Detection of Rhythmic Synchronized Double Neuronal Discharges☆

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***Abstract*— Bursting neurons play an important role in motor pattern synchronization and neuronal communication resulting in the ability to coordinate muscles across large anatomical distances. We developed an expert system to detect and assess such synchronization among multiple double-firing neurons.**

I. Introduction

In this research, we investigate the underlying neuronal bursting behavior in human Central Pattern Generators (CPGs) revealed by rhythmic surface electromyographic (sEMG) activity [1]. The Discrete Wavelet Transform (DWT) has long been used to explain motor unit recruitment by selecting a mother wavelet similar to the Motor Unit Action Potentials (MUAPs), such as Daubechies 3 (db3) [1], [2], where high scale subbands have served to single out the spiking neuronal events, and lower scale subbands are mainly comprised of high-frequency noise [1]. However, the periodicity of the DWT and variability in the return times of bursts may cause the multiple MUAPs be misaligned with the mother wavelet during the spiking events (e.g. burst #2 of Fig. 1), or half aligned (e.g. burst #3 of Fig. 1), compared to a relatively better alignment that occurs in burst #1 of Fig. 1.

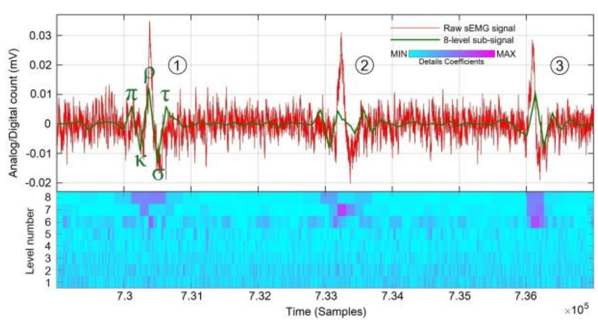

Figure 1. Raw sEMG signal overlaid with its 8-level sub-signal and its scalogram below: The D_8 burst #1 better mimics the spiking event than the D_8 bursts #2 & #3, as it appears to naturally match the raw sEMG signal with its 8-level sub-signal; this D_8 waveform has been labeled with "π-κ-ρ-σ-τ."

Thus, we developed a system [3] that delays the DWT multiple times and increases the waveform matching between raw sEMG signal and its 8-level sub-signal to provide time-localization and characterization of spiking events.

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*Prior to electrode placements, volunteers had signed the *Informed Consent Form* drafted by the investigators and approved by the IRB of USC.

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II. Methods

Four-minute recordings of sEMG data were collected at a sampling rate of 4,000 Hz from volunteers with different states of health, who had four reduced-noise tripolar sEMG electrodes placed along their paraspinal muscles and aligned with the fibers at cervical, thoracic, lumbar, and sacral positions*. To solve the mentioned *shift variance* issue, we designed a set of expert rules that consist of nested conditional statements each within a *for* loop (with index representing the chronological appearance of each burst) that computes the minimal error between the local maxima of a delayed DWT sub-signal and a smoothed (Savitzky-Golay filtered) sEMG signal. This process resulted in delays at which this waveform matching is located on the Pareto front.

III. Results

The delays θ_1=5 ms for D_8 burst #1', θ_2=14 ms for D_8 burst #2'', and θ_3=24 ms for D_8 burst #3''' were found on the Pareto front, thus providing a better match (Fig. 2).

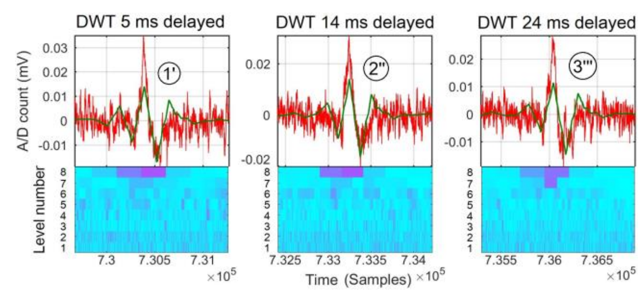

Figure 2. Zoom around each burst with its 8-level sub-signal: The DWT has been delayed the amount of time that the expert system found on the Pareto front for each burst, recovering the πκρστ morphology of D_8 bursts #2 & #3.

IV. Discussion & Conclusion

The *entire* spiking events are best reconstructed from two relatively high and successive D_8 coefficients (each spanning ~60 ms), suggesting a high incidence of multiple neurons firing double "exceptional" spikes [4] within each burst (doublet). From this highly synchronized firing pattern, the neuronal connection *structure learning* is also contemplated.

References

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