Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 120 (2017) 422–429

Procedia Computer Science

www.elsevier.com/locate/procedia

9th International Conference on Theory and Application of Soft Computing, Computing with Words and Perception, ICSCCW 2017, 24-25 August 2017, Budapest, Hungary

Electromyogram (EMG) signal detection, classification of EMG signals and diagnosis of neuropathy muscle disease

Fahreddin Sadikoglu[a], Cemal Kavalcioglu[b*], Berk Dagman[c]

a,b,,c Near East University, Department of Electrical and Electronic Engineering, Near East Boulevard P.O.Box:99138, Nicosia, TRNC, Mersin 10, Turkey*

Abstract

Electromyography (EMG) signals is usable in order to applications of biomedical, clinical, modern human computer interaction and Evolvable Hardware Chip (EHW) improvement. Advanced methods are needed for perception, disassembly, classification and processing of EMG signals acquired from the muscles. Objective of this article is to show various methods and algorithms in order to analyze an electromyogram signal to ensure effective and efficient ways of understanding signal and its nature. Early diagnosis was indispensable and very important in medical health practice. For this reason, it is important to design accurate diagnostic methods. Today, diagnostic methods include evaluating the patient's story, blood tests, and muscle biopsies. In this article, analysis and Electromyogram signals classification and electromyography are mostly used. System has been successfully implemented utilizing MATLAB software that can distinguish EMG signals from different patients. This article also provides the researcher with a well understanding of electromyogram signalling and analysis processes. This information will auxiliary to improve stronger, more resilient and effective implementations.

Peer-review under responsibility of the scientific committee of the 9th International Conference on Theory and application of Soft Computing, Computing with Words and Perception.

Keywords: Electromyography (EMG); Fast Fourier Transformation (FFT); muscles; nervous system; healthy; neuropathy.

* Corresponding author. Tel.:+0-542-856-8366;
E-mail address: cemal.kavalcioglu@neu.edu.tr

1877-0509
Peer-review under responsibility of the scientific committee of the 9th International Conference on Theory and application of Soft Computing, Computing with Words and Perception.
10.1016/j.procs.2017.11.259

1. Introduction

In 1666, the development of the electromyogram began with the documentation of Francesco Redi. Document states that electric ray fish extremely specialized muscles produce electricity. Basmajian and Luca (1985). By 1773, Walsh had been able to indicate that muscle tissue of Eel fish's could create a spark of electricity. The publication written by A. Galvani, named 'De Viribus Electricitatis in Motu Musculari Commentarius', demonstrated that electricity could launch contractions of muscle in 1792 Kleissen et al. (1998). Six decades later Dubios-Raymond, in 1849 was explore that electrical activity could be recorded during voluntary muscle contraction. In 1890 Marey made first recording of this activity, who also presented term electromyography Cram et al. (1998) Gasser and Erlanger in 1922, for indicating electrical signals coming from the muscles utilized an oscilloscope. Only rough knowledge could be obtained from its observation, owing to stochastic nature of myoelectric signal. Ability to sense signals of electromyography developed steadily from 1930s until 1950s, and researchers started to utilize the advanced electrodes more broadly to search for muscles Shahid (2004). In order to treatment of more certain disorders, clinical utilize of surface Electromyogram was started in 1960s. sEMG was utilized by Hardyck and his researchers in 1966 as a first practitioners. Cram and Steger at beginning of the 1980s developed a clinical method of scanning various muscles utilizing an electromyogram detection apparatus Cram et al. (1998). To give permission small and light instrumentation and amplifiers to be mass produced, it should be noted that until the mid-1980s, the integration techniques in electrodes had evolved. Today appropriate number of amplifiers are commercially present. In early 1980s, cables became present which manufacture artifacts in desired microvolt range. Researches in last 15 years have led to a better idea of surface electromyogram properties of recording. In order to record from skin-deep muscles in clinical protocols, where intramuscular electrodes are utilized only in order to deep muscle, in recent years superficial electromyography is increasingly being utilized Kleissen et al. (1998). There are many implementations in order to use of Electromyogram. Electromyogram is utilized clinically in order to neurological and neuromuscular diagnosis problems. Gait laboratories are utilized diagnostically by trained clinicians with biofeedback or ergonomic evaluation. It is utilized in many research laboratories containing those involving electromyogram, biomechanics, motor control, physical therapy, movement disorders, neuromuscular physiology and postural control. A biomedical signal is a common electrical signal that represents a physical change in any organism. This signal is ordinarily time function and can be described in amplitude, frequency and phase terms. Signal of biomedical that represents the neuromuscular activity, which measures electrical currents in the muscles during constriction, is known as the Electromyogram signal. Nervous System every time controls activity of muscle (contraction/relaxation). For this reason, Electromyogram signal is a complex signal that is controlled by nervous system and depends on anatomical and physiological muscle characteristics. The electromyogram signal makes noise when traveling with different tissues. Moreover, if the electromyographic detector is located on a particularly deep surface, it picks up signals from different engine units that can produce the interaction of the individual signals. EMG, powerful and advanced methodologies and perception signals become a very significant necessity in biomedical engineering. Primary reason in order to interest in analysis of electromyogram signal is biomedical implementations and clinical diagnosis. Up to now, research and intensive efforts have been made in field, the improvement of better algorithms, and the development of existing methodologies, the development of detection techniques for noise reduction, and the acquisition of correct Electromyogram signals. EMG is a technique utilized to evaluate and record electrical activity generated by skeletal muscle. The electromyogram is performed utilizing a device named an electromyograph, to make a record. When an electromyograph is neurologically or electrically active it detects electrical potential created by muscle cells Nikias and Raghuveer (1987). Nerves and muscle action is substantially electrical. The information is transmitted along the nerve, a series of electrical discharges carrying information with the frequency of pulse repetition Basmajian and Luca (1985).

