Hardware Architecture of O-Sort Spike Clustering

Chia-Hsiang Yang, Sarah Gibson, Vaibhav Karkare, and Dejan Marković

INTRODUCTION

The simultaneous recording of action potentials from multiple neurons is required to understand the function of neural circuits and to develop brain-machine interfaces. Spike sorting is the technique to differentiate action potentials originating from multiple neurons recorded by a single electrode. Online sorting (O-sort) provides the possibility for fast nerve-activity tracking and closed-loop experiments.

SYSTEM OVERVIEW

Spike sorting consists of three main steps: (1) spike detection and alignment, detecting neural spikes from the background noise and aligning to a reference point along the time axis; (2) feature extraction, analyzing and projecting spike waveforms onto a “feature” space; and (3) clustering, classifying spikes into different clusters (i.e., neurons) using the extracted features (see [1] for details). Based on our previous work on a 64-channel spike-sorting DSP chip [2], a hardware-efficient O-sort architecture is developed to facilitate hardware realization for further silicon integration.

ONLINE-SORTING ALGORITHM

The O-sort algorithm adopted in this work was proposed in [3]. The original algorithm uses data points of the spike waveforms as features, but the concept can be applied to other extracted features, as discussed in [1]. The algorithm is summarized as follows. First, the variance of the signal $x(n)$ is calculated as the threshold $\mathcal{T}$ between two clusters. Second, the (Euclidean) distance of a new neural waveform $f(n)$ to all known clusters (represented by the mean waveforms) is used to create a new cluster if the minimum distance is less than the threshold. Third, the waveform will be assigned to the nearest cluster or two clusters will be merged if the distance is less than the threshold.

HARDWARE-EFFICIENT REALIZATION

Dedicated hardware is more energy efficient in implementing the O-sort algorithm. Fig. 1 shows the proposed architecture for O-sort. In the create-cluster state, the “Thr. check” compares the minimum distance from the threshold $\mathcal{T}$. It either (1) activates the delay line to generate one cluster if the distance $> \mathcal{T}$ or (2) enables the cluster with the minimum distance to update the mean waveform if the distance $< \mathcal{T}$. In the merge-cluster states, all clusters are reconfigured to calculate mutual distance sequentially. The “Thr. check” updates the mean waveform and cleans the contents of one cluster in the scenario of distance $< \mathcal{T}$. In this case, the two clusters are indistinguishable from one another so they should be merged.

RESULTS

The proposed low-complexity O-sort architecture provides higher than 80% classification accuracy for real physiological recordings SNR above 6.4dB.

REFERENCES