BIOMEDICAL ENGINEERING
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Spike sorting based on reverse principle component analysis and waveform properties

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Introduction

Brain-controlled prosthesis needs to acquire signals from subjects. However, when collecting signals using electrodes, noise that comes from thermal fluctuation or electrodes drifting would also be recorded, leading to waveforms that are generated by the same neuron to be not identical. A simple method to de-noise the signal is needed. Moreover, different neurons generate different spikes. If spikes generated by different neurons can be told apart, waveforms may be related to activities that originate from corresponding neurons, thus prosthesis can be more accurately controlled, or systems that can fully utilize the potential of brain-machine interface may even be built. This project intends to utilize Reverse Principle Component Analysis (PCA) to de-noise the signal, and then sort spikes using properties extracted from the de-noised signal.

PURPOSE:
Develop an MATLAB algorithm to de-noise the signal, and then sort spikes using waveform properties

Methods

The working process for the design algorithm is as follows:

- Find spikes from the collected/simulated signal
- De-noise the signal through performing PCA and then use the first four PCs to do reverse PCA for individual spikes
- Calculate properties, for example, peak/trough width, power, work, frequency-domain peak position, etc.
- Normalize each property
- Cluster spikes, and find outliers for each clusters
- Combine similar clusters by performing statistical analysis and template-matching
- Rearrange outliers into the group that suits them/discard spikes if they do not belong to any group
- Output the spike sorting result

Validate the sorting algorithm using simulated data:
Simulated data is generated by first positioning different spikes into a thirty second blank signal. In this way, the total number of spikes and their positions in the signal are known. Second, Gaussian noises of different amplitudes are superimposed onto the signal to generate data with different levels of noise. Generated signals are then inputted into the sorting algorithm to validate it.

