Machine Learning to predict Neuronal Firing in a Multi Neuron System
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Introduction
To understand the neural responses in V1 cortex and cluster them based on their specialization.

Societal Need
- 940 million people suffer from vision loss.
- 39 million people suffer from complete blindness.
- Economic loss of eye problems was $51.4 billion in 2004.

Underlying Neurophysiology
Vision is perceived in the visual cortex (V1). Simple lines and contours are processed in V1 and V2 where networks of neurons fire depending on shape and orientation. Calcium plays an important role across different cell sub compartments:
- Within the presynaptic terminals, calcium ion influx causes the exocytosis of neurotransmitters contained in the synaptic vesicles in the postsynaptic terminals.
- The transient rise in the calcium ions is essential for activity dependent synaptic plasticity.

Calcium Imaging
Calcium tracing is used to determine the amplitude and location of neuronal responses to a stimuli.

Figure: The mouse is placed in the customized apparatus and is shown certain images as stimuli. The mouse cells are mutated with GCAMP3 calcium indicator and calcium traces can be observed because of the fluorescence as seen in the image. A custom made 2 photon microscope is used to observe the readings.

Missing From State of the Art
Researchers have predicted the activity of networks of neurons using SVMs, generalized linear models, elastic net regression and neural networks.
Novel dataset of calcium traces of neurons in mice, sampled at 15 Hz. However, more data is sampled at 5 Hz. Our project is the first to study the effects on responses is possible.

The Dataset
1 mouse is exposed to 77 different types of stimuli each for 1 minute. Sampling occurs at 15 Hz. This is repeated over all 337 neurons being monitored and the experiment is repeated for 16 trials.

Analysis
First, we performed t-SNE on the response matrix to see if there was clustering within stimuli across trials and neurons.

We used a neural network with two hidden layers of response waveforms to a higher frequency.

Figure: t-SNE on the first 10 stimuli. We observe that there is good clustering, indicating that stimuli classification based on responses is possible.

We used a neural network with two hidden layers to predict the stimuli based on the response values for all neurons. Given a neural network $f_w$ parametrized with weights $w$, and $N$ training datapoints $(x_i, s_i)$, the is defined as follows:

$$L = -\frac{1}{N} \sum_{i=1}^{N} s_i \log(y_i)$$

Figure: Left: Neural network architecture. ReLU activations were used after the hidden layer and Softmax activation after the output layer. Dropout = 0.2, Adam optimizer, learning rate = 0.001. Right: cross entropy loss function to train the network.

Three new response matrices were then constructed based on the three different 5 Hz samples of the original calcium trace.

Results
We used the same neural network model and parameters to see how accurately we could predict the stimuli based on three different subsampled response values for every neuron in each trial.

<table>
<thead>
<tr>
<th>Data</th>
<th>Stimuli Classification Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Sample</td>
<td>39.8</td>
</tr>
<tr>
<td>Subsample 1</td>
<td>24.6</td>
</tr>
<tr>
<td>Subsample 2</td>
<td>23.7</td>
</tr>
<tr>
<td>Subsample 3</td>
<td>23.9</td>
</tr>
</tbody>
</table>

Table: Stimuli classification accuracy using the network and on the full dataset and its 3 subsamples.

Advance State of the Art
We were able to investigate the loss in information due to lower sampling rate. Our next task is to perform reconstruction from 5 Hz to 15 Hz, and is in progress. Eventually, we will be exploring a new 6-plane neuron activity dataset sampled in 5 Hz, so good reconstruction will be essential.

End User
- Patients with a degree of vision impairment.
- Researchers and doctors would be able to reconstruct an entire image based on the partial activation of specialized cells in the visual cortex for patients suffering from defects.

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