Real-Time Sharp Wave Ripple Detection System

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Abstract

We demonstrate an open-source, cross-platform solution for online **sharp-wave ripple (SWR)** detection and disruption.

Specifically, we show that our system can achieve **high accuracy** (>97%) and **low latency** (~40-60 ms) in **online detections** of SWR activity in a synthetic "gold-standard" dataset (matching state-of-the-art latencies). Additionally, we show that optimizing the platform, results in online detections ~10-15 ms behind offline SWR detections.

Background & Motivation

What are **sharp-wave ripples (SWRs)**?

Coordinated bursts of neural activity in the hippocampus that stem from the CA3 region causing oscillations in the CA1 region. These events are ~150-250 Hz and last ~100 ms.[A],[B],[C]

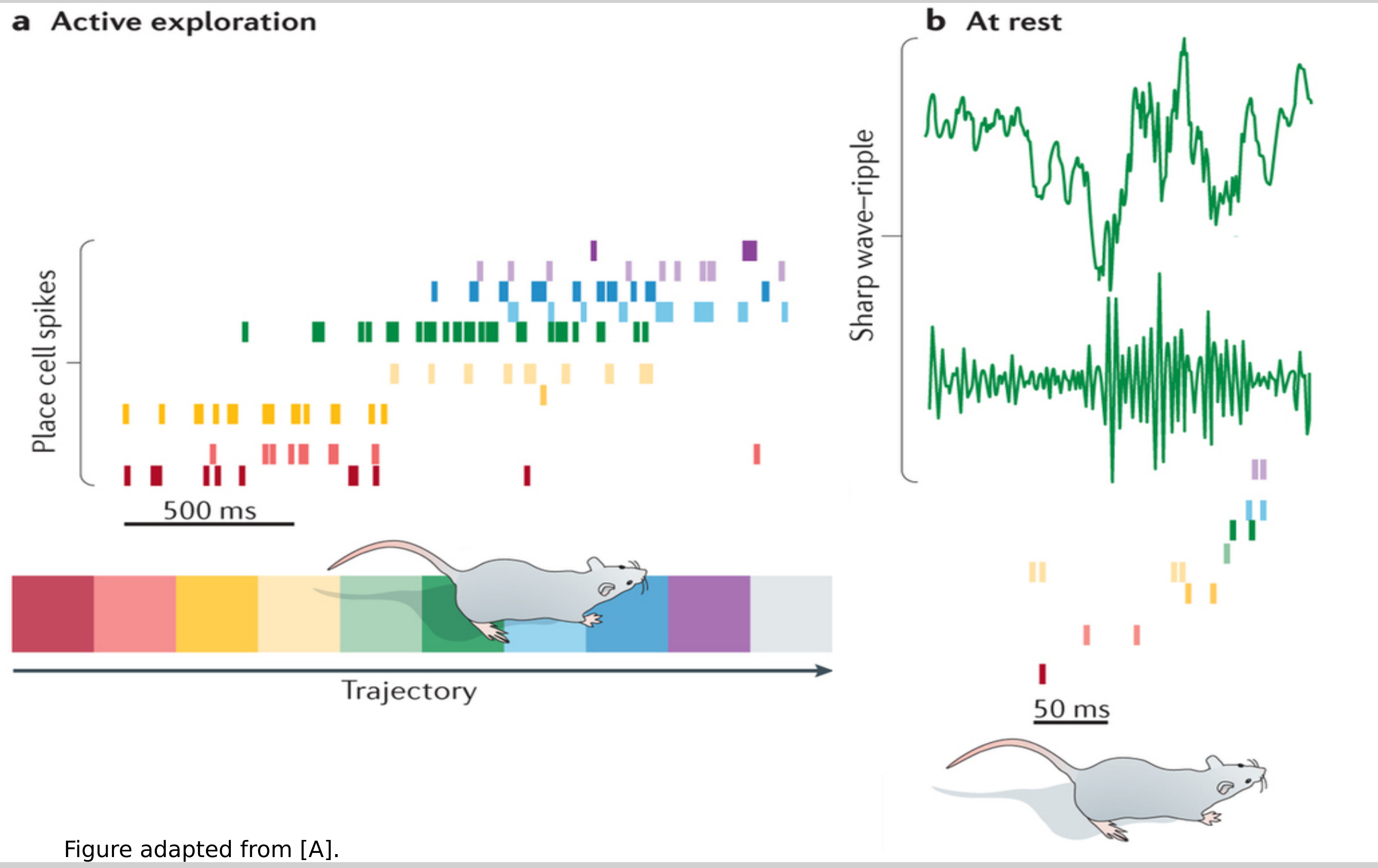


Figure adapted from [A].

