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Real-time Sharp Wave Detection and Stimulation

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Motivation

Hippocampal **sharp wave ripples** have been identified as key biomarkers of important brain functions such as memory consolidation and recall of episodic memory.

In order to understand **the causal relationship** between the mechanism of the sharp waves and behaviour. The SWR events can be disturbed by electrical stimulation. This is rely on accurate **real-time SWR detection system**.

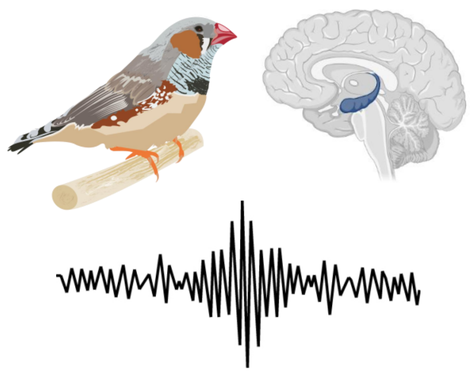

Figure 1 Sharp wave ripples (SWR) are brief, highly synchronous, fast oscillations observed in the CA1 region of the hippocampus

This project is aimed at building a **real-time system for detecting sharp wave ripples** that can be used in a closed-loop perturbation experiments, i.e future optogenetics researches.

Results

- The **duration time** needs to be optimized; the minimum time that the signal must stay above the threshold to be detected.
- It can be different from species to species. Previous evaluation is done mostly on rat data. **New investigation** has to be done on **Zebra Finch**.

Data setup: 15 minutes of the dataset injected randomly with 450 SWR signals.

Quantifying the best parameter			
Parameter	TP%	FP%	F1 score
2ms	98.8 %	38.2 %	0.835
5ms	97.3%	22.98%	0.887
10ms	96.66%	1.16%	0.977
15ms	80.1%	0.69%	0.88
20ms	73.3%	0.31%	0.846

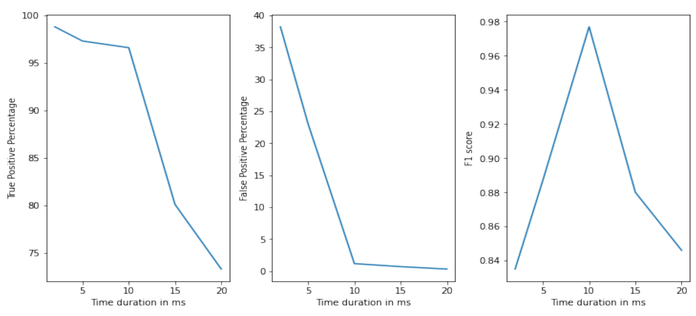

Figure 2 Evaluation on the five parameters using graphs to demonstrate the effects of these parameters on the TP,FN and F1.

- The results show that **10ms** is the optimum duration time.
- The detection model performed **5 false positive** from the 15 minutes. (0.3 FP per minute) and it performed **15 false negative** out of 450 SWR.

Method and Model

The methods were used to achieve the real-time system can be described in these procedure steps:

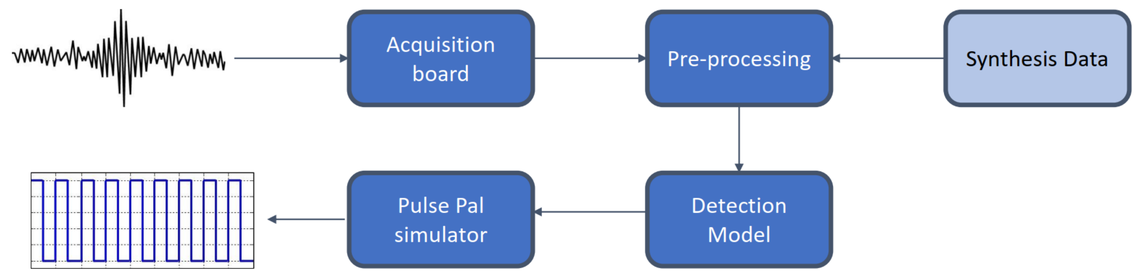

Figure 3 The system diagram

1: Creating two data-generating pipelines: Synthetic data, pseudo-experiment for a prerecorded real data.
2: Implementing the pre-processing/detection model based on the statistical characteristics of the real data.
3: Interfacing the code with OpenEphys GUI using PythonPlugin and other Plugins.
4: Executing the real-time pipeline on the OpenEphys Acquisition Board to extract a command output.
5: Using the command output from OpenEphys to stimulate the Fiber-coupled LED using Pulse Pal Plugin.

