USING EMG DECOMPOSITION[BR] FOR EXTRACTION AND VISUALIZATION OF MOTOR UNIT ACTION POTENTIALS

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Abstract – This paper presents a developed tool capable of decomposing electromyographic signals (EMG) named EMG Decomposition[BR]. The main aim of this software is to extract and to visualize motor unit action potentials (MUAPs) extracted from EMG signals during a muscular contraction. The identification and clustering of MUAPs that show similar features is most important for the definition of such cluster structure. The results obtained from the tool have application in the study of the behavior of the central nervous system, in the diagnosis of disorders that affects muscles or nerves. For the implementation of this technique, traditional and recent digital signal processing tools for signal filtering, detection and clustering are applied.

Keywords: Electromyography – Motor unit action potential – Digital filters.
Area of knowledge: III – Engineering.

Introduction

Electromyography is the study of the muscular function based in the analysis of electromyographic signals (EMG), that are electrical activities generated by muscles during voluntary, involuntary or stimulated contractions (Andrade, 2005). It can be used as an instrument in the analysis of the human motion, for the identification of traumatisms and for describing the role of several muscles in specific activities.

From a practical perspective the extraction of information from single motor units (e.g., firing rate, motor unit action potential shape, and number of active motor units) is of great importance in clinical applications. For instance, neuromuscular disorders can be diagnosed by means of such analyses.

The main objective for decomposing EMG signals is the definition of the number of active motor units during a muscular contraction and the extraction of action potentials generated by these units. The process of identification of these action potentials consists in the visualization of their waveforms and in the detection of the time when they occur.

When two or more MUs discharge at the same time, the detected potential is the algebraic summation of the individual potentials from these MUs that are termed as superimposed waveform (Figure 1) (LeFever and DeLuca, 1982).
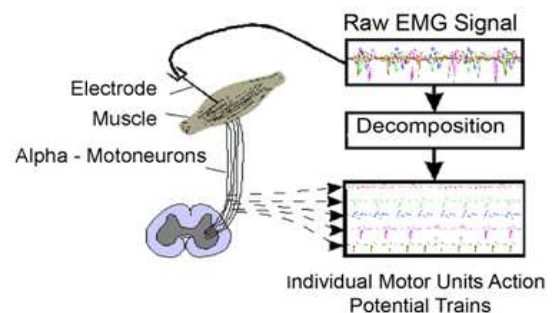

Figure 1 – Decomposition of EMG signals.

In the decomposition of the EMG signal, the superimposed waveforms need to be resolved into their constituent MUAPs. The percentage of overlapped waveforms depends of several factors, for instance, the contraction level during signal detection and the type of electrode employed.

Methodology

This work describes the development of an automatic tool, so-called EMG Decomposition[BR] (Andrade, Nasuto et al., 2005; Andrade, Nasuto et al., 2005; Avellido and Andrade, 2007; Bernardes, Andrade et al., 2007; Bernardes, Andrade et al., 2007; Bernardes, Andrade et al., 2007), for visualization and extraction of motor unit action potentials obtained from surface EMG signals. More information about this project can be obtained from the website http://www.biolab.eletrica.ufu.br/emgsignal.

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In this research a tool, designated as EMG Decomposition[BR], was designed for decomposition of EMG signals. The tool allows the user to apply a sequence of steps required for visualization and extraction of MUAPs from EMG signals. For this, a graphical user interface (GUI) was implemented in MATLAB[®]. The context diagram shown in Figure 2 show the resumed sequence of steps for EMG decomposition. A typical use of the system consists in selecting EMG signals from a database, loading them into the system, and performing several digital signal-processing steps, such as signal filtering, detection and projection.
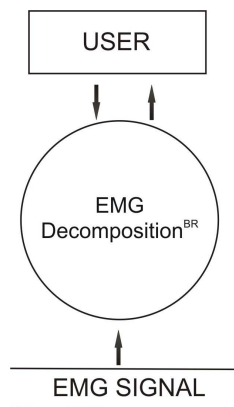
Figure 2 – Context diagram.

