Develop and Control of Upper Limb Prosthetic Arm by EMG Features & Activation Function

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Abstract— The loss of an upper limb can be a very stressful experience for a person. Prosthetics devices can help to restore some of the functionality for user. In the recent time, bio-signal such as electromyography has been deployed to develop control system for disable people. Empirical mode decomposition technique is use to extract useful information from single-channel EMG signal. For analysis EMG signal first segmenting signal and then appropriate features are extracting from each segments. Segmentation is done by sliding window approach. The system consist of EMG sensor module, Arduino UNO, MATLAB 2013a (version 8.1), servo motor. This methodology is use as its decompose EMG signal from single channel.

Key words: EMD (empirical mode decomposition) method, DC servo motor, spectral analysis, ARDUINO UNO, MATLAB 2013a (version 8.1)

I. Introduction

- In order to control movement of prosthetic arm, EMG signals are detected from person's desired muscle area of arm. Movement of arm is such a smooth & parallel like human persuasive. Pre-Processing EMG signal for further analysis. For analysis of EMG signal Segmentation of contracted part of signal by sliding window approach. Then extracting features for defining movement. Convert into form that can control motor. Develop prosthetic arm by using muscle signals.
- Time scale features are decomposing signal in time domain and identification of contraction by spectral measure or power analysis. Time scale method is as given below:-

A. *EMD (empirical mode decomposition)*

- Decomposition of the signal into a set of Intrinsic Mode Functions (IMF) which are defined as
  1) Functions with equal number of extrema and zero crossings (or at most differed by one)
  2) Signal must have a zero-mean.

EMD is determining characteristic time/frequency scales for the energy. EMD method is useful for Nonlinear and Nonstationary signal decomposition in time scale manner.

- Basic Parts of the Empirical Mode Decomposition
  1) Interpolation technique (cubic spline).
  2) Sifting process to extract and identify intrinsic modes.
  3) Numerical convergence criteria (mainly to stop the iterative process of identifying every IMF as well as the whole set of IMFs).
- Steps of decomposition
  1) Find local maxima and minima of d_0 (t) = x(t).
  2) Interpolate between the maxima and connect them by a cubic spline curve. The same applies for the minima in order to obtain the upper and lower envelopes $e_u(t)$ and $e_l(t)$, respectively.
  3) Compute the mean of the envelopes
  $$m(t) = \frac{e_u(t) + e_l(t)}{2}$$
  4) Extract the detail d_1 (t) = $d_0(t)$-m(t) (sifting process)
  5) Iterate steps 1-4 on the residual until the detail signal d_k (t) can be considered an IMF: $c_1(t)= d_k(t)$.
  6) Iterate steps 1-5 on the residual $r_n(t)=x(t) - c_n(t)$ in order to obtain all the IMFs $c_1(t)$,.., $c_N(t)$ of the signal.

The procedure terminates when the residual signal is a constant, a monotonic slope, or a function with only one extrema.

- Mathematical Expression of EMD processed signal

$$x(t) = \sum_{n=1}^{N} c_n(t) + r_N(t)$$

Lower order IMFs capture fast oscillation modes while higher order IMFs capture slow oscillation modes.

- Criteria for Numerical Convergence

The sifting process ends (IMF extraction) when standard deviation value reach predefined value. Iteration process ends when n value is 3.

II. Methodology

We can improve the movement analysis technique by using different parameters like power spectrum analysis, and extract features from power spectrum. The sequence of methods, which is used in the system represent following:

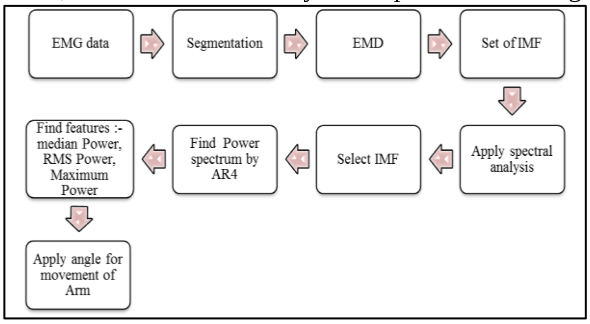

Fig. 1: block diagram of system

A. *EMG data*

EMG data collected from UCI database Machine learning repository[24]. Data collected by 2 forearm surface EMG electrodes Flexor Capri Ulnaris and Extensor Capri Radialis, Longus and Brevis at a sampling rate of 500 Hz, using as a programming kernel the National Instrument's (NI) Labview. The signals were band-pass filtered using a Butterworth Band Pass filter with low and high cutoff 15Hz and 500Hz respectively and a notch filter at 50Hz to eliminate line interference artifacts.