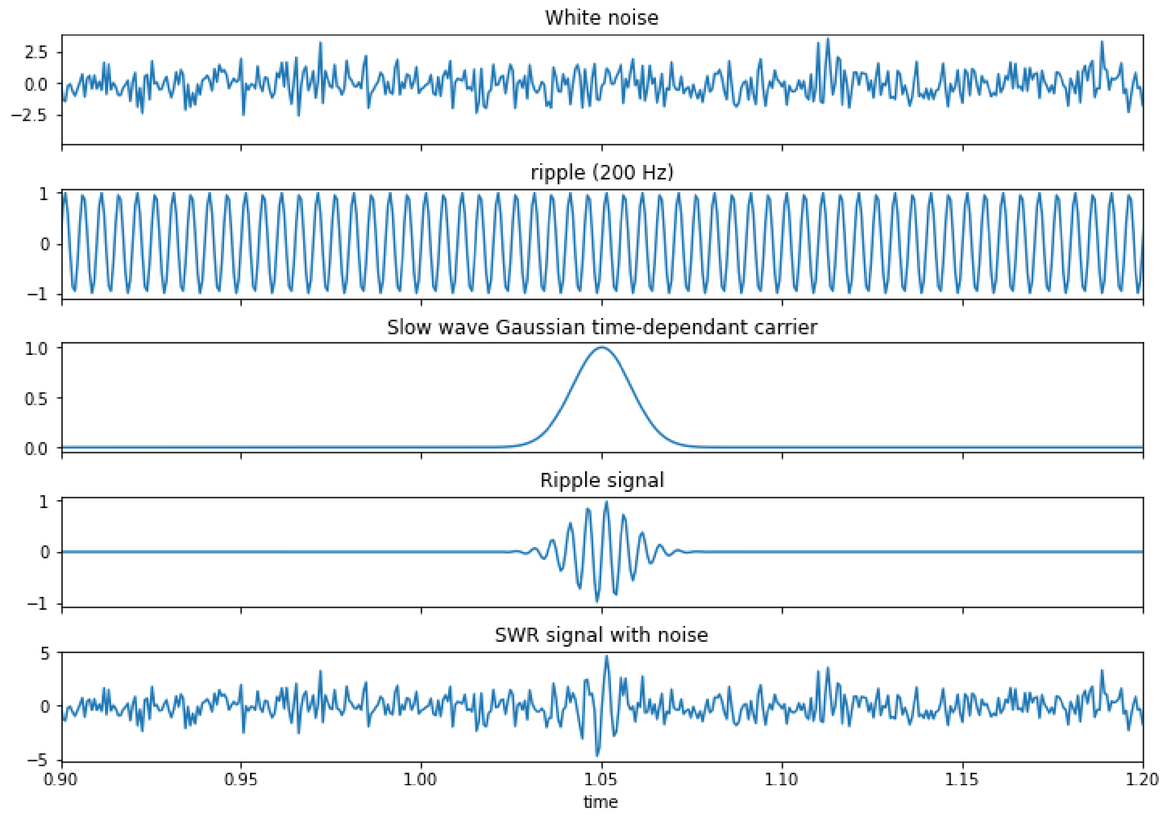

Figure 4 Steps of Generating SWR Synthesized Data

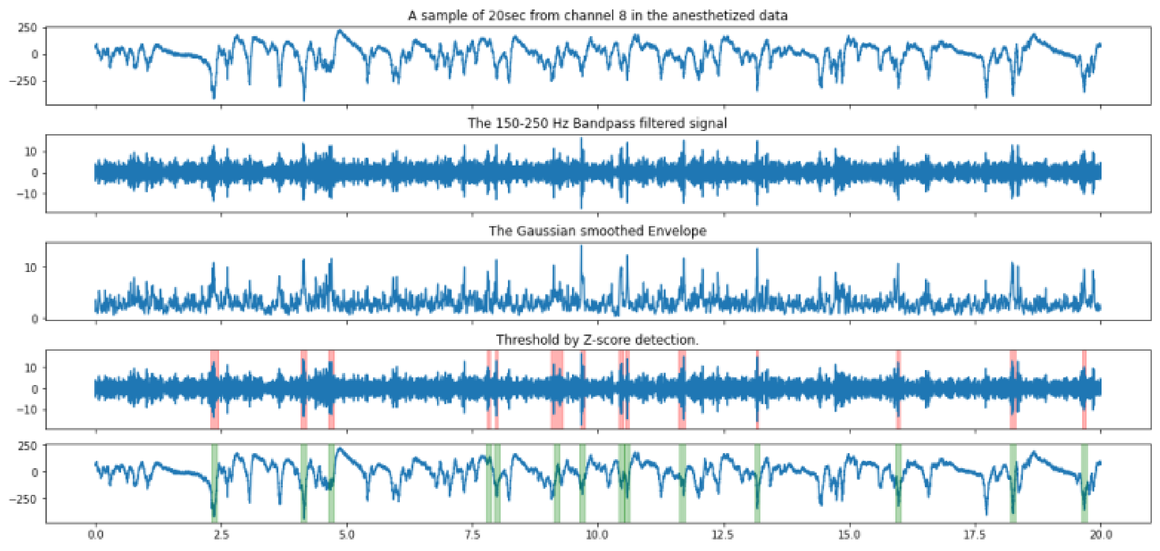

Figure 5 Step by step detection process for a raw synthesized data illustrated from the raw signal to the detected ripples.

Conclusion

This model can achieve **less than 20ms latency**, which less than the speed duration of generating and vanishing of the sharp-wave ripples signal, so it can detect it and disturb it before it disappears. With **around 97% accuracy** makes it a reliable model to be implemented in the closed-loop system.

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