Other applied technique is the Diagram of Flow of Data (DFD), in that there are the description of the flow of information and the applied transformations (Figure 3).
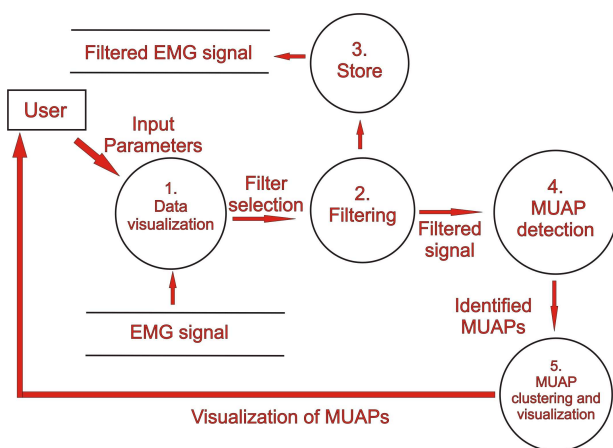
Figure 3 – Sequence of steps employed for decomposition of EMG signals.

Results

The Figure 4 shows the initial screen of the system. From it we can obtain information about the team of work involved in the project. Once the system is loaded four tab pages are created.

Each of these is responsible for a required step for the decomposition of EMG signals.

Figure 4 – Initial screen of the system.

The available tab pages are: Input Signal, Filtering Stage, MUAP Detection and MUAP Clustering.

The main aim of the Input Signal tab page is to allow the user to easily import EMG data into the system. The system can read text files, and it assumes that each column of the file is a vector representing an EMG signal. If time information is available, it can be stored as the first column of the text file, and the system will automatically interpret it as time (and not EMG activity).

Each column of the text file is individually imported into the system. The user can assign names to variables that will represent these signals as shown in the list box at the left of Figure 5. Note that this strategy for data loading allows that signals from distinct text files are available in the system for further processing.

Once a variable (signal) is created in the system it can be visualized by selecting it from the "EMG signal" list box. A number of features for data visualization have been implemented in the tool. For instance, the Panner tool (Figure 5) allows the user to select a small rectangular region (window) for signal visualization, which is shown in the larger graph in this tab page.

Other basic operations can be carried out from the main menu of the system. Four options are available: 1) File, 2) Edit, 3) Tools e 4) Help. They are shown, together with their sub-menus, in Figure 6.

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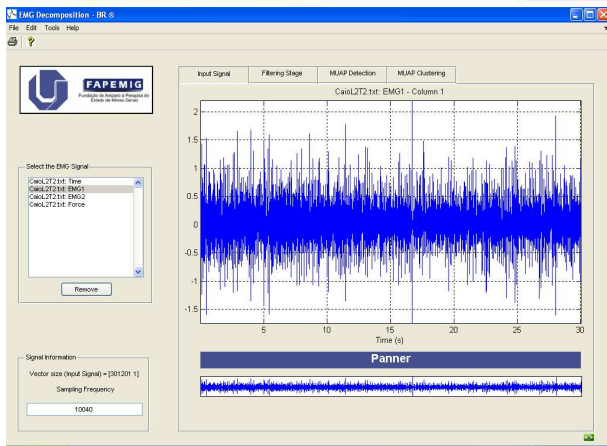
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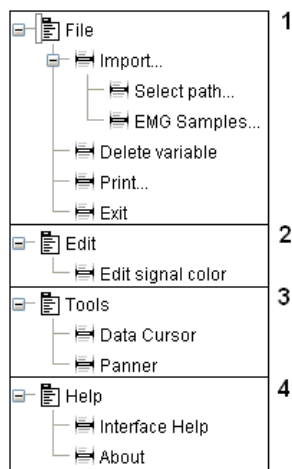Figure 5 – Main interface of the devised system.

Figure 6 – Main menu of the system. 1) File Menu, 2) Edit Menu, 3) Tools Menu e 4) Help Menu.

The program offers two types of filters in the Filtering Stage tab stage: the Butterworth and one based on the Empirical Mode Decomposition (EMD) technique (Andrade, Nasuto et al., 2006). Parameters of each filter can be adjusted by the user from the interface.

