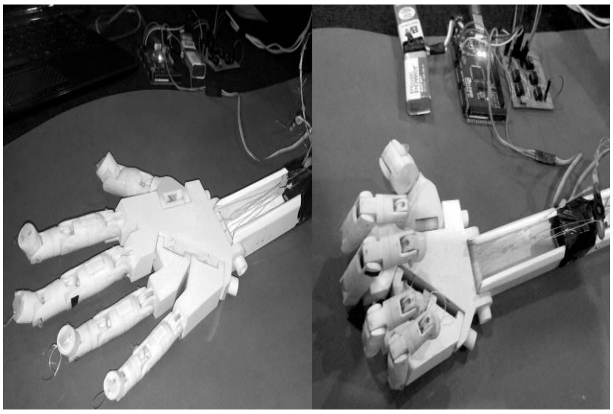


Fig: Arm Response

While closing and opening of arm the delay response of signal and arm was 1 second. The signal response should be less than 100 milliseconds to replicate the behavior of real arm. The error could be due to the various muscles artifacts and slower impulse response of the system.

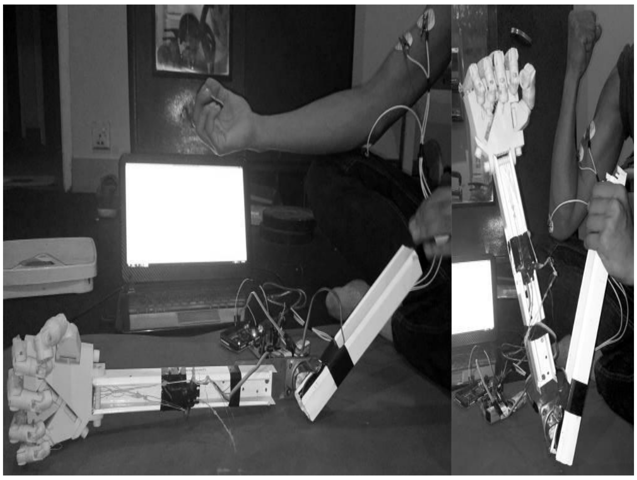


Fig: Forearm response

However, there was only delay of 100 milliseconds during the simulation phase. The degree of movement is limited by the mechanical design of the robotic arm. Rectification and smoothing of signal, which was essential for signal extraction, limits the signal information to amplitude of only one muscle group from a pair of electrode and eliminates most the frequency information.

VI. References

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