B. Segmented EMG signal

Contracted EMG signal segmented by sliding window approach. Window size is 300ms with overlap of 270ms. Empirical mode decomposition applies to all segmented part of signal for find IMF set.

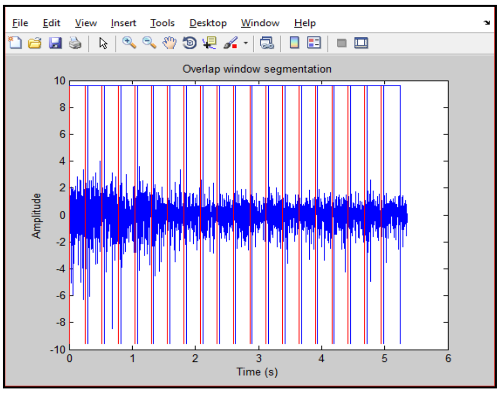

Fig. 2: segmentation of EMG data

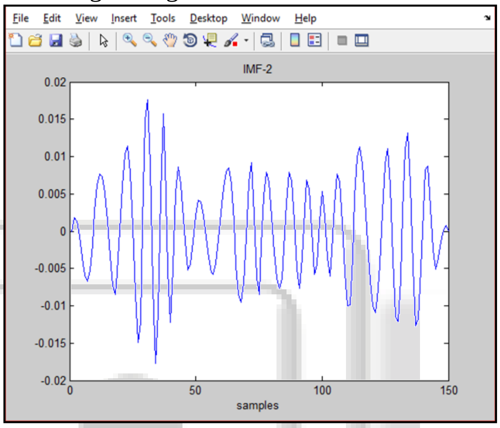

Fig. 3: Spherical EMG IMF-2 by EMD method

C. IMF-2(intrinsic mode function)

Function represent calculation of equal number (or at most differ by one) of extrema and zero crossing from segmented EMG data.

D. Absolute power of 2nd IMF of EMD

Calculate power spectrum by AR (auto-regression) 4th order method. AR model is as good spectrum estimation as Hilbert huang transform[1]. As see in below figure discriminate all six movements from each other.

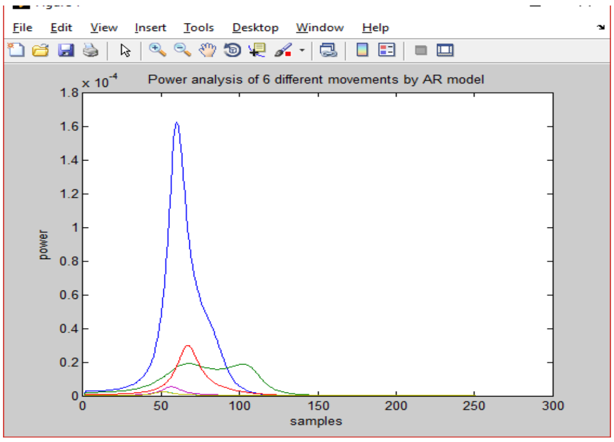

Fig. 4: Absolute Power of IMF-2

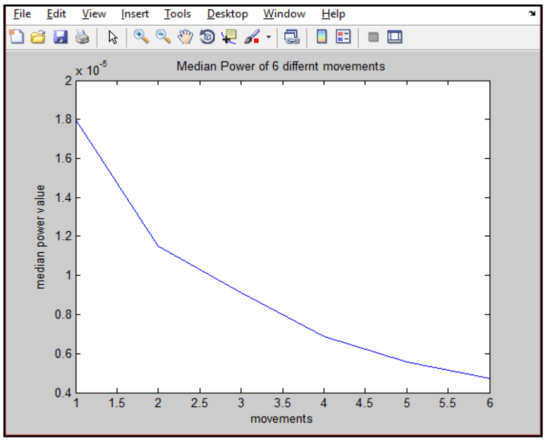

Fig. 5: Median Power of IMF-2

E. Median power of 2nd IMF of EMD

In this method calculate median feature from Power spectrum of IMF-2.

F. Root mean squared

In figure.5 a) RMS value calculate from power spectrum of IMF-2. And in figure.5 b) maximum value of power is calculated for all 6 movements.

