



HAL
open science

Myoelectric signal analysis using Hilbert-Huang transform to identify muscle activation features

Alvaro Altamirano-Altamirano, Arturo Vera, Lorenzo Leija, Didier Wolf

► **To cite this version:**

Alvaro Altamirano-Altamirano, Arturo Vera, Lorenzo Leija, Didier Wolf. Myoelectric signal analysis using Hilbert-Huang transform to identify muscle activation features. 13th International Conference on Electrical Engineering, Computing Science and Automatic Control, CCE 2016, Sep 2016, Mexico, Mexico. 10.1109/ICEEE.2016.7751246 . hal-01631210

HAL Id: hal-01631210

<https://hal.science/hal-01631210>

Submitted on 11 Jun 2023

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Myoelectric signal analysis using Hilbert-Huang Transform to identify muscle activation features

Altamirano-Altamirano¹, A.; Vera¹, A.; Leija¹, L.; Wolf², D.

¹Electric Engineering, Bioelectronic Section, CINVESTAV-IPN, Mexico City, Mexico

²CRAN Université de Lorraine CNRS UMR 7039, Nancy, France

Abstract—Surface EMG signals have many important characteristics that could be useful to anticipate user’s movements for orthotic and prosthetic devices. New methods for signal processing have appeared, but not all of them apply to non-linear and non-stationary processes such like myoelectric signals. To perform a real-time analysis over these signals is important to simplify the processing and reduce time computing. Using the Empirical Mode Decomposition (EMD) method we obtained the Intrinsic Mode Functions (IMFs) for a multichannel signal to filter, discard and identify characteristics. sEMG signals were acquired using NI-DAQ system with four differential inputs for four forearm muscles. Seven hand movements were considered, that signals were recorded into a 4 x 20480 matrices in 1000 records. These records were divided in three segments: dross, transitory and contraction; through EMD method we obtained their IMFs to analyze with Hilbert transform. Results will be considered to simplify the sEMG signal for real-time analysis to control a prosthetic device.

Keywords—multichannel, myoelectric, Hilbert-Huang Transform, Empirical Mode Decomposition, characteristics

I. INTRODUCTION

EMG signals are biomedical signals that measures activities in muscles during a contraction or relaxation process; these were collected at the skin surface using electrodes. Raw EMG is an important source of information capable of provide enough information about muscular activity in a non-invasive way to control prosthetic devices but noisy [1] [2] [3]. Surrounding tissue of muscles have electric activity that add non-desire information. Electronic devices introduce noise as electric signals in different ways [4] [5].

Signals that control muscles come from neural system, their properties depends of the anatomical and physiological properties of the muscles [6]. The shapes and firing rates of Motor Unit Action Potentials (MUAPs) could be quantified in time and frequency. The main characteristics of myoelectric signals are amplitudes and frequencies, their amplitudes are from 0.1 mV to 10 mV and a bandwidth from 20 Hz to 500 Hz [7].

Several algorithms have been proposed to clean, denoise and filter signals, however, in recent years the most used methods were based on decomposition schemas to extract the components of the signal [8] [9] [10].

Recent research support the hypothesis that EMG signals could be used to anticipate human movements, this suggest that patterns or intrinsic characteristics are present into signals [11].

This paper reports the processes to analyze multichannel myoelectric signals using Hilbert-Huang method as a technique to decompose signals into a sets of elemental signals (IMFs) and obtain their characteristics and even patterns.

II. METHODOLOGY

A. Acquisition

Using a embeeded acquisition system with four input channels with CMRR of 94dB in the circuit and bandwidth filter from 20 Hz to 450 Hz, sEMG signals from four muscles were recorded for 20 healthy individuals. Differential mode configuration was used to place acquisition electrodes over four muscles with two common references placed over the elbow and wrist.

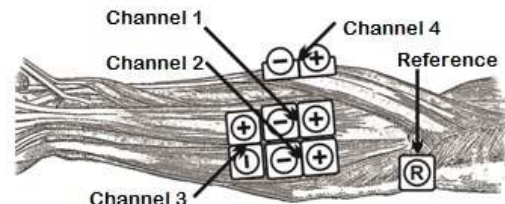


Figure 1. Forearm with differential mode electrodes configuration placed over four muscles.

