Processing of optical brain images

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Implementation using MATLAB (no DROID phone required)

Motivation
Current technology allows optical recording of brain activity in awake behaving mice through the use of miniature head-mounted microscopes [1]. These images require processing, as they are unevenly illuminated, contain framewise shifts, and do not readily reveal individual neurons (Fig. 1). To process these images one first estimates and divides out the uneven illumination by performing a spatial lowpass. A motion correction procedure follows [3]. Finally, Principal Component Analysis (PCA) can be used to reduce dimensionality and Independent Component Analysis (ICA) is used to identify neuron locations [2]. Even after these steps, manual intervention is necessary to identify components (ICs) which correspond to neurons.

Fig. 1 Example frame from an optical brain imaging movie

Goals
Aberration removal
Images are obtained through a Gradient Refractive Index (GRIN) lens, which can cause noticeable aberrations. There is an aesthetic motivation to produce clear brain activity images for academic publication and public outreach. Given the optics used, there is a limited set of well-characterized aberrations possible, each with a stereotypic effect on the morphology of the neurons in the images. We want to identify these aberrations and correct them.
Neuron region selection
Human interaction is required to remove independent components (ICs) that correspond to features other than neurons (e.g. blood vessels and dust). Automating this final step would greatly increase the throughput of the movie analysis pipeline.

Real time neural activity
All movie analysis is currently performed offline. Real-time readout of neural activity would be a prerequisite for biofeedback experiments in which an organism receives a stimulus based on current brain activity. We will present algorithms that enable reporting of neuronal activity in real time.

Implementation
Aberration removal will be performed on movies that have been illumination-normalized and motion corrected. Our algorithm will use various region characterization algorithms to identify the types of optical aberrations present in the movie. Given the aberrations present, the corresponding global filter will be applied to correct for the aberration.

The ICs which represent neurons are characterized by concentrated circular regions of bright pixels surrounded by darker pixels. We can identify ICs corresponding to blood vessels by the comparatively higher eccentricity of their bright regions. Similarly, we can identify ICs corresponding to dust specs by their lack of a single concentrated region of bright pixels.

The only obstacles to real-time extraction of neural signals are fast implementations of illumination normalization and motion correction. We can exploit simplified lowpass filtering and motion correction techniques and hardware acceleration to do this in real time.

References