Why do we care about them?

The CA1 neurons active during a SWR can be the same ones active while an animal is going through a spatial navigation task. This implies that SWRs are associated with a subject **replaying a past experience**. This association has been causally linked through online detection and disruption of SWR activity.[D] Further studies with closed-loop control are required to determine the extent to which SWRs contribute to memory consolidation and decision making based on past experiences.

Objectives

To fascilitate the dissemination closed-loop SWR manipulation studies, we aim to:

1. build an open-source, cross-platform online SWR detection and disruption system
2. achieve "acceptable" detection latencies using simple algorithm SWR detection (as it has been shown that a variety of detection algorithms result in similar latencies)[E].

System Architecture & Detection Algorithm

Hippocampal neural data (LFP) is collected and sent to a computer (1-3).

Trodes software is used to detect SWR events and initiate a stimulation pulse (4-6).

A microcontroller triggers a biphasic stimulator to disrupt the SWR (7-8).

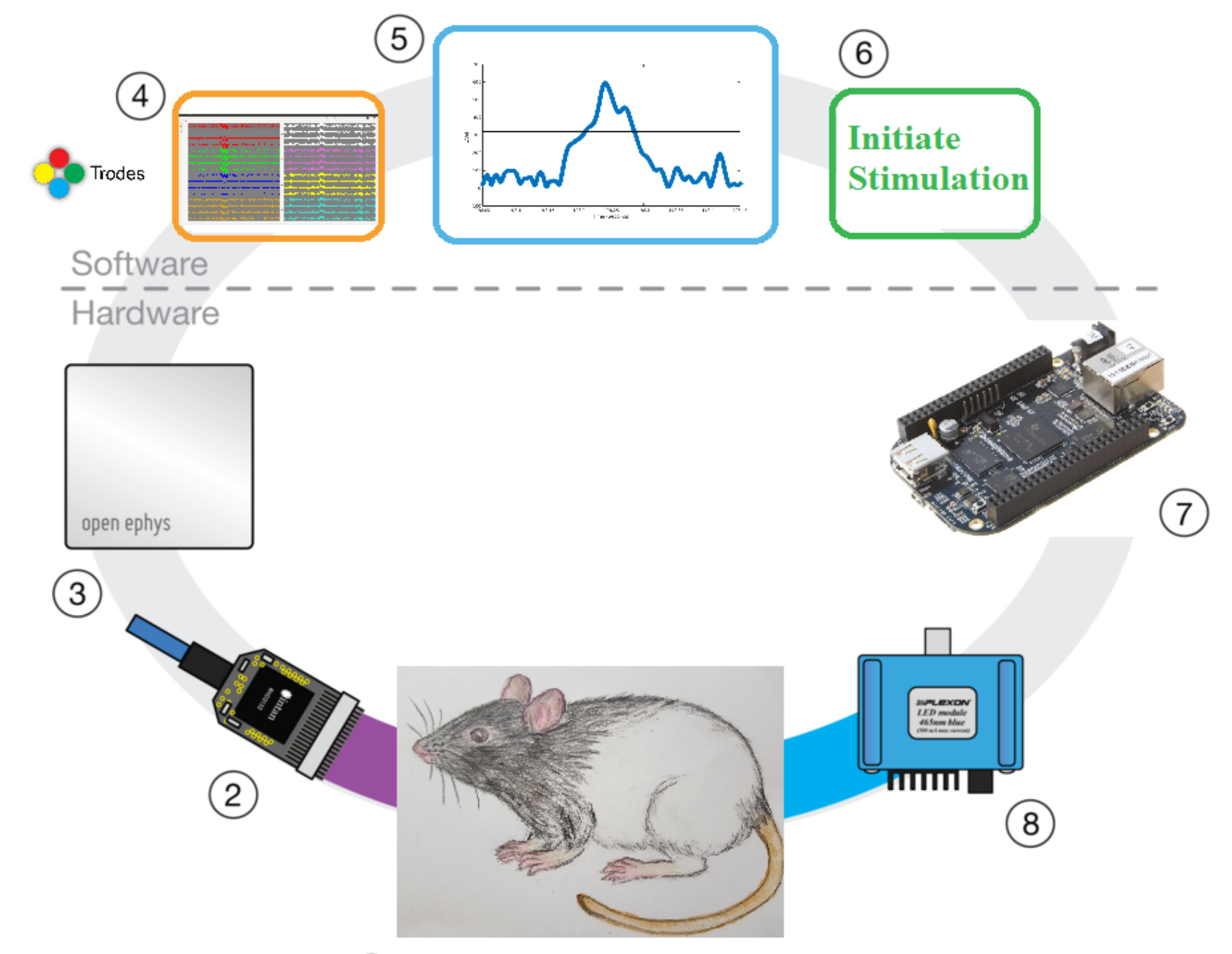
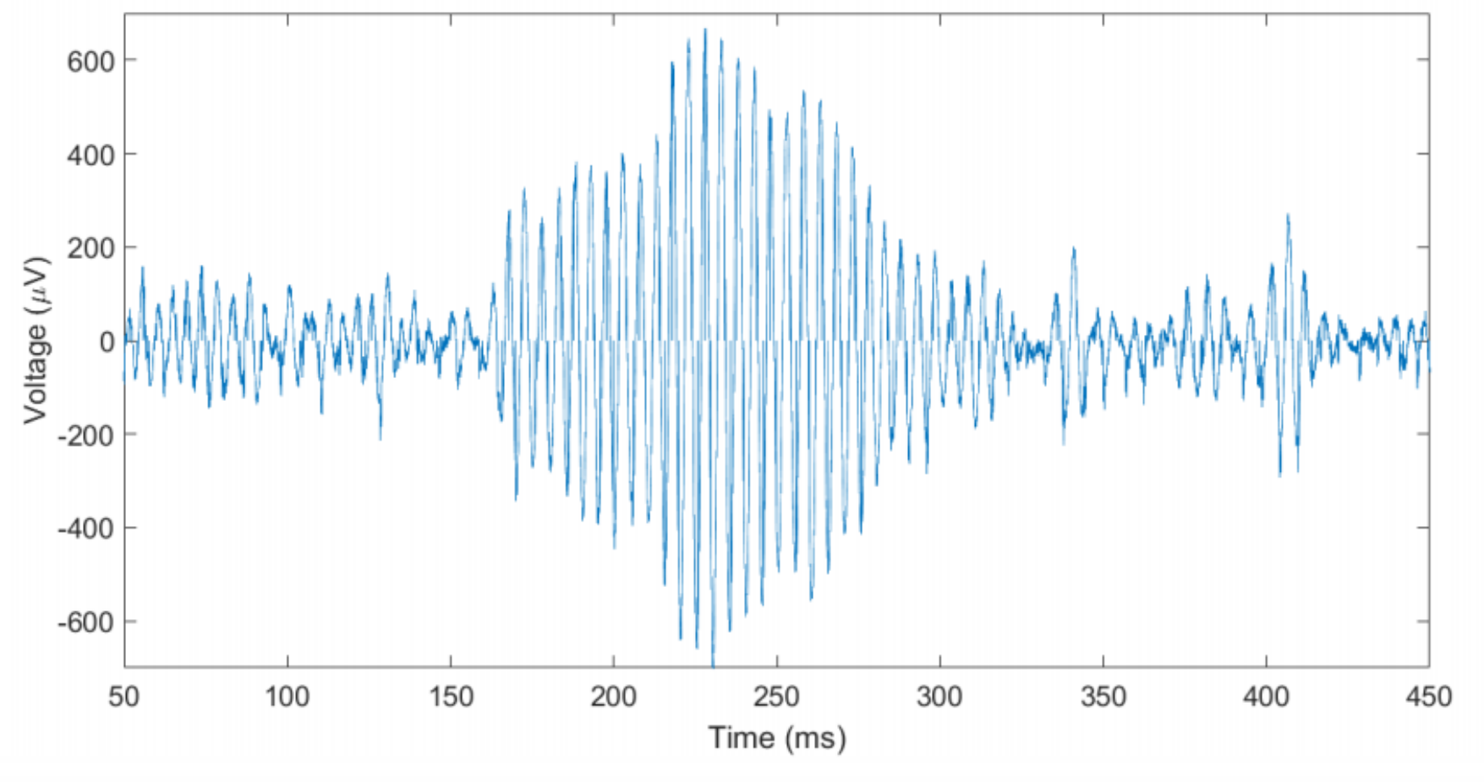
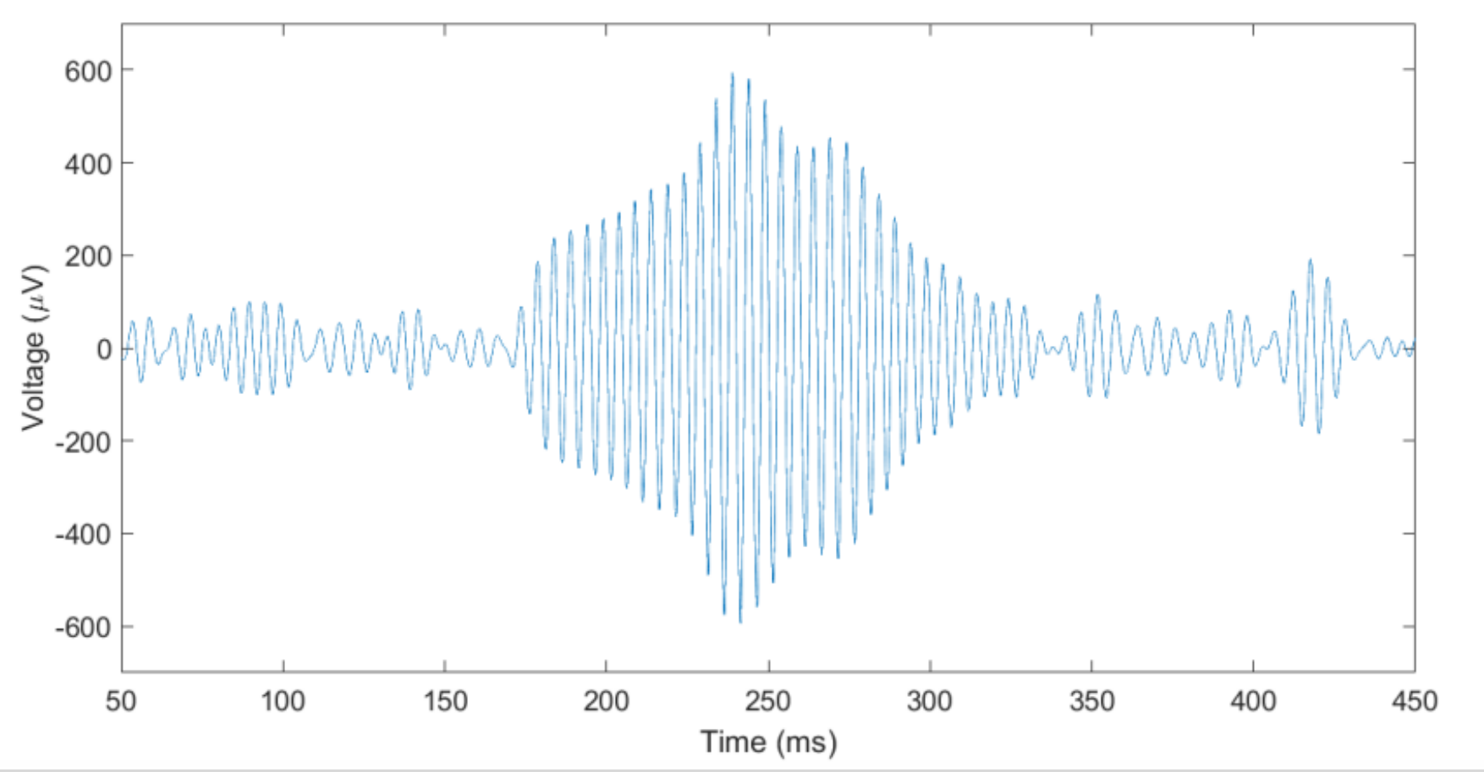