EMG signals acquire advanced methods in order to detect, decompose, process and classify. It would be shown some software applications to identify signals from different patients, in order to ensure effective and efficient ways of understanding the signal and its nature. This knowledge may auxiliary in medical healthcare center to improve more resilient, powerful, and efficient applications Kleissen et al. (1998). Recent developments in the processing of signal technology and mathematical models have been practiced to improve analysis and detection techniques of advanced Electromyogram. Artificial Intelligence (AI) and various mathematical techniques were very interested. Mathematical models contain wavelet transform, Wigner-Ville distribution (WVD), Fourier transform, time-frequency approximation, higher order statistics and statistical measures. Artificial Intelligence approaches to recognition of signal contain fuzzy logic systems, Networks of Artificial Neural (ANN) and Neural Networks of Dynamic Repeating (DRNN). This article is arranged in that: Section 2 explains a brief review of anatomical and physiological background. Section 3 shows the factors affecting the electrical noise and Electromyogram signal. Section 4 gives details of Methodology of research. Section 5 shows experimental results of work done and discussion and last section will be about conclusion.

2. Physiological and Anatomical Background

EMG signify electromyography. It is a muscle electrical signals investigation. The electromyogram is occasionally called myoelectric activity. Tissue of muscle carries electrical potentials as nerves do, and name given to these electrical signals indicates potency of muscle movement. The recording information method available in these muscular motion potentials is known as Surface Electromyogram. When sensing and recording an electromyogram signal, there are two basic concerns that are concerned about effect and signal integrity. SNR and signal distortion. Signal to Noise Ratio (SNR) is energy ratio in electromyogram signals is the ratio of energy in noisy signal. Generally, noise is described as electrical signals that are not part of desired Electromyogram signal. Signal distortion is, relative contribution of any frequency component in Electromyogram signal should not be changed. Two kinds of electrodes were utilized to obtain the signal of muscle: Invasive and non-invasive electrode. When the electromyogram is obtained directly from the skin-mounted electrodes, signal is a combination of all fibers of muscle action potentials that occur in muscles below deep. These action potentials occur at random intervals. For this reason, at any time, Electromyogram signal can either be a negative or a positive voltage. Individual muscle fiber action potentials are obtained utilizing wire or needle electrodes placed directly into muscle. Action Potential of Motor Unit in that a combination of fibers of muscle action potentials from all single motor unit fibers of muscle is detected by an electrode of skin surface (non-invasive) or a needle electromy (invasive) Basmajian and De Luca (1985). EMG signal simple model was illustrated at equation 1:

