ALGORITHM FOR DETECTION OF MUSCLE CONTRACTIONS IN THE EMG SIGNAL, FOR USE IN ACTIVE PROSTHESIS

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Abstract

An active prosthesis needs a reliable and easy real-time algorithm for detection of the muscle contraction. An algorithm based on the Pan-Tompkins ECG QRS detection algorithm is proposed. It uses band-pass filter and subsequent differentiation, squaring and moving averaging. The output signal is then compared to set of thresholds to determine the contraction of the muscle and its strength.

1. INTRODUCTION

Skeletal muscle is organized functionally on the basis of the motor unit (fig. 1). The motor unit is the smallest unit that can be activated by a volitional effort, in which case all constituent muscle fibres are activated synchronously. The component fibres of the motor units extend lengthwise in loose bundles along the muscle. In cross section, however the fibres of a given motor unit are interspersed with fibres of other motor units. Thus the component muscle fibres of the single motor unit (SMU) constitute a distributed, unit bioelectric source located in a volume conductor consisting of all other muscle fibres, both active and inactive. [5]

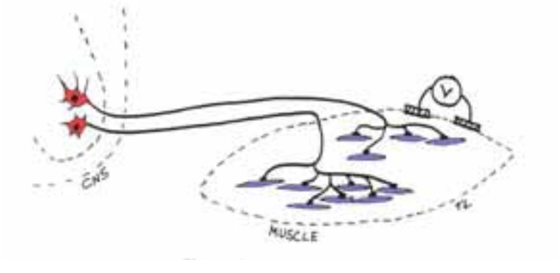

Fig.1

The evoked extracellular field potential from the active fibres of an SMU has a triphasic form of brief duration (3-15ms) and an amplitude of 20-2000 uV, [4] (fig 2) depending on the size of the motor unit. Due to the small size of the SMU the recording of the SMU action potential is only possible with needle electrodes. When using surface electrodes the recorded signal consists of many SMU action potentials form different depths. The resultant signal has a frequency range from 25Hz to several thousand Hertz and amplitude in the range of 20-2000 uV (fig. 3)

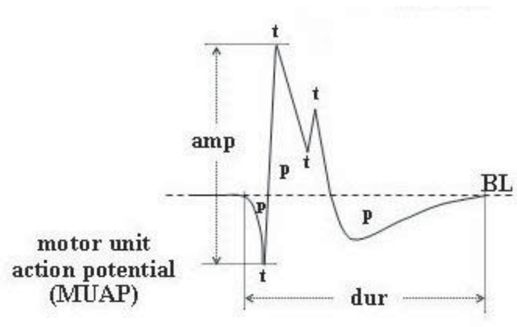

Fig. 2

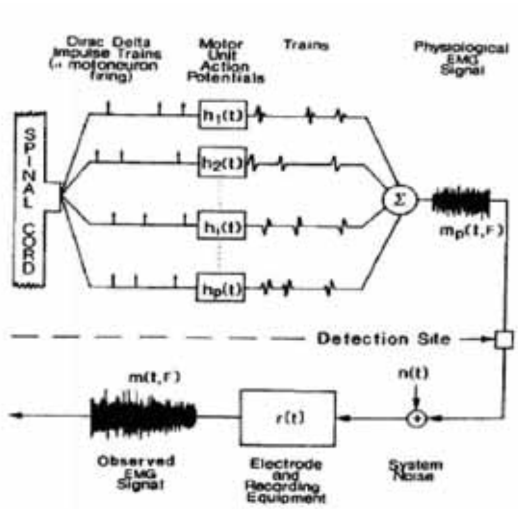

Fig. 3

The most frequently used algorithms for detecting muscle contraction consists of simple integration of the EMG signal. This is simple enough and can be implemented even with hardware means only, but does not provide enough sensitivity and signal to noise separation.

Pan and Tomkins [1] have proposed a real-time algorithm for detection of the ECG QRS complex based on analysis of the slope, amplitude and width of QRS complexes. The algorithm includes a series of filters and methods that perform low-pass, high-pass, derivative, squaring, integration, adaptive thresholding, and search procedures. Figure 4 Illustrates the steps of the algorithm in schematic form.