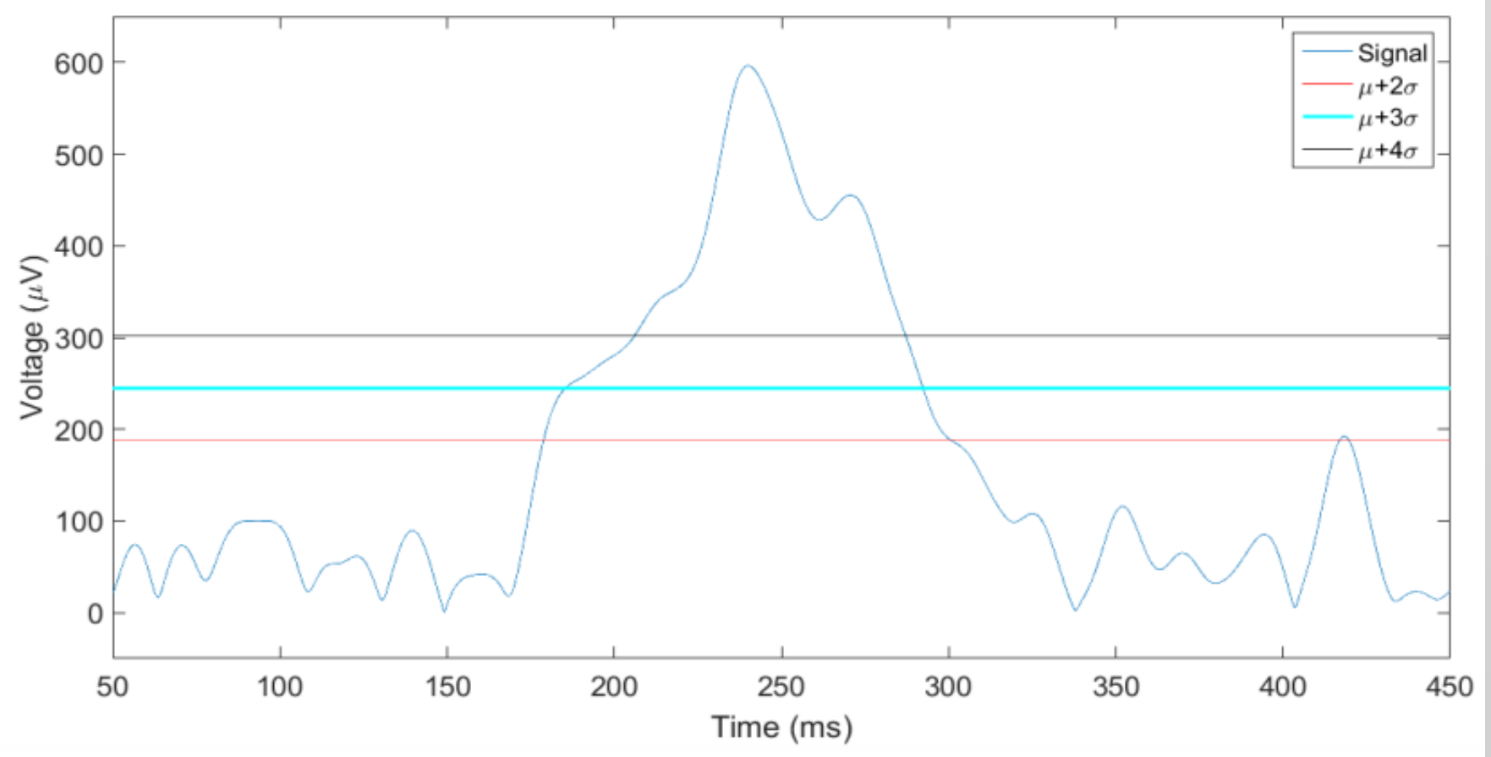
Figure adapted from Open-Ephys
Rodent Art Credit: Keya Dutta