B. Segmentation

sEMG data recorded was made for 20 seconds, starting in dross position, followed by one of the seven movements holding the muscle contraction to keep the signal stable. From zero to first second was for dross position, from one to five second were for transitory signal and the last fifteen seconds were to establish the contraction as shown in figure 2.

C. sEMG recognition processing: Hilbert-Huang method

Raw EMG offer valuable information into a very noisy form. This information is useful if is quantified. To achieve this, Hilbert-Huang method was applied to the records.

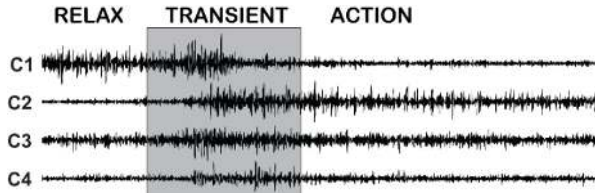


Figure 2. Recorded vectors with three segments: doss, transitory and contraction.

The sEMG recognition system could be summarized as four steps.

1. Collected signals were segmented, windowed into 300 ms parts and normalized to -1 V to 1 V.
2. Decompose signals into IMFs using Empirical Mode Decomposition for each channel.
3. Hilbert transform were applied to IMFs to obtain the spectre and instantaneous frequencies.
4. Discriminate features

The success of pattern recognition depends almost entirely on the choice of the features representing data sequence [12].

D. Empirical Mode Decomposition

Empirical mode decomposition is a technique to decompose a given signal into a set of elemental signals called IMFs. The EMF is the first stage of the so-called Hilbert-Huang Transform.

Given any signal, $x(t)$, the IMFs were found by a iterative procedure called sifting algorithm which is described in the following steps and in figure 3:

1. Find the local maxima, M_i , $i = 1, 2, \dots$, and minima, m_k , $k = 1, 2, \dots$, in $x(t)$.
2. Compute the corresponding interpolating signals; $M(t) = f_M(M_i, t)$, and $m(t) = f_m(m_k, t)$. These signals are the upper and the lower envelopes of the signal.
3. Let $e(t) = \frac{M(t)+m(t)}{2}$.
4. Subtract $e(t)$ from the signal: $x(t) = x(t) - e(t)$.
5. Return to step 1, stop when $x(t)$ remains nearly unchanged.
6. Once we obtained an IMF, $\phi(t)$, remove it from the signal $x(t) = x(t) - \phi(t)$ and return to 1 if $x(t)$ has more than one extremum (neither a constant or a trend).

By construction, the number of extrema should increase when going from one IMF to the next, and the whole decomposition is expected to be completed with a finite number of IMFs.

E. Hilbert transform

Spectral estimation is the second step of the HHT. This consists in computing the instantaneous frequency for each IMF using the Hilbert Transform and the analytic signal concept.

Let $\phi(t)$ be an IMF, $y(t)$ the corresponding analytic signal.

$$\begin{aligned}\phi(t) &= Re\{|y(t)|e^{j\arg(y(t))}\} \\ &= |y(t)| \cos \theta(t)\end{aligned}$$

where $\theta(t) = \arg[y(t)]$. So, instantaneous amplitude were obtained and an oscillating function that is a constant AM/FM signal. If $|y(t)|$ is known, we can perform an amplitude demodulation and obtain:

$$s(t) = \cos[\theta(t)]$$

such that,

$$|s(t)| \leq 1$$

$s(t)$ can be considered as an FM signal. Its demodulation leads to the instantaneous frequency.

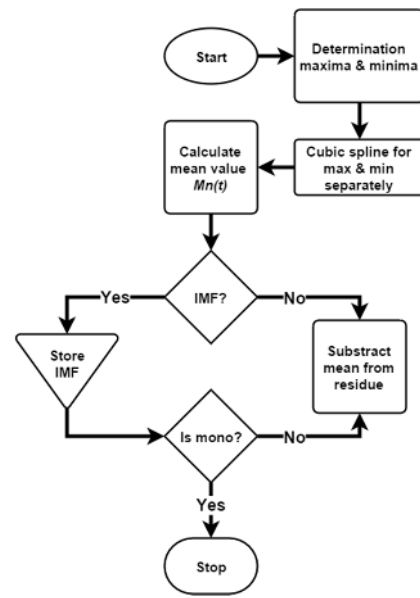


Figure 3. Flow chart of the sifting algorithm, basis of the empirical mode decomposition.