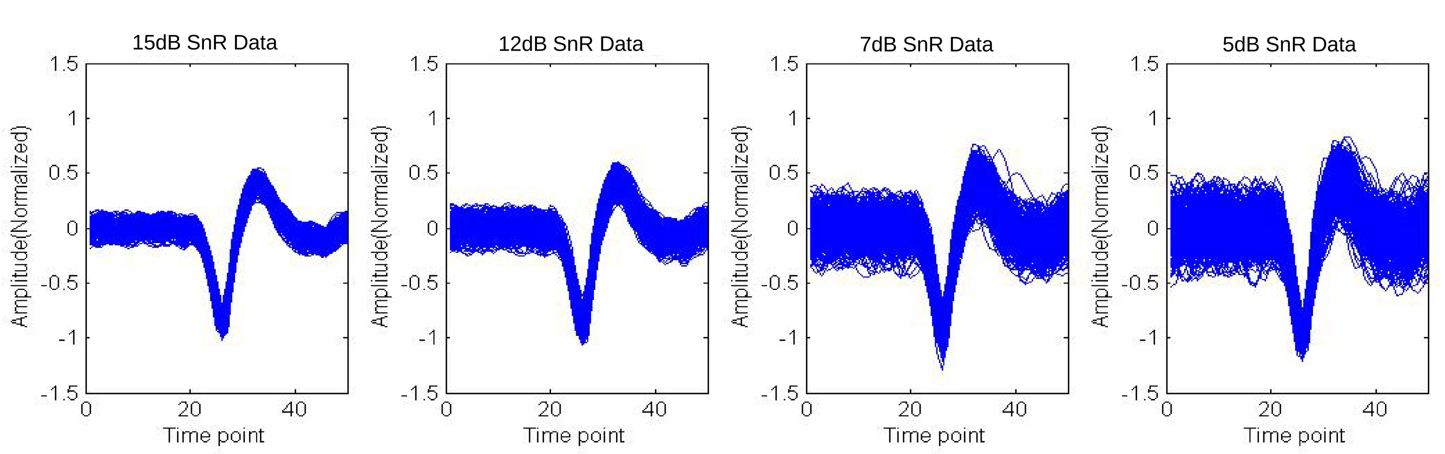

Figure 1: Sample Spikes from Channel 2 at Varying SnR Level

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Results

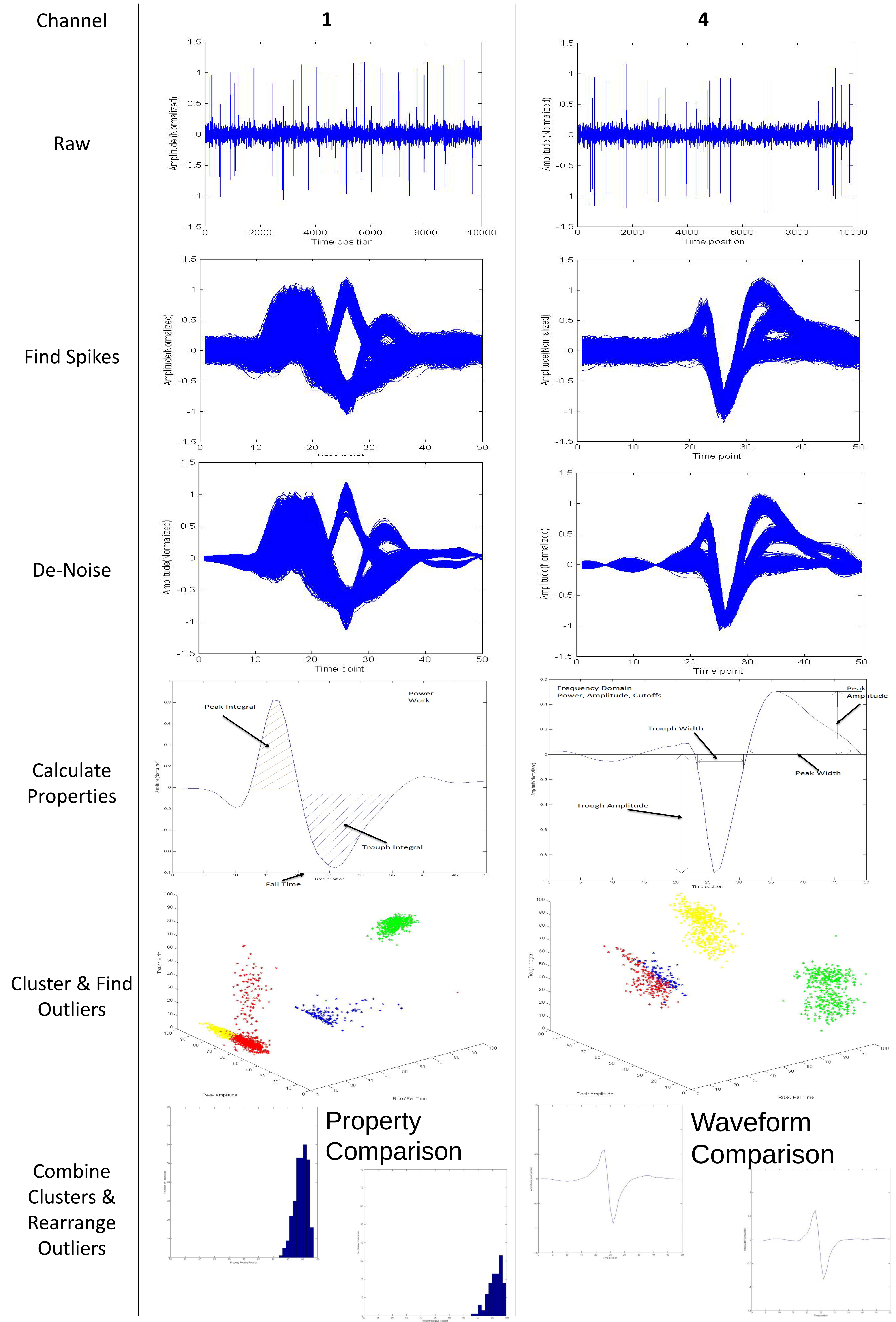

Figure 2: Spike Sorting Step Demonstration for 12dB Noise Data

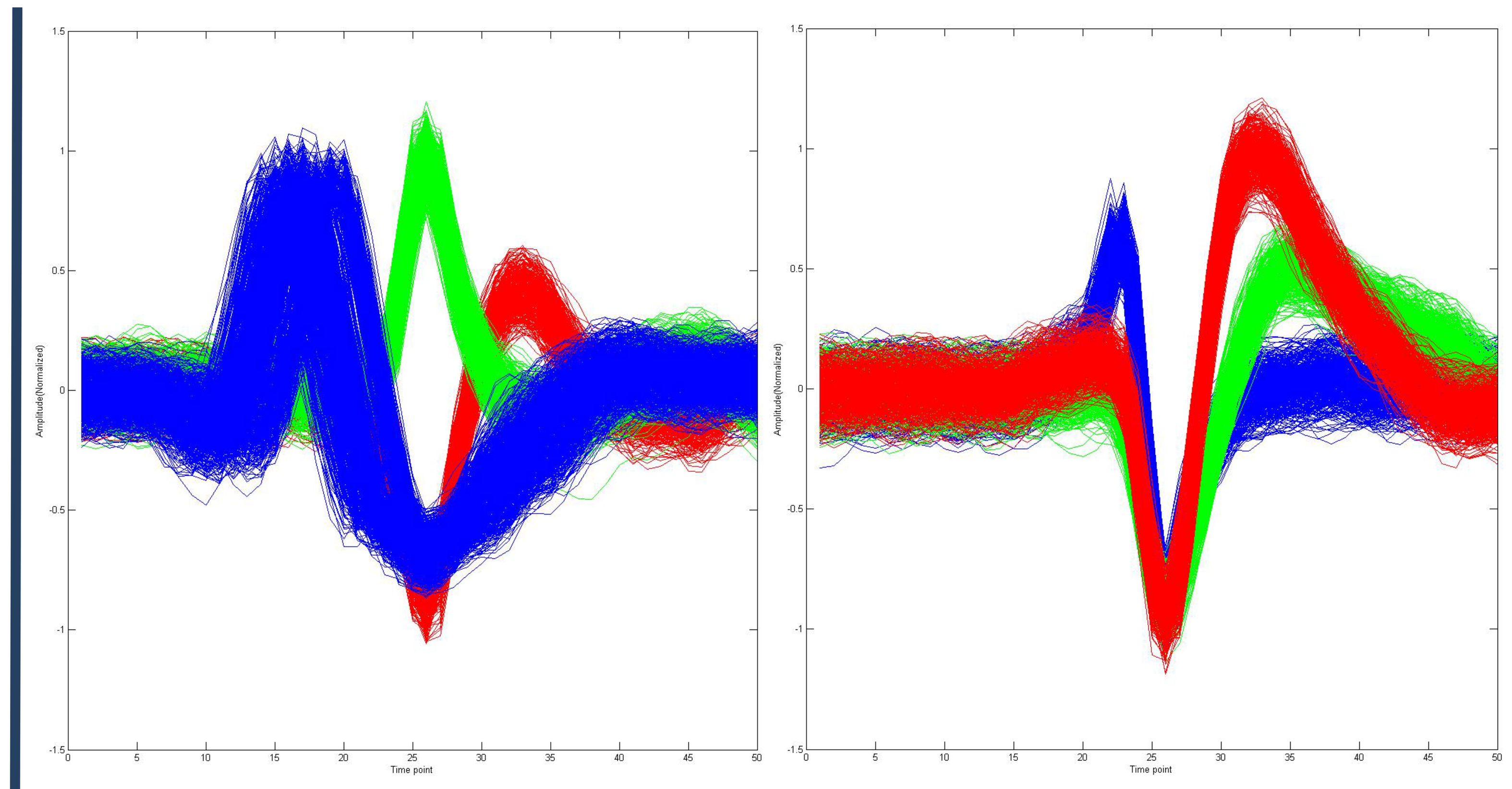

Figure 3: Two Channels' Pile Plot Result for 12dB Noise Data

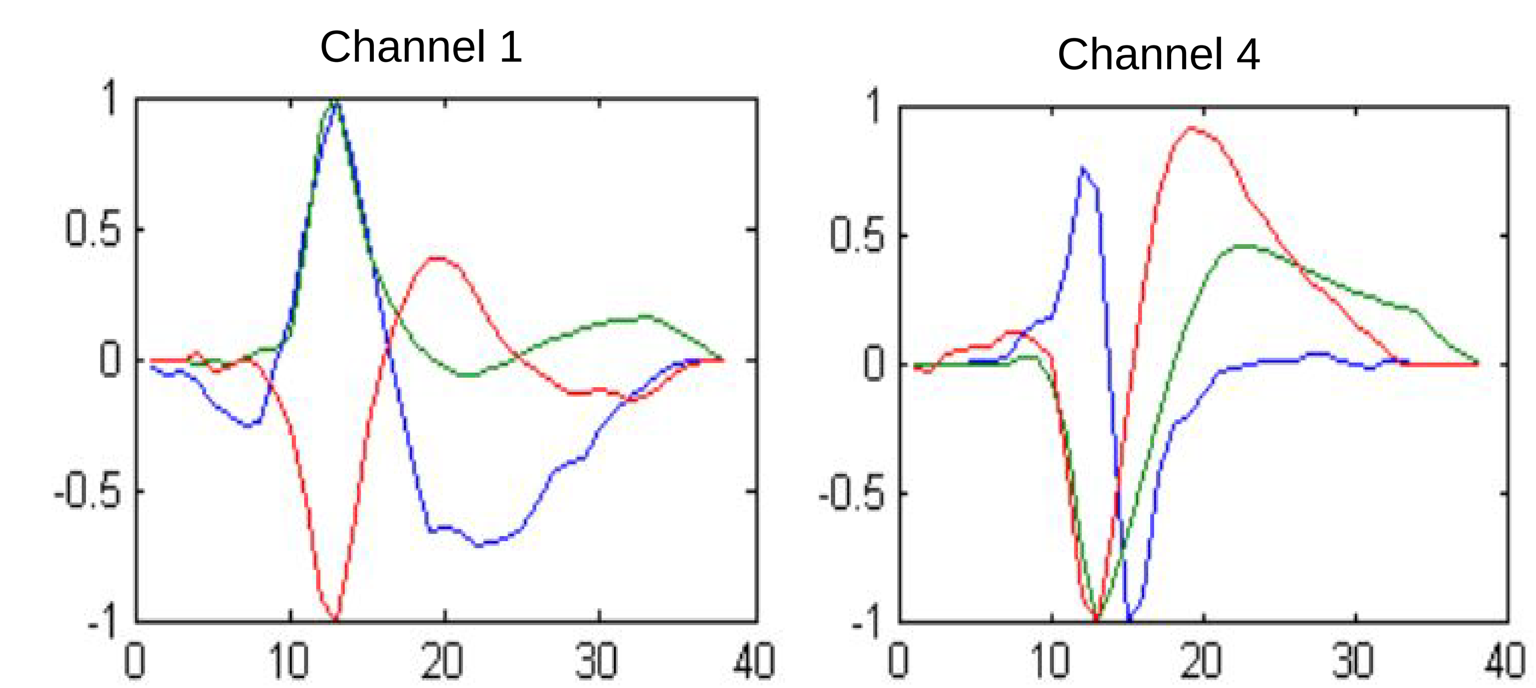

Figure 4: Base Waveforms Used to Generate the Simulation Data for These Two Channels [1]

Conclusions

The new de-noising and spike sorting technique showed improved results compared to both manual sorting and previous work only utilizing PCA and clustering.

In the future, we will expand our analyses across multiple SnR simulated datasets to validate algorithm performance (ongoing). We will also demonstrate the feasibility of using these techniques with in vivo electrophysiological data to evaluate performance in a more natural dataset. Further, the implementation of more advanced clustering methods, including genetic algorithms, machine learning, and fuzzy-logic clustering methods may be implemented to further improve sorted unit efficacy in the presence of higher noise environments.

References

[1] Langhals, N., "Strategies for Optimizing Information Extraction from Cortical Recordings", Chapter II, pp. 36

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