Proposal for Senior Project in Computer Science
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Introduction and Background
The mouse’s visual system has long been studied as a proxy or model for better understanding human vision. Traditional spatial frequency analyses of mice’s vision have concluded that mice have very low sensitivity to stimuli smaller than 0.5 cycles per degree (cpd) of visual field, but mice’s performance in vision-mediated activities, such as catching prey in a grass field, indicate that mice have higher resolution than previously thought. A new class of stimuli, moving patterns called “flows”, has recently been shown to elicit responses from mice, even at much higher spatial frequencies than previously recorded. Many neurons have also been shown to respond to several distinct stimulus classes. These cells’ responses are likely the result of a network made out of simpler responses to individual stimulus classes, which points to further investigation in the direction of network computations rather than individual features. Convolutional Neural Networks trained with a goal-driven approach have been shown to be a promising direction for simulating sensory processing in the brain.

Datasets
Steven Zucker’s lab, in collaboration with labs at UCSF and Duke, has collected and analyzed data on mice’s neuronal responses to various grating and flow patterns at various directions, orientations and contrast levels. These massive data tensors are being factorized in order to determine the circuitry and architecture of clusters and classes of neurons in retina, lateral geniculate nucleus (LGN), and visual cortex. I will be collecting corresponding data (i.e. responses to different images/patterns) from an artificial neural network.

Proposed approach
For this project I will:
- Learn in detail about the lab’s previous work and read up on all relevant literature
- Implement and train deep neural networks meant to simulate the retina, LGN, cortex of the mouse visual system
- Find a way of adapting current network models from the literature to generate outputs in the format of 2-dimensional PSTHs, (peristimulus time histograms – the lab’s approach for expressing cells’ responses to the stimulus ensemble)
• Conduct preliminary simulation experiments at a small scale to determine the best NN architecture to use

• Build a medium to large scale NN model representing the mouse visual system, train it on the grating and flow patterns described in the introduction, and compare the properties of trained artificial network with those of the network inferred from responses recorded from live animals

• Time permitting, determine whether the developed artificial NN is useful for machine learning classification purposes

Significance

By looking at the connections learned by the artificial neural nets we design, we can identify what kind of structures we get and see how they compare to the ones obtained by tensor factorization. This should in principle tell us whether the neural network scheme is sufficient to faithfully mimic how the cells organize in an actual brain, and/or whether the characteristics that were used to build these model networks are sufficient.

Deliverables

• Several small neural network models

• One medium to large scale model of mouse retina, LGN, and visual cortex

• The response data collected by subjecting the NN model to the same visual stimuli given to the mice

• A report detailing our methods and findings

References