$$Y(n) = \sum_{r=0}^{n-1} H(r)E(n-r) + W(n) \tag{1}$$

Here, Y(n) represents the modeled electromyogram signal, E(n), the processed point symbolizes pitch trajectory, H(r), MUAP, W(n) represent the null mean additive white Gaussian noise and “n” is number of motor unit firings. Signal is collected and amplified in the electrode. Generally, as a first stage amplifier, differential amplifier is utilized. Additional amplification steps can be followed. Signal can be processed to remove low or high frequency noises or another feasible artifacts before stored or displayed. Generally, user is interested in amplitude of signal. As a result, signal is usually corrected in some format and averaged to define the Electromyogram amplitude. Nervous system is both control and body's communication system. This system includes a large number of excited connected cells named neurons that communicate with distinct body sections via electrical signals that are specific and fast. Nervous system contains three basic sections: peripheral nerves, brain and spinal cord. Neurons are fundamental structural nervous system unit, the size and shape of which vary considerably. Neurons are highly specialized cells which give messages in nerve stimulation form from one body section to another. The muscle contains specialized cells bundles with the ability to contract and relax. Fundamental function of these specialized cells is to produce communication, such as forces, movements and speech, writing or other expression forms. Tissue of muscle has the extensibility and flexibility property. To alerts and can be contracted or shortened, It has talent to accept and respond. Tissue of muscle has four basic functions: producing movement, generating heat, stabilizing and moving body. Based on structure, contractile features and control mechanisms, three tissue of muscle types can be defined: (i) skeletal muscle, (ii) cardiac muscle and (iii) smooth muscle. An electromyogram is used for skeletal surveys. In order to support skeleton, tissue of skeletal is attached to bone and is liable. Skeletal contraction is initiated by stimuli to muscles in the neurons and is generally under voluntary control. Skeletal fibers are fed well with neurons for constriction. This specific neuron kind has the title "motor neuron" and approaches, but is not linked to, muscle tissue. A motor neuron generally provides stimulation of many fibers of muscles. Human body is electrically neutral as a whole; there are positive and negative charges in same amount. Because of differences in ionic composition and plasma membrane concentrations however, at rest, nerve cell membrane is polarized. There is a potential difference between intracellular and extracellular fluids. A fibers of muscle becomes depolarized as it transmits a signal along the switches of fiber and surface, in response to a stimulus from neuron. In the presence of ions, this depolarization creates an electric field near every fiber of muscle.

3. Electrical noise & factors affecting Electromyogram signal

Before amplification Electromyogram signal range of amplitude is 0-10 mV (+5 to -5). Electromyogram signals make noise when traveling with different tissues. It is significant for understanding electrical noise characteristics. Electrical noise that affects electromyogram signals can be classified into following kinds:

- Ambient noise
- Artefact of motion
- Inherent noise in electronics equipment
- Inherent instability of signal

Factors that primarily affect electromyogram signal can also be categorized. Such classification is established so that the electromyogram algorithms of signal analysis can be optimized and the equipment can be designed in a coherent manner. Factors effecting the electromyogram signal are divided into three main classes:

- Factors of Intermediate
- Factors of Causative
- Factors of Deterministic

Only positive values are analyzed during electromyogram processing of the signal. When half-wave rectification is performed, entire negative data are discarded and positive data are kept. Absolute value of each data point is utilized, in the full wave direction. Generally, in order to correction, full wave rectification is preferential.

4. Methodology of research

First and most important, a block diagram must be designed to be fundamental reference. Figure 1 indicates generic block diagram of this study. System was received two difference Electromyogram signals coming from two different patients. Then, system was decided signal for diagnosis Healthy or Neuropathy.

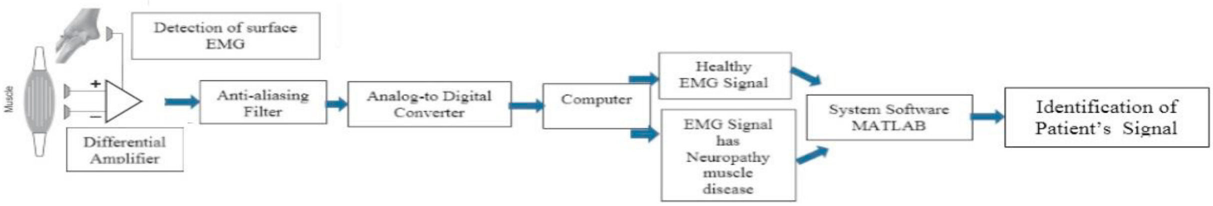

Fig. 1. Block diagram of Electromyogram signal acquisition, classification and analysis.