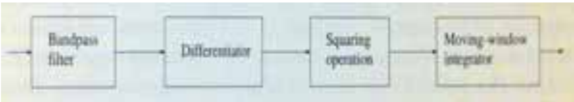

Fig. 4

The band-pass filter eliminates the noise from electrical interference and the low-frequency noise (baseline drift, P and T wave). The derivative operator further suppresses the low frequency components of the P and T wave and motion artifacts and provide large gain on the high-frequency components. The squaring makes the result positive and further emphasize high-frequency components. The subsequent moving average integration smooth the multiple peaks within the duration of a single QRS complex. The a set of thresholds are calculated for the signal and the noise.[2] A result of the Pan and Tompkins algorithms is shown on figure 5.

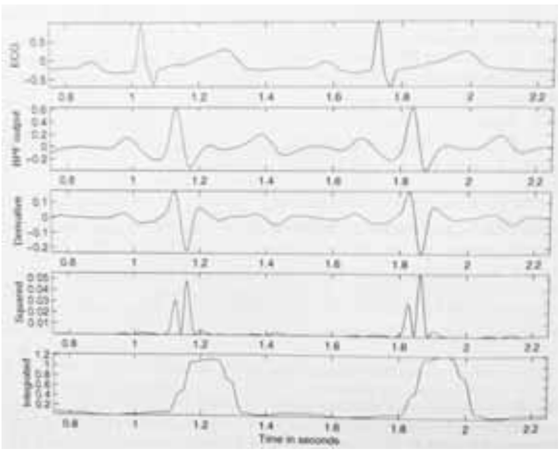

Fig. 5

2. METHODS

A dedicated amplifier was designed for the development of this algorithm. It is a one channel differential amplifier with a Driven Right Leg feedback circuitry for suppressing artifacts. The frequency range of the amplifier is 25Hz – 500Hz. This range is chosen to eliminate the low frequency noise witch is mostly below 25Hz. The upper cutoff frequency is chosen so that the signal will include the most of the EMG signal and to ease the signal processing. The electrical line interference is supressed by a Driven Right Leg feedback circuitry. A dedicated filter for the 50 Hz power line interference is not suitable because this frequency is in the range of the EMG signal. The sampling rate of the ADC is chosen to be 2000Hz.

The digital signal is then send via USB to a PC where a specially developed software EmgLab will make the signal analysis.

The use of Pan-Tompkins algorithm was inspired by the insight that the EMG signal can be very random and depends on the MUPs activated, the place and size of the surface electrodes used. This is why a pattern recognition is very difficult and not reliable enough. On the other hand this algorithm is very sensitive to the power of the signal witch is directly related to the strength of contraction.

The low-pass and high pass-filters used in the original Pan-Tomkins algorithm are omitted because in the frequency band of the digitized signal the low-frequency and high frequency noise is already filtered.

The steps used in the algorithm are the following:

1. Derivative operator: The derivative operation used is specified as:

$$y(n) = 1/8[2x(n) + x(n-1) - x(n-3) - 2x(n-4)]$$

2. Squaring: $y(n)^2$ – this makes the result positive and emphasizes the large differences

3. Moving average: The moving average smooth the multiple peaks from the squaring operation:

$$y(n) = 1/N[x(n-(N-1)) + x(n-(N-2)) + x(n)]$$

The window width is chosen to be N=500 in the proposed algorithm.

4. Adaptive thresholds: In this step it is important to find accurately the onset and the offset of the muscle contraction. Since the muscle can by contracted slowly or very rapidly a slope analysis is not suitable. Therefore only amplitude threshold is used which is defined as:

$$THR = 0.1*MAX\_CONTRACTION$$

3. EXPERIMENTS

The algorithm is tested on different muscles with real-time signal processing.