Our implementation utilizes a synthetic SWR dataset to replace the rodent in (1) of the system architecture figure above.

The first step of the SWR detection algorithm is to filter the signal into the "ripple band" (150-250 Hz).

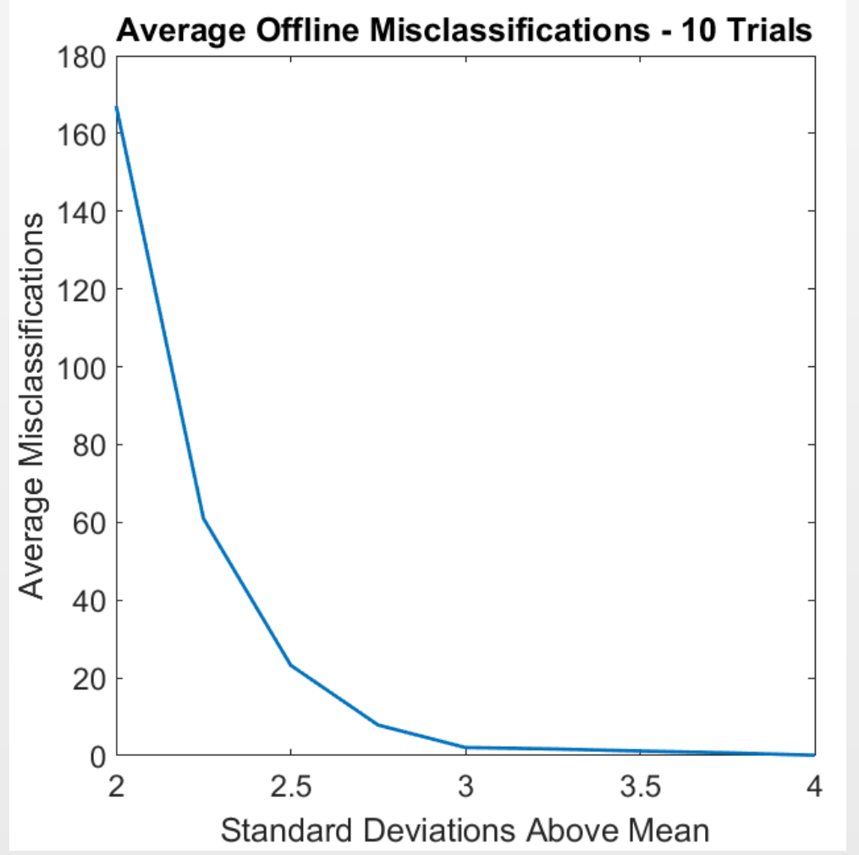


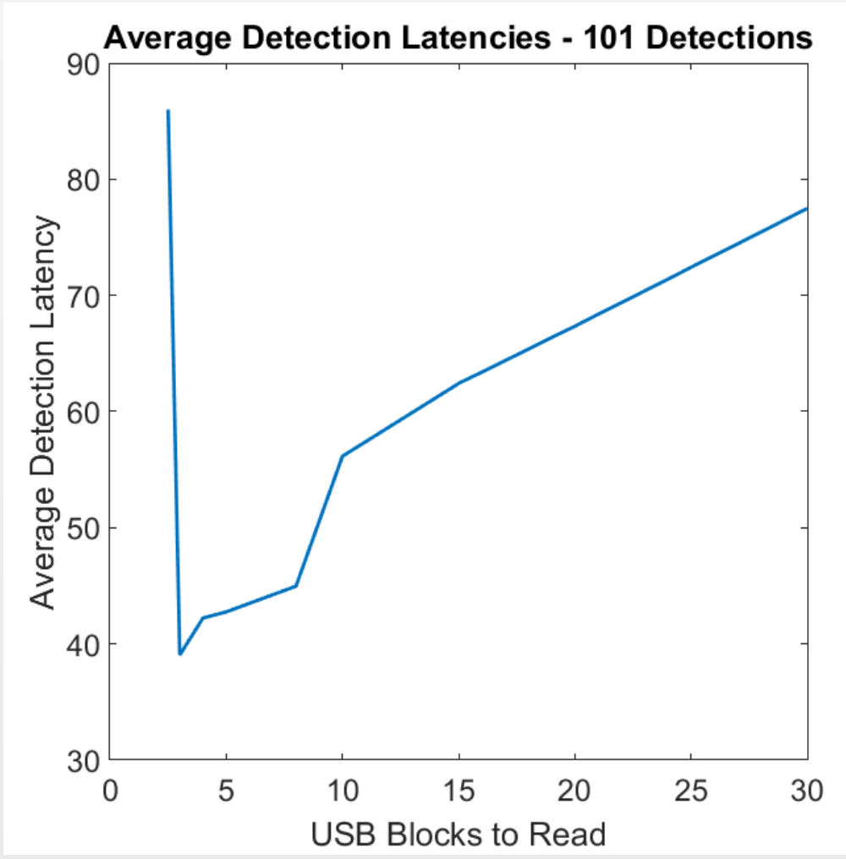


