Chapter 10
Techniques for Decomposition of EMG Signals

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ABSTRACT

The information extracted from the EMG recordings is of great clinical importance and is used for the diagnosis and treatment of neuromuscular disorders and to study muscle fatigue and neuromuscular control mechanism. Thus there is a necessity of efficient and effective techniques, which can clearly separate individual MUAPs from the complex EMG without loss of diagnostic information. This chapter deals with the techniques of decomposition based on statistical pattern recognition, cross-correlation, Kohonen self-organizing map and wavelet transform.

INTRODUCTION

The electrical signals produced by the muscles and nerves are analyzed to assess the state of neuromuscular function in subjects with suspected neuromuscular disorders. The repetitive activation of several individual motor units (MUs) results in a superposed pulse train and constitutes the electromyogram (EMG) signal. The analysis of the EMG is based on its basic constituent i.e. motor-unit action potentials (MUAPs). The motor unit is the smallest functional unit of a muscle, which can be activated voluntarily. It consists of a group of muscle fibers, which are innervated from the same motor nerve. The shape of MUAP reflects the pathological and functional states of the motor unit. With increasing muscle force, the EMG signal shows an increase in the number of activated MUAPs recruited at increasing firing rate, making it difficult for the neurophysiologist to distinguish individual MUAP waveforms. In most of the clinical EMG examinations, it is the shape of the action potential that is analyzed for diagnostics

The shape and amplitude of MUAP waveform generally differ from motor unit to motor unit due to unique geometric arrangement of the muscle fibers in each motor unit. However, the MUAP

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waveforms from different motor units may also be nearly similar in amplitude and shape when the muscle fibers of two or more motor units have a similar spatial arrangement in detectable vicinity of electrode. The variations in the MUAP waveform are greater when the MUAP waveform actually arises from two or more of the motor units fibers at approximately same distance from the electrode and thus of similar amplitude. The variable latencies in the onset of individual muscle fiber action potentials may produce large uncorrelated changes in compound MUAP waveform from one firing to the next. When few (less than three) motor unit action potential train (MUAPTs) are present in the EMG signal, much of the noise actually results from variations in an MUAP waveform from one firing to the next. When a greater number of MUAPTs is present, the additional noise is also produced by many low amplitude MUAP waveforms.

Number of different factors attribute for noise in MUAPs, namely, increase in degree of severity, instrument noise, neuromuscular junction jitter, detection electrode movement, and interference from the MUAPs of nearby motor units [2]. The shape of the MUAP waveforms within a MUAPT remains constant, if (i) all the initial relationships between the electrode and the active muscle fibers remain constant (i.e. there is no variation in geometrical arrangement between the recording electrode and active muscle fibers), (ii) the relative time difference between the initiation of each constituent fiber action potential, and (iii) the properties of the recording electrode remain constant, and (iv) there are no significant biochemical changes in the muscle tissues. The presence of noise in the EMG signal is a major problem to obtain clean MUAPs after decomposition.

Due to overlapping of MUAPs in the EMG signal, physicians have great difficulty in classifying superimposed waveforms and have no valid reason for their conclusions. With the help of decomposition technique, it is possible to provide more accurate information w.r.t. the EMG signal and MUAPs to know the state of a subject's peripheral neuromuscular system.

DECOMPOSITION OF EMG

The parameters of the MUAPs have proven to be of major importance for the clinical diagnosis of myopathies and neuropathies [1]. For perfect diagnosis, accurate decomposition of EMG signal is needed. The success of EMG signal decomposition is decided by the accurate classification of the MUAPs. There is a long list of limiting factors, which hamper the process of successful decomposition. Some of them arise from the characteristics of the MUAPs. The MUAPs have different durations (finite) and overlap in time and frequency domains. They occur at different time instants are time varying in nature and contaminated by noise and background activity produced by non detectable MUAPs. The repetition frequencies are so high that individual MUAPs rarely appear as isolated potentials [1].

The major challenge in decomposition is to break down the waveforms and analyze them accurately as these are the outcome of a complicated activity and require complete understanding of the electrical fields generated within and around the muscle fibers. Manual decomposition of EMG signal has been successfully done for a long time for clinical diagnosis. It has been shown that the relevant MUAP parameters such as shape, amplitude, duration, and number of phases and turns can be identified manually. However, manual analysis is tedious, time-consuming and inaccurate, and therefore, the investigators have worked for long time to automate the process of decomposition. Significant features and other details of various techniques for automatic decomposition of an EMG signals. are given in (Figure 1).

It has been found that most automatic detection schemes cannot accommodate slow changes in shape or amplitude in MUAPs.