Low-Latency, Open-Source, Real-Time Sharp-Wave Ripple Detection System

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 perfect detection accuracy and low latency (~40-60 ms) in online detections of SWR activity in a synthetic “gold-standard” dataset (matching state-of-the-art latencies). In vivo, our system shows low detection latencies (~35-60 ms) with low false stimulation rates (~1/2/sec). Additionally, we show that our system’s latency is within ms of threshold crossing.

Background & Motivation
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.

What are sharp-wave ripples (SWRs)?

The CA1 neurons active during a SWR can be the same ones that were active during a past experience. This implies that SWRs are associated with a subject's memory consolidation and decision making based on past experiences.

Detection Algorithm

400 Hz LPF and decimated signal sent to module.

Causal filters in the online and simulated cases cause a phase in the signal as opposed to the non-causal offline filter.

Offline envelope and smoothing by Hilbert Transform and Gaussian filtering.

Online/Simulated smoothing by absolute value and low pass filter.

System Architecture

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

The code 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).

Detection with Open Ephys and Spike Gadgets

Algorithm accurately detects ripples in “gold standard” data but there is a latency between simulated and online.

Can We Improve Performance? Two Channel In Vivo

In multichannel case we enable, multiple channels to vote on ripple events prior to sending stimulation pulse. Higher accuracy is achievable at lower thresholds with similar detection latencies compared to single channel.

Conclusions & Future Works
We have built an open-source, cross-platform system for online SWR detection system. This system has comparable latencies to those reported by previous works in the field. This system has been validated in vivo showing acceptable latencies and accuracies. We have shown that two channel detection shows a marked improvement in accuracy versus one channel. Currently, we are incorporating multiunit activity based detection algorithms.

References

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 reproducing a past experience. This association has been causally linked through online detection and disruption of SWR activity. 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.