III. EXPERIMENTAL RESULTS

For a 300 seconds segment shown in figure 4 corresponds to a transitory segment. The plots shown different behaviors between channels, each movement has a particular muscular activity into the four muscles. For each channel, IMFs were calculated to extract the main components, in figure 4 were shown the AM/FM components for channels one to four, respectively; those IMFs satisfy the following conditions:

- Resolution: 50dB between signal and bias energy.
- Residual energy: 50dB between signal/residual.

With these resolution and residual energy, were obtained between eight to ten IMFs per channel.

The original signal could be reconstructed in almost 88% using just the IMFs, and with the IMFs and residual to 91%.

After decomposition, IMFs were analyzed. Baseline drift is reflected in higher scales, like in IMFs 6 to 10. High-frequency noise is in the lower scales, like IMF 1 to 3.

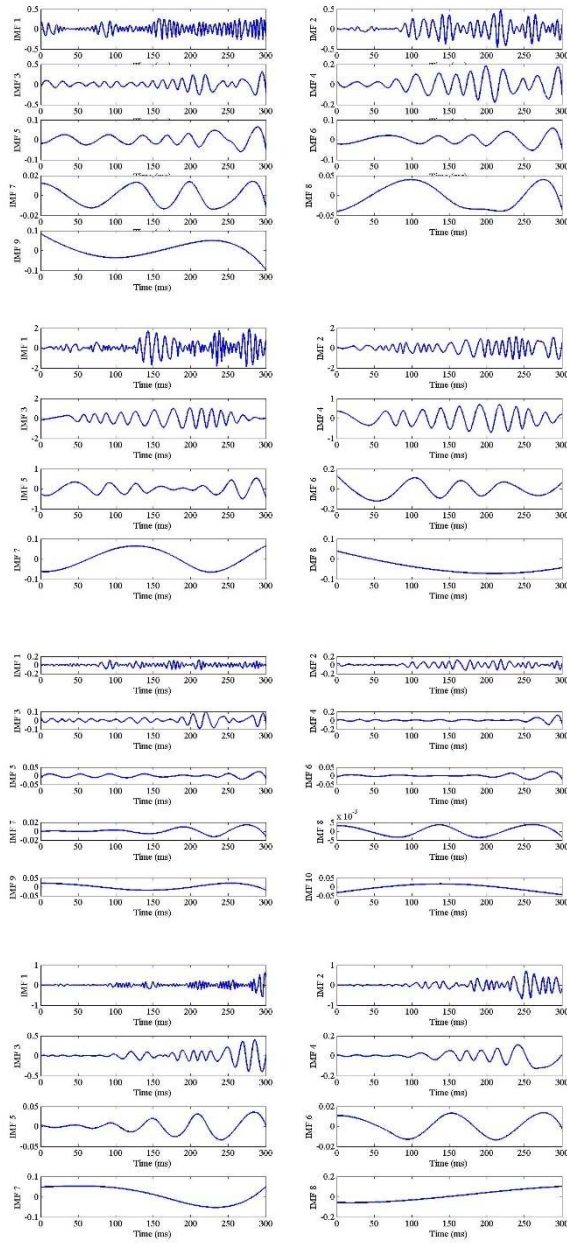


Figure 4. IMFs of the four channels from up to down for raw EMG for closing in transitory segment of one individual.

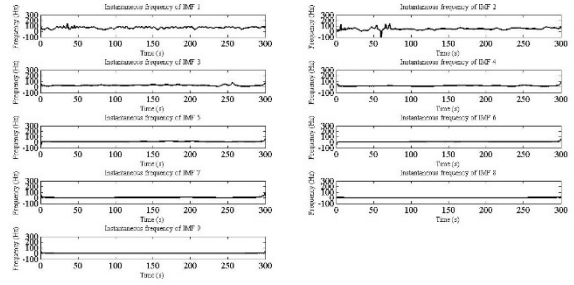


Figure 5. Instantaneous frequencies for IMFs related to channel one during closing movement.