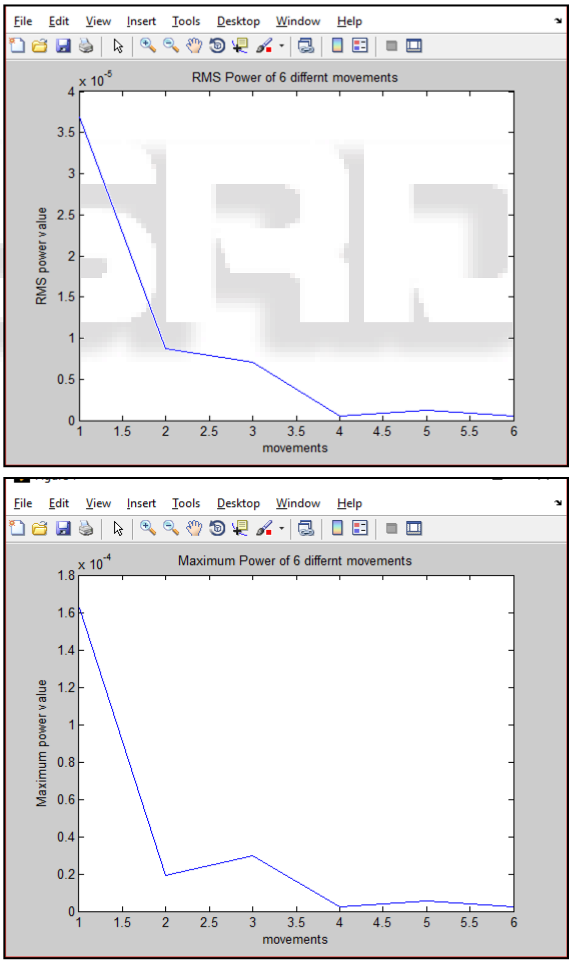

Fig. 6: a) Root mean squared of Power spectrum of IMF-2; b) Maximum power

By all these 3 features movements discriminate in certain range. In ranges of all movement angle is apply to drive prosthetic arm. After done processing on UCI library EMG data then real time display EMG sensor is use to acquisition EMG signal by single channel sensor.

- Specifications of sensor module: -Power supply voltage: min.±3V to max.±30V; Output: Analog
- Hardware and Software Required: - Arduino Uno; Arduino IDE
- Hardware Connections: - +Vs to +12v; Ground to Ground; -Vs to -12V; SIG to Analog 0(A0)

III. EXPECTED RESULT

This paper is described various methodology for movement of prosthetic arm. For the desired output controlled signal requires working in certain ranges where range is not cover noise or any spectral leakage. Various grips are as given figures.

