

SURFACE EMG BASED FATIGUE INDEX ESTIMATION FOR BICEPS BRACHII MUSCLE WITH POLYNOMIAL WIGNER-VILLE MARGINAL SPECTRUM

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ABSTRACT

Surface electromyography (sEMG) is the electrical activity of skeletal muscles that contains clinically relevant data which can be used for the diagnosis of neuromuscular disorders. Fatigue is the reduction in the ability of muscle to generate the required force. The challenge is estimation of its index from a sEMG signal. Instantaneous frequency (IF) is one of the common features used for fatigue index estimation. It can be obtained using Wigner-Ville distribution (WVD) method. The disadvantage of using WVD is cross-terms that affect the IF estimator and it needs to be addressed. In this work, a new framework is proposed based on polynomial WVD (PWVD) to measure muscle fatigue. For this, sEMG from biceps-brachii muscles of 25 healthy volunteers are recorded using well-defined isometric contraction protocol. The three regions associated with nonfatigue, progression of fatigue and fatiguing condition of each signal is segmented and the corresponding time-frequency distributions (TFD) are obtained using 6^{th} order PWVD. In addition, IFs and marginal spectrum (PWMS) of each segment is estimated for the respective TFDs. Further, maximum singular values (MSV) of TFDs, statistical measures such as skewness and kurtosis of PWMS are calculated which are used as fatigue indices. The preliminary results show that the MSV and statistical measures are able to distinguish the nonfatigue and fatigue conditions. The recorded signals show low amplitude and high frequencies in nonfatigue region and vice-versa. The obtained results are statistically significant with $p < 0.002$. It appears that the PWMS obtained from PWVD based IF estimator is able to measure the fatigue index. It is very much applicable in medical diagnosis of neuromuscular disorders.

Keywords: Biceps-Brachii, Fatigue, sEMG, Polynomial Wigner-Ville Distribution, Marginal Spectrum

INTRODUCTION

Fatigue is an incompetence of muscle to generate the required force for continuing a physical activity. Surface EMG is the superposition of motor unit action potentials (MUAPs) of muscles which is recorded with noninvasive surface electrodes. The amplitude and frequency of MUAPs are determined by the number of active motor units (MUs), firing rate of MUs, conduction velocity of MUAPs and recruitment stability of MUs. The biochemical processes associated with reduction in conduction velocity is the decrease in pH of a bath fluid encompassing the muscle. The effect of sustained contractions contributes to decreasing pH of the interstitial fluid and accumulation of lactic acid in the membrane environment. For an instance, fatigue prevents blood flow in the muscle that modifies the conduction velocity to the factor obtained from the amount of interstitial H^+ and K^+ with the causal influence of H^+. Typically, muscle fatigue leads to reduction of conduction velocity and increased arrival time of sEMG. Therefore, an advanced signal processing method is an essential need to understand the sEMG in order to define the indices of complex muscle fatiguing process [1].

The time domain features such as mean absolute value and root mean square values are used to measure the signal amplitudes. The measure of spectral modifications in the sEMG spectrum is used as fatigue index in frequency domain [2]. Further, joint time-frequency distribution (TFD) methods such as short time Fourier transform and Cohen class based TFD represents signal energy in time-frequency axis. Discrete Wavelet Transform based sEMG analysis was used to localize the muscle fatigue in [3]. According to physiological insights, increase in MU firing rate outcomes higher amplitude in low