For designing system, there are six stages to be done. There were sequences of our procedure given below. First step was we required to detect Electromyogram characteristic in terms of its power and frequency. To proceed next stage those characteristic helped us. From input signals, system produced spectrum of power. By utilizing fast Fourier transformation (fft), EMG power spectrum can be obtained with a preferable (better) resolution. We investigated EMG patients' power spectrum to describe parameters that can be utilized to identify various patients. The signal parameters can be utilized as input to the rule base classifier to be applied in the software.

- Define EMG properties
- Analyze power spectrum
- Define signal parameters
- Rule-based classifier
- Application in MATLAB Software
- Performance verification

Finally, analysis and classification of EMG signal to distinguish which patient's signal is confirmed.

Table 1. Sample of Healthy and Neuropathy EMG Signals dataset

Sample Healthy EMG Signal Data Set		Sample Neuropathy EMG Signal Data Set	
0.00025	-0.0333	0.00025	0.0900
0.0005	-0.0350	0.0005	0.0767
0.00075	-0.0350	0.00075	0.0767
0.001	-0.0300	0.001	0.0733
0.00125	-0.0300	0.00125	0.0717
0.0015	-0.0333	0.0015	0.0667
0.00175	-0.0317	0.00175	0.0683
0.002	-0.0333	0.002	0.0917
0.00225	-0.0333	0.00225	0.0950
0.0025	-0.0367	0.0025	0.2033
0.00275	-0.0350	0.00275	0.2100
0.003	-0.0417	0.003	0.7717
0.00325	-0.0417	0.00325	0.8333
0.0035	-0.0383	0.0035	-0.4383
0.00375	-0.0417	0.00375	-0.4200

5. Results

A biomedical signal from any muscle organ and a collective electrical signal that symbolizes physical change is an electromyogram signal. As known, such signal is normally a function of time and is explained in terms of amplitude, frequency and phase. Thus, power spectrum generated from output signal was examined to identify appropriate signal parameters to distinguish signal from respective patients. From power spectrum point of view, both signals can be easily analysed and classified in terms of amplitude, in terms of power spectral density. Many parameters can be calculated to use as rule base classifier input, which is mean frequency, median frequency, amplitude in terms of root mean square (rms), minimum and maximum power spectral density. Figure 2 shows a Healthy EMG signal in time domain that is used for this work. EMG signal has Neuropathy in time domain is defined in figure 3.