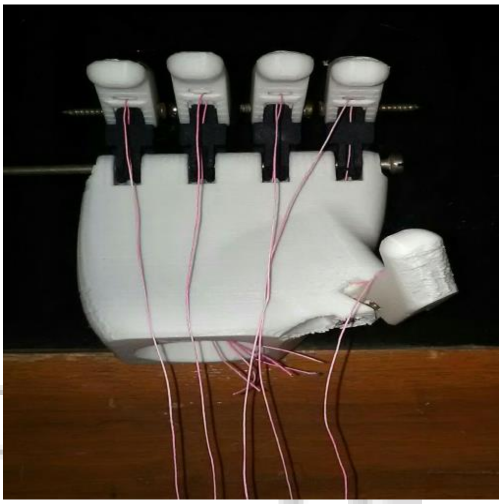

Fig. 7: Cylindrical grip

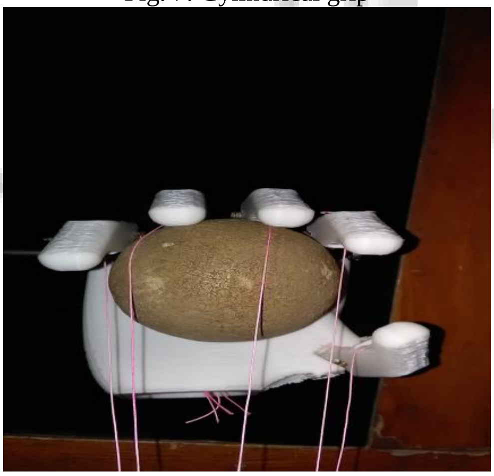

Fig. 8: Spherical grip

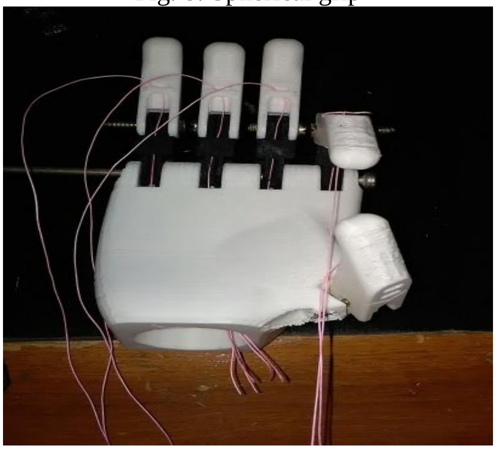

Fig. 9: Lateral grip

Sr. No.	Fingers movement	Angle	Apply voltage	\Movement
1	Four fingers with thumb grip	90°	5volt to all individual	Cylindrical
2	Four Fingers with thumb grip	180°	5volt to all individual	Spherical
3	1st finger with thumb	180	5volt to 1st finger and thumb	Palmer

Table 1: Angle apply to arm movements are as given below table.

REFERENCES

A. Papers

[1] Hongbo xie "Mean Frequency derived via Hilbert Huang transform with application to fatigue EMG signal analysis", doi:10.1016/j.cmpb.2006.02.009, computer methods and programs in biomedicine 82 (2006)114–120.
[2] Christos Sapsanis," EMG based classification of basic hand movements based on time frequency features", 978- 1-4799- 0997-1/13/$31.00 ©2013 IEEE.
[3] Jinal rajput,"Real Time Multichannel EMG Acquisition System", Volume 1, 2349-784X, International Journal of Science Technology & Engineering, May 2015.
[4] T. S. POO, K. Sundaraj," Design and Development of a Low Cost EMG Signal Acquisition System Using Surface EMG Electrode", 978-1-4244-7456-4/10/ 2010 IEEE.
[5] Yu Su, "Towards an EMG-Controlled Prosthetic Hand Using a 3-D Electromagnetic Positioning System", vol. 56, no. 1,IEEE transactions on instrumentation and measurement, February 2007.
[6] Vivek Bhojak, "Gesture Controlled Mobile Robotic Arm Using Accelerometer", 2319-8753, International Journal of Innovative Research in Science, Engineering and Technology, June 2015.
[7] S. Lee, "Fuzzy logic versus a PID controller for position control of muscle like actuated arm", 12206-008-0424-7, Journal of Mechanical Science and Technology, Springer, April 23, 2008.
[8] Xiaorong Zhang, "Real-Time Implementation of a Self-Recovery EMG Pattern Recognition Interface for Artificial Arms", 978-1-4577-0216-7, 13 July, 2013.
[9] Miki Nikolic EMGTools, an Adaptive and Versatile Tool for Detailed EMG Analysis, 0018-9294/$26.00,2011 IEEE
[10] Mahyar Zardoshti-Kermani, "EMG Feature Evaluation for Movement Control of Upper Extremity Prostheses", IEEE transactions on rehabilitation engineering, vol. 3, no. 4, December.
[11] Dapeng Yang, "EMG Pattern Recognition and Grasping Force Estimation: Improvement to the Myocontrol of Multi-DOF Prosthetic Hands", 2009 IEEE/RSJ International Conference on Intelligent Robots and Systems.

B. Manuals

[12] Peter Konrad, Noraxon, "The ABC of EMG", INC. USA, ISBN 0-9771622-1-4 , Version 1.4 March 2006
[13] Basic of MATLAB, document center, MATLAB2013a
[14] Arduino interface to MATLAB, Mathworks.inc,2011-1012,help
[15] Analogue input, Arduino Uno demos, 2013
[16] Servo drive, Arduino Uno demos, 2013
[17] EMG signal processing, help, Mathworks.inc,2011-1012
[18] Filter signal, Signal processing tool, MATLAB 2013a

C. Lab Practical

[19] Arduino demos, The Mathworks.inc,2012
[20] MATLAB tutorials, documentation center, MATLAB 2013a(version 8.1)

D. Websites

[21] http://en.wikipedia.org/wiki/Electromyography
[22] http://www.merrian-webster.com/medlineplus/muscle
[23] http://www.ni.com/labview/
[24] http://mlr.cs.umass.edu/ml/datasets/sEMG.