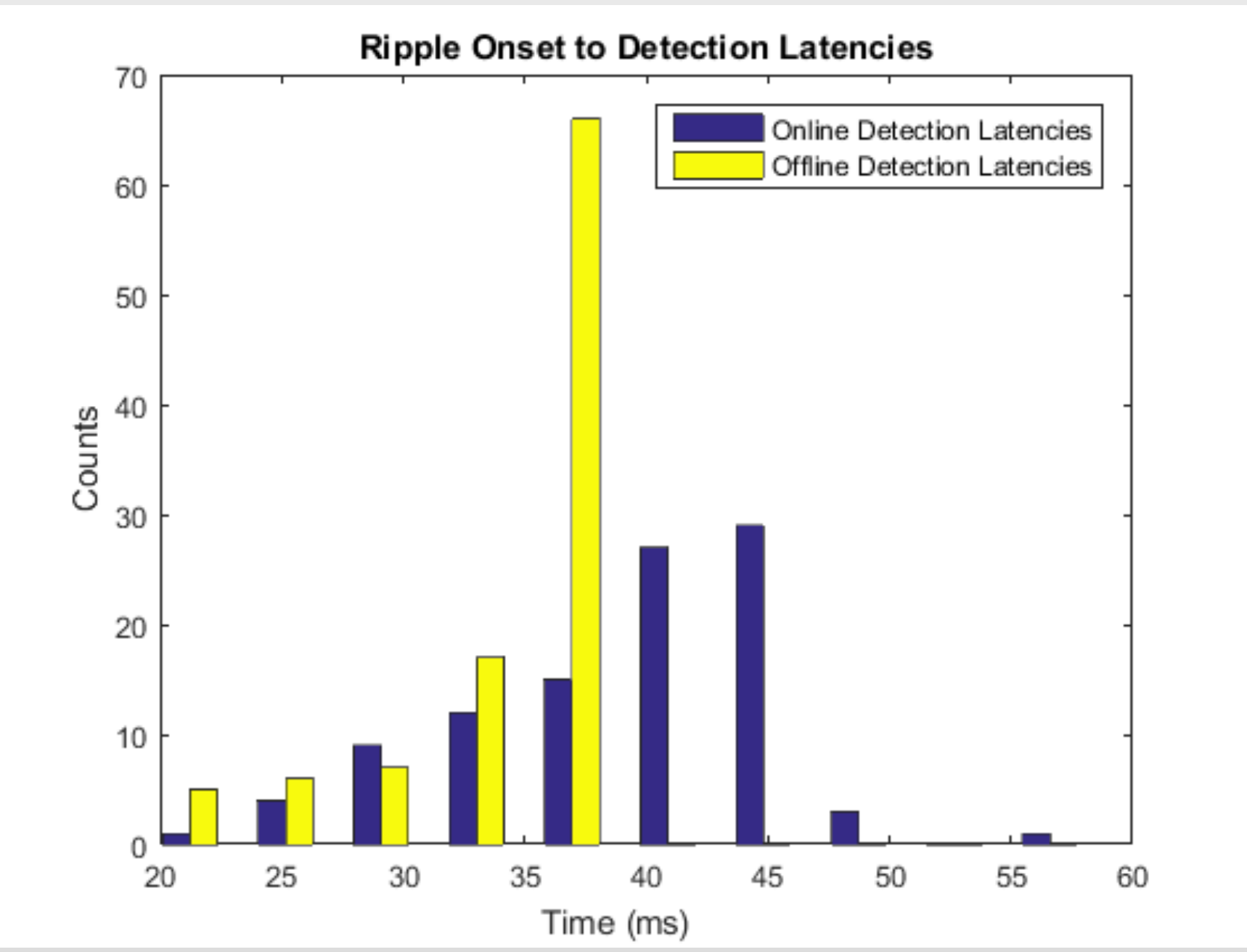
The signal is "enveloped" and parameters are estimated. The mean and standard deviation are used to set a threshold to qualify SWRs.

Results and Discussion

Variations in the threshold show an intuitive optimization plot. Additionally, optimizing the hardware and software communication leads to lower latencies.