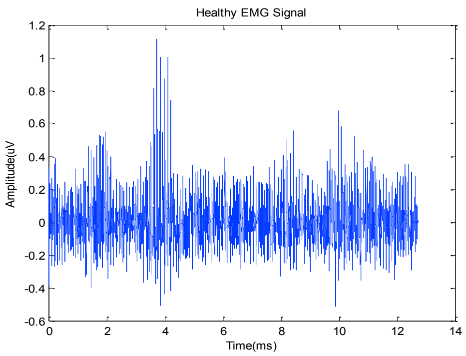

Fig.2. Healthy Electromyogram Signal in Time Domain

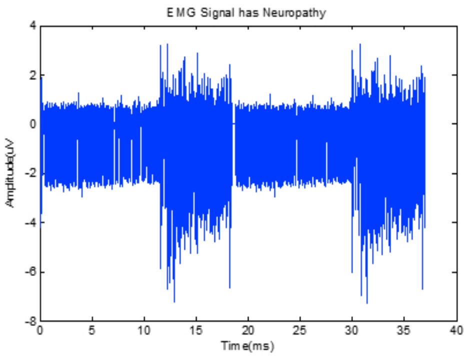

Fig.3. EMG Signal has Neuropathy in Time Domain

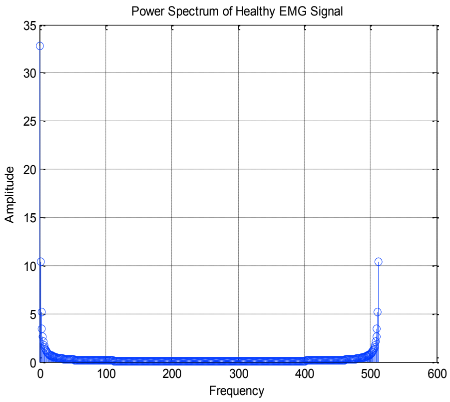

Fig.4. Power Spectrum of Healthy EMG Signal

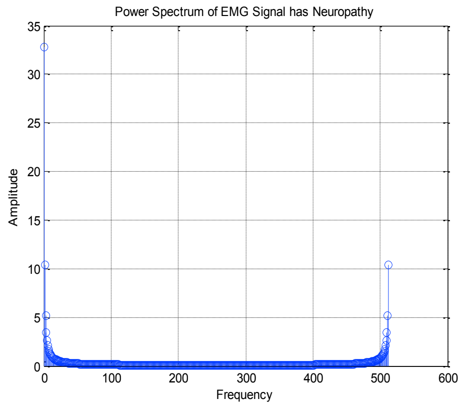

Fig.5. Power Spectrum of EMG Signal has Neuropathy

Table 2. Classification for Result Process

Parameter 1: Median Value :	0.0640
Parameter 2: Average Value:	2.5000e-04
Parameter 3: Root Mean Square:	1.1893
Parameter 4: Maximum Power:	32.8320
Parameter 5: Minimum Power:	0.0640

Fig.6. Outcome displayed to detect the signal coming from Healthy Electromyogram

Fig.7. Outcome displayed to detect the signal coming from Patient that has Neuropathy

Conclusion

Research investigates rule-based classifier from Electromyogram signal parameters to differentiate Electromyogram signals from distinct patients. These Electromyogram signals give signals produced by muscles in the human body, mostly for utilize in medical field diagnostics. Based on our experimental results, we have found that the appropriate parameters have been successfully applied for the completion of the system. The performance of the system has been verified to determine the EMG signals from different patients. The Electromyogram signal carries precious information about nervous system. Aim of this work was to present a variety of methodologies for briefing EMG and analysing the signal. EMG is discussed along with advantages and disadvantages of signal detection, separation, process and classification techniques. Having a disadvantage or problem in a method leads to another developed methods. This research demonstrates various EMG signal analysis techniques for applying the correct methods during any biomedical research, clinical diagnosis, end-user implementations and hardware application.

References

Basmajian JV, de Luca CJ., 1985. Muscles Alive-The Functions Revealed by Electromyography. The Williams & Wilkins Company; Baltimore.

Bernatos L, Crago P, Chizeck H., 1986; A discrete-time model of electricity stimulated muscle. IEEE Trans Biomed Eng. 33:829-838.

Cheron G, Draye J-P, Bourgeios M., 1996. A Dynamic Neural Network Identification of electromyography and trajectory relationship during complex movements. IEEE Trans Biomed Eng. 43(5):552–558. doi:10.1109/10.488803.

Christodoulou CI, Pattichis CS., 1995. A new technique for the classification and decomposition of EMG signals. Proceedings in IEEE International Conference on Neural Networks. 5:2303–2308.

Cohen L., 1995. Time-frequency analysis. Englewood Cliffs, Prentice-Hall; New Jersey, USA.

Cram JR, Kasman GS, Holtz J., 1998. Introduction to Surface Electromyography. Aspen Publishers Inc.; Gaithersburg, Maryland.

De Luca CJ., 1997. The use of surface electromyography in biomechanics. J Appl Biomech. 13:135-163.

Del Boca A, Park DC., 1994 Myoelectric signal recognition using fuzzy clustering and artificial neural networks in real time. IEEE International Conference on Neural Networks and IEEE World Congress on Computational Intelligence; 5:3098-3103.

Duchene J, Hogrel J. A., 2000. Model of EMG Generation. IEEE Transactions on Biomedical Engineering. 47(2):192–201.

Fang J, Agarwal GC, Shahani BT., 1997. Decomposition of EMG signals by wavelet spectrum matching. Procedures of the 19th Annual International Conference of the IEEE Engineering in Medicine and Biology Society Chicago, IL, USA. pp. 1253-1256.

Gabor D., 1946. Theory of communication. J Inst Elect Eng. 93:429-457.

Hamilton-Wright A, Stashuk DW., 2005. Physiologically based simulation of clinical EMG signals. IEEE Transactions on Biomedical Engineering. 52(2):171-183.

Hefftner G, Zucchini W, Jaros G., 1988. The electromyogram (EMG) as a control signal for functional neuro-muscular stimulation part 1: Autoregressive modeling as a means of EMG signature discrimination. IEEE Trans Biomed Eng. 35:230-237. doi: 10.1109/10.1370.

Ismail AR, Asfour S S., 1998. Continuous wavelet transform application to EMG signals during human gait. Thirty-Second Asilomar Conference on Signals, Systems & Computers 1:325-329.

