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Wiener filtering and classification of neurographic recordings

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Abstract- **Methods were developed to improve the S/N ratio and selectivity of nerve recordings, and to allow classification of nerve signals originating from activation of different fiber diameter populations (e.g. different receptors). The need for these methods arose from our 'bladder pace-maker' research, where nerve cuff electrodes were placed around the feline sacral spinal roots to monitor urinary bladder afferent activity. A novel technique to design Wiener filters for neurographic recordings was developed, which resulted in improved S/N ratio and selectivity of the recordings. Since the sacral roots innervate dermatomes and the rectum, the nerve signal increases had to be classified to extract bladder afferent information only. Multilayer perceptron neural network was trained with different autocorrelation functions to classify bladder, rectal and cutaneous nerve signal increases.**

I. Introduction

Signal detection of neurographic recordings is impaired by low S/N ratio [1]. Therefore it is desirable to improve the S/N ratio by optimizing nerve-electrode interface, using low-noise electronics, and/or signal processing. A method to design Wiener filters [2] that optimizes S/N ratio of signals contaminated by uncorrelated, additive noise was developed. Additionally, nerve signal increases might also need to be differentiated when recording from a mixed nerve, as they might originate from the activation of different fiber populations. In the case that these fiber populations have different conduction velocities, the autocorrelation functions of the nerve signals will have different shapes. This allowed classification of nerve signals. Wiener filtering and nerve signal classification were applied to nerve cuff recordings made in cats. The methods arose from our 'bladder pace-maker' research, where overactive bladder contractions were detected using neurographic recordings from bladder afferents, and inhibited by electrical stimulation of the S1 dorsal root [3].

II. Methods

Six acute cat experiments were perfomed under general anaesthesia, where the sacral nerve roots were exposed and identified. Nerve cuff electrodes were placed around the S1 nerve root, and nerve signals recorded during manual stimulation of the bladder, rectal, and cutaneous mechanoreceptors. The signals were BP filtered (100-3000Hz) and digitized at 8 kHz. Wiener filters were designed using artificially generated nerve cuff signal [4] for different animals and different receptor types. Nerve cuff signal autocorrelation functions were calculated and used as input to multilayer perceptron neural network to classify the nerve signals.

III. Results

Wiener filters designed for bladder, rectal, and cutaneous afferent activity improved the S/N ratios by 144±101%, 41±16% and 33±21% respectively (mean±sd). Wiener filtering also improved the selectivity of the recordings i.e. Wiener filter designed for rectal mechanoreceptors improved the S/N ratio during rectal excitation, but decreased the S/N ratio during cutaneous stimulation. The shapes of autocorrelation functions were found to be different when different types of receptors were active. The mean times of the first zero-crossing of the autocorrelation function after the first minimum was reached were 1.39±0.35 ms (n=26, 3 animals), 1.86±0.42 ms (n=66, 4 animals), and 2.96±0.55 ms (n=18, 2 animals) for cutaneous, bladder, and rectal receptors respectively. The percentage of correct neural network classification was 100% and 83.3% for training and validation data respectively.

IV. Discussion and Conclusions

Wiener filtering greatly improved the S/N ratio and selectivity of nerve cuff recordings. The presented Wiener filter design can also be used for other types of neurographic recordings. Nerve signal autocorrelation functions allowed for classification of the activation of different receptors, which was accomplished by neural network classification.

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