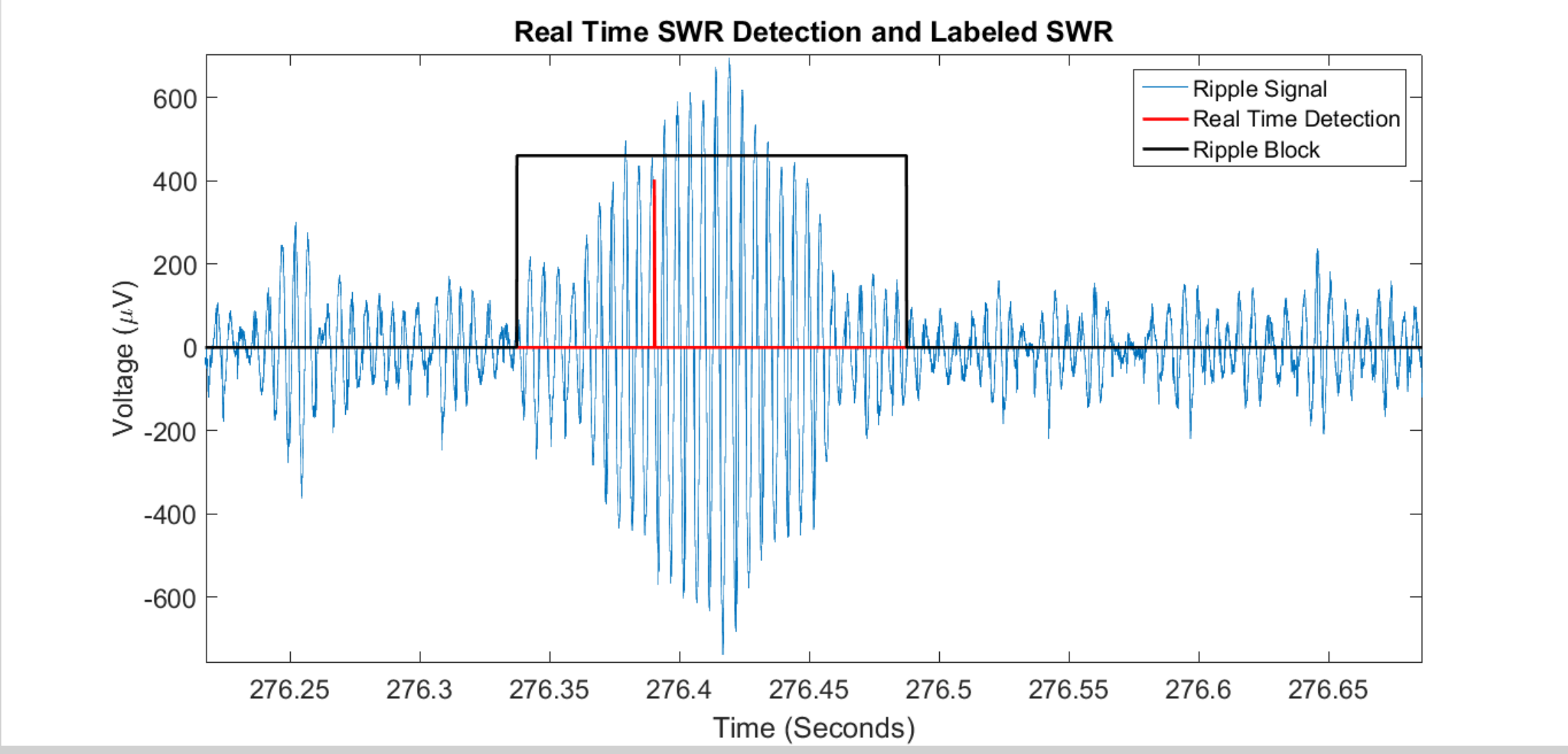






Based on the optimizations above, threshold set to 4 standard deviations above the mean and 3 USB blocks to read per buffer, we report the latencies shown to the left. Note that there is usually only ~10-15 ms delay between online and offline detections.

As the general length of a SWR is ~100 ms, these detection latencies show that we can interrupt the SWR prior to a majority of the event transpiring.



Conclusions & Future Works

We have been able to build an open-source, cross-platform system for online SWR detection and disruption. This system has comparable latencies to those reported by previous works in the field. This modular system is being extended to support behavioral traces and multiunit activity.

Currently, we are preparing for in vivo testing to answer further neuroscience inquiries. We believe this system will enable researchers to better understand the mechanisms of memory.

References

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