After filtering the signal the EMG signal is segmented into small windows, so-called regions of activity (RA) in the MUAP Detection tab page, that may contain the activity of single MUAPs, MUAP overlaps or noise (Andrade, 2005). Furthermore, a detector of RA was devised for extraction of RA from EMG signals. Its input may be either a raw or filtered EMG signal and the output is regions of activity.

Basically, the system will estimate the signal envelope and it will select from it reference points which define the beginning and end of the RAs.

A doted line indicates the beginning of an RA whereas a solid line indicates its end (Figure 7).
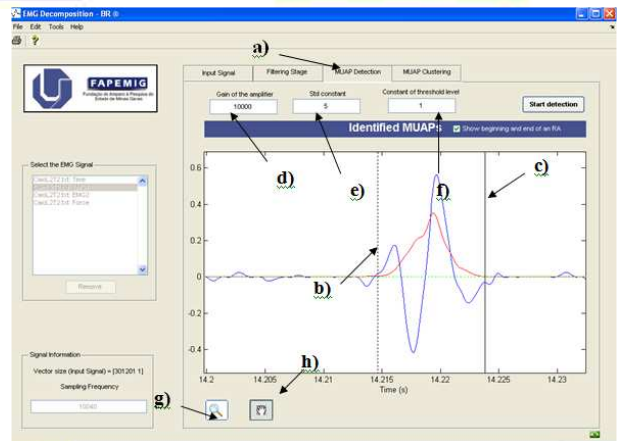

Figure 7 – MUAPs detection: a) MUAP Detection tab page, b) Beginning of the region of activity, c) End of the region of activity, d) Gain of the amplifier, e) Standard deviation constant, f) Threshold level constant, g) Zoom and h) Drag tool.

Finally after the detection of the RA, it is possible to cluster the action potentials into logical units, but firstly it is necessary to obtain the features from RAs. MUAP amplitudes are used as features for data clustering. The technique for data clustering is detailed in (Andrade, Nasuto et al., 2005; Andrade, Nasuto et al., 2005; Bernardes, Andrade et al., 2007).

Once the data are clustered they can be visualized in a grid (GTM grid – see (Andrade, Nasuto et al., 2005; Andrade, Nasuto et al., 2005; Bernardes, Andrade et al., 2007)) (Figure 8).
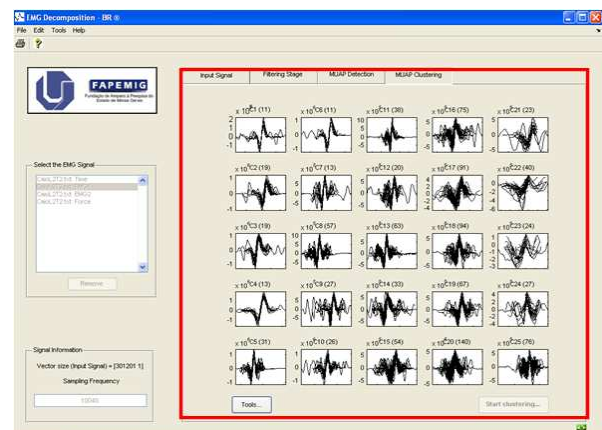

Figure 8 – MUAP clustering.

Discussion

The decomposition of EMG signals is a process that can be performed manually (Desmedt, 1983). However, the manual analysis of biomedical signals is subjected to errors.

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In this context, the use of computational tools (LeFever and DeLuca, 1982; Stashuk, 2001) plays an important role in the standardization and speed of the analysis of EMG signals.

The ideas and techniques studied in this research may be extended in different ways. Currently the procedure for signal filtering based on the EMD requires the user to select a window of noise for the signal threshold. An interesting extension of this procedure would be to detect the window of noise automatically and use this information for filtering the signal. In addition, this procedure might be applied to other biological signals.

Conclusions

This work presented a graphical user interface that allows the user to easily apply basic steps for EMG decomposition. In the future the authors will introduce new features in the system, such as the estimation of the number motor units, which will allow the system to be employed in the practical clinic.

Acknowledgments

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