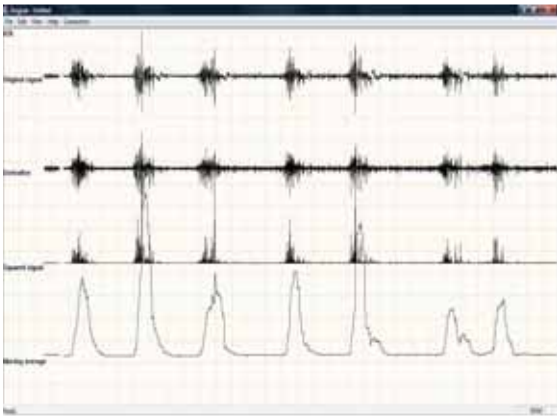

Fig. 6. Biceps branchii

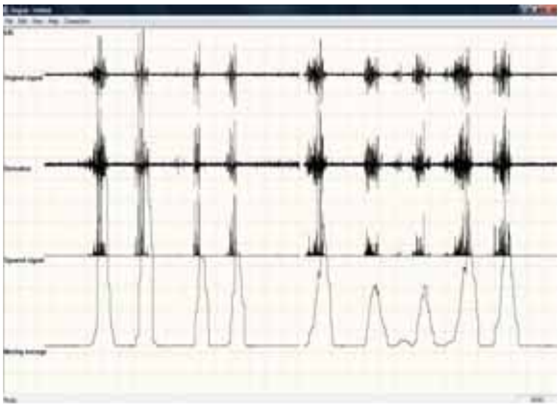

Fig. 7. Flexor radialis

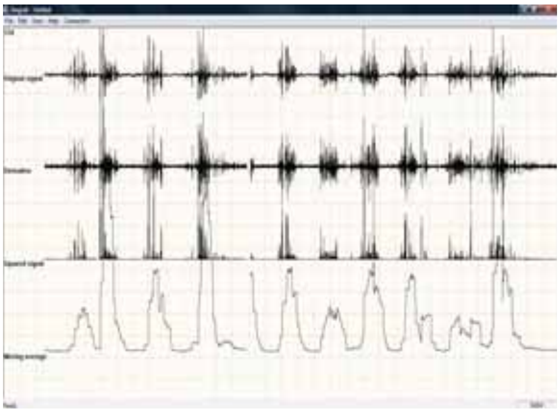

Fig. 8. Rectus femoris muscle

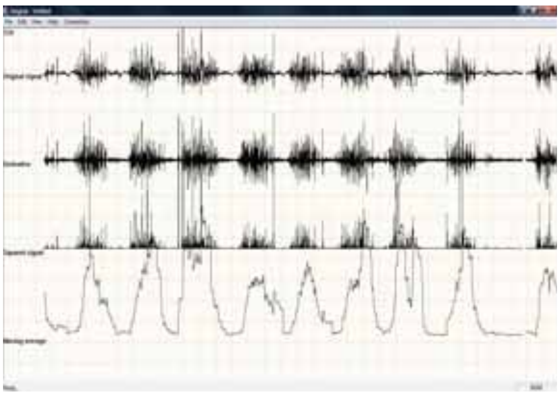

Fig. 9. Rectus femoris during walking

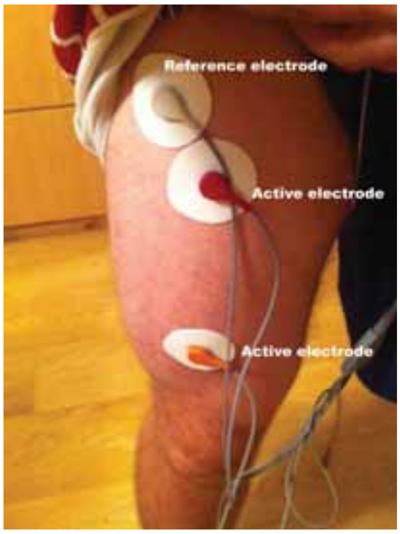

Fig. 10. Electrode placement for the Rectus femoris experiment

4. CONCLUSION

The algorithm gives very good results on the detection of the muscle contraction of different muscles. During walking the work of the muscle visible and the onset and offset of the contraction can easily be detected.

Further experiments are needed to tune the size of the Moving Average N.

References

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