Kaplanis PA, Pattichis CS., 2000Hadjileontiadis LJ, Panas SM. Bispectral analysis of surface EMG. 10th Mediterranean Electro technical Conference 2:770-773.

Karlsson S, Nystrom L., 1995. Real-time system for EMG signal analysis of static and dynamic contractions. IEEE 17th Annual Conference on Engineering in Medicine and Biology Society. 2:1347-1348.

Kavalcıoğlu C., Dağman B., 2016. Filtering Maternal and Fetal Electrocardiogram (ECG) Signals using Savitzky-Golay Filter and Adaptive Least Mean Square (LMS) Cancellation Technique, Bulletin of the Transilvania University of Brasov Vol 9(58), No.2- Series III: Mathematics, Informatics, Physics, 109-124.

Kleissen RFM, Buurke JH, Harlaar J, Zilvold G., 1998. Electromyography in the biomechanical analysis of human movement and its clinical application. Gait Posture.; 8(2):143-158. doi: 10.1016/S0966-6362(98)00025-3.

Kumar DK, Pah ND, Bradley A., 2003. Wavelet analysis of surface electromyography to determine muscle fatigue. IEEE Trans Neural Syst. Rehabil Eng. 11(4):400-406. doi: 10.1109/TNSRE.2003.819901.

Laterza F, Olmo G., 1997. Analysis of EMG signals by means of the matched wavelet transform. Electronics Letters. 33(5):357359.

Malcown, C. Brown., 2007. The Medical Equipment Dictionary- Electromyogram. Liverpool, United Kingdom.

Merlo A, Farina D., 2003. A Fast and Reliable Technique for Muscle Activity Detection from Surface EMG Signals. IEEE Trans Biomed Eng. 50(3):316-323. doi: 10.1109/TBME.2003.808829.

Micera S, Vannozzi G, Sabatini AM, Dario P., 2001. Improving detection of muscle activation intervals. IEEE Engineering in Medicine and Biology Magazine. 20(6):38-46.

Nikias CL, Raghuveer MR., 1987. Bispectrum estimation: A digital signal processing framework. IEEE Proceedings on Communications and Radar. 75(7):869-891.

Nikias CL, Petropulu AP., 1993. Higher-Spectral Analysis: A Nonlinear Signal Processing Framework. Prentice Hall; New Jersey.

Nikias CL, Mendel JM., 1993. Signal Processing with Higher-Order Spectra. IEEE Signal Processing Magazine. 10:10-37.

Raez I. B. M., et al. Zhu, J., et al., 2006. Techniques of EMG Signal Analysis: Detection, Processing Classification and applications.

Ricamato AL, Absher RG, Moffroid MT, Tranowski JP., 1992. A time-frequency approach to evaluate electromyographic recordings. Proceedings of Fifth Annual IEEE Symposium on Computer-Based Medical Systems pp. 520-527.

Sadıkoğlu F., Kavalcıoğlu C., 2016. Filtering Continuous Glucose Monitoring Signal using Savitzky-Golay Filter and Simple Multivariate Thresholding, Elsevier Procedia Computer Science, DOI: 10.1016/j.procs.2016.09.410.

Shahid S., 2004. Higher Order Statistics Techniques Applied to EMG Signal Analysis and Characterization. Ph.D. thesis, University of Limerick; Ireland.

Wan Mohd Bukhari Bin Wan Daud., 2009. Classification of EOG signals of Eye Movement Potentials.

Wellig P, Moschytz GS., 1998. Analysis of wavelet features for myoelectric signal classification. IEEE International Conference on Electronics, Circuits and Systems. 3:109-112.

Yamada R, Ushiba J, Tomita Y, Masakado Y., 2003. Decomposition of Electromyographic Signal by Principal Component Analysis of Wavelet Coefficient. IEEE EMBS Asian-Pacific Conference on Biomedical Engineering; Keihanna, Japan. pp. 118-119.

Zhang Y T, Herzog W, Liu M. M., 1995. A mathematical model of myoelectric signals obtained during locomotion. IEEE 17th Annual Conference on Engineering in Medicine and Biology Society. 2:1403-1404.
Zhou Y, Chellappa R, Bekey G., 1986. Estimation of intramuscular EMG signals from surface EMG signal analysis. IEEE International Conference on Acoustics, Speech, and Signal Processing. 11:1805-1808.