Hilbert transform is useful only if the signals, IMFs, are symmetric, by the way, each IMF was obtained from the decomposition with this characteristic. Instantaneous frequency of each was able to compute.

Finally, analyzing the resulting instantaneous frequencies, in figure 5 for transitory segment, was identified a change in IMF 1 and 2, those are related to the activation of the closing movement.

IV. CONCLUSION

The method of Hilbert-Huang for treating myoelectric signals was described on this paper, all possible results are not shown on this paper, is still in development. Algorithms were programed in Matlab, but is able to be translate to another programming language.

During the development of this work, new ways of processing resulted, like filtering, normalization and noise elimination methods.

HHT method can remain more valuable detail of the signal, because it prevents the energy leak. Also help to find intrinsic features if the EMG signals for short-time analysis. Is possible to reduce time computing in myoelectric signals just to fit the shapes and firing rates to be use as prediction patterns.

Is possible to avoid some traditional calculations, only identifying the main frequencies involved to a specific movement.

To control a prosthetic or orthotic device with a high-accuracy and quick response is able reducing time computing and using patterns in time-frequency and muscular activity characteristics.

ACKNOWLEDGMENT

Authors would like to thank the National Council for Science and Technology (CONACYT, Mexico) for the support received with projects CONACYT-Salud 2013-I-201590, 201256, project joint cooperation México-Uruguay (SRE-AUCI) 2012-2013 and project CSIC-COOPB20166.

REFERENCES

- [1] F. M. Loren and A. N. Wilkins, *Functional Electromyography*, Springer New York Dordrecht Heidelberg London: Springer Science+Business Media, 2011.
- [2] A. Naït-Ali, *Advanced Biosignal Processing*, Springer-Verlag Berlin Heidelberg: Springer, 2009.
- [3] J. Rafiee, M. Rafiee, F. Yavari and M. Schoen, "Feature extraction of forearm EMG signals for prosthetics," *Experts Systems with Applications*, vol. 38, no. 4, pp. 4058-4067, 2010.
- [4] R. Pallás-Areny and J. G. Webster, *Analog Signal Processing*, John Wiley & Sons, 1999.
- [5] J. G. Webster, *Medical Instrumentation: Application and Design*, 4th ed., Wiley, 2010.
- [6] J. Basmajian and C. De Luca, *Muscles Alive - The Functions Revealed by Electromyography*, Baltimore: The Williams & Wilkins Company, 1985.
- [7] K. Najarian and R. Splinter, *Biomedical Signal and Image Processing*, CRC Press, 2006.
- [8] V. R. Lesser, S. H. Nawab and F. I. Klassner, "IPUS: an architecture for the integrated processing and understanding of signals," *Artificial Intelligence*, vol. 77, no. 1, pp. 129-171, December 1995.
- [9] J. Fang, G. Agarwal and B. T. Shanani, "Decomposition of EMG signal by wavelet spectrum matching," in *Engineering in Medicine and Biology Society, 1997. Proceedings of the 19th Annual International Conference of the IEEE*, 1997.
- [10] C. J. De Luca, A. Adam, R. Wotiz, L. D. Gilmore and S. H. Nawab, "Decomposition of Surface EMG Signals," *Journal of Neurophysiology*, no. 96, pp. 1646-1657, 2006.
- [11] A. Hoffman and H. Herr, "Predicting Human Biomechanics with EMG," MIT AI Lab Abstracts, Boston, Massachusetts, USA., 2002.
- [12] N. E. Huang, "Introduction to the Hilbert-Huang Transform and Its Related Mathematical Problems," in *Hilbert-Huang Transform and Its Applications*, N. E. Huang and S. S. P. Shen, Eds., Massachusetts, USA, World Scientific Publishing Co. Pte. Ltd., 2005, pp. 1-26.