Development & Application of a Closed-Loop Continuous Optical Neural Interface

Procedures for real-time image processing, neural signal extraction, and application to closed-loop control using wide-field Ca2+ fluorescence with awake behaving animals

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The latest generation of genetically encoded calcium sensors deliver a substantial boost in signal strength. This – combined with equally critical advances in the size, speed, and sensitivity of image sensors available in scientific cameras – enables high-throughput detection of neural activity in behaving animals using traditional wide-field fluorescence microscopy. However, the tremendous concomitant increase in data flow presents challenges to processing, analysis, and storage of captured video, and prompts a reexamination of traditional routines used to process data in neuroscience.

In this document I describe an open-source MATLAB toolbox for efficiently analyzing and visualizing large imaging data sets. The toolbox is capable of interactive or fully automated use. This software package provides a library of image pre-processing routines optimized for batch-processing of continuous functional fluorescence video, and additionally automates a fast unsupervised ROI detection and signal extraction routine. Further, I describe an extension of this toolbox that uses GPU programming to process streaming video, enabling the identification, segmentation and extraction of neural activity signals on-line.

The final component of this project is evaluation of this system in a closed-loop signal extraction and neural control setup. Using a wide-field Ca^{2+} fluorescence microscope and awake behaving mice running on adjacent spherical treadmills, I'll train a feature extractor to encode motor states from one mouse, and use the output to modulate motor control of the other mouse using optogenetics.