Closed-loop Neural Stimulation with Real-time Spike Sorting

Link to paper: https://iopscience.iop.org/article/10.1088/1741-2560/11/4/046005

1 Introduction

Neurological disorders, from Parkinson's and epilepsy, to depression and addiction, affect millions of people in the United States alone. To treat these conditions, neuroscience researchers need systems and devices that allow them to understand and interact with the brain at the neuron level. Nguyen et al.'s system captures signals from neurons, sorts them by which neuron produced them, and stimulates the neurons in response, all within 8ms. While many systems exist that capture and send neural signals, Nguyen et al.'s system is among the first to send stimuli that vary based on the neural signals captured by the system. This type of system is called "closed-loop". Closed-loop experiments enable studies of how neurons respond to specific local stimuli.

2 System description

With its closed-loop format, Nguyen et al.'s system captures neuron-level signals, through implanted electrodes, and sends stimuli in response, through LEDs. What stimulus the system sends in response to a captured neural signal depends on which neuron the neural signal originated from. The process of determining which neuron a signal – i.e. "spike" – came from is called spike sorting. Nguyen et al.'s spike sorting operates in real-time, meaning it sorts each spike as soon as it is captured. Once a spike is sorted, the appropriate stimulus can be sent.

3 Results

3.1 Processing Time

Reducing the system's processing time is a major challenge in the implementation of closed-loop neural recording and stimulation systems. The processing time of Nguyen et al.'s system is the time it takes to capture a neural spike, sort it, and send the appropriate stimulus to the brain. Currently, no spike sorting systems can accomplish these steps in true real-time (zero processing time), however Nguyen et al.'s system achieves a processing time of 8ms. This 8ms processing time marks a significant contribution to the field, as it enables future researchers to perform experiments with closed-loop local neural stimulation in near real-time.

3.2 Validation Testing

This 8ms processing time and closed-loop functionality were validated through short experiments in which the system was coded to turn on the LED in response to select neurons. The results of one such experiment are shown in Figure 1. For this experiment, the system first captured and sorted a neural spike. On the left, it sorted the spike into neuron 12, and correctly turned on the LED. On the right, it sorted the spike into neuron 17, and correctly left the LED off. The rightmost plot also shows a processing time (gray) of 8ms, as desired.

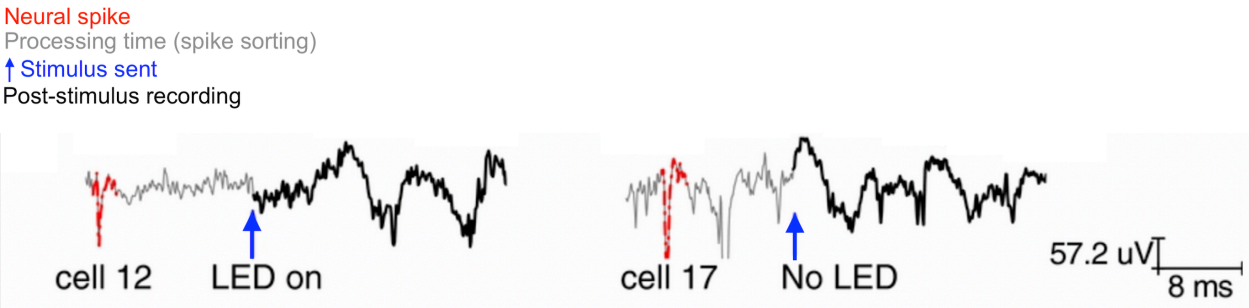

Figure 1. Voltage plots of two neural spikes and subsequent activity

4 Conclusion

Through validation, Nguyen et al.'s system proved capable of closed-loop operation, with a processing time of down to 8ms. While various neural stimulation systems have been developed, few enable full closed-loop operation. The system's processing time of 8ms marks a significant improvement from previous "real-time" systems. This system will enable neuroscience researchers to experiment with real-time local neuron stimulation, and thus bring us closer to treating neurological disorders.