JOHNS HOPKINS
BIOMEDICAL ENGINEERING

Deep learning-based Neuron Detection in Brain CLARITY Imaging

Members: Prerna Singh

Mentor: Dr. Jeremias Sulam

Background: CLARITY imaging

Clear

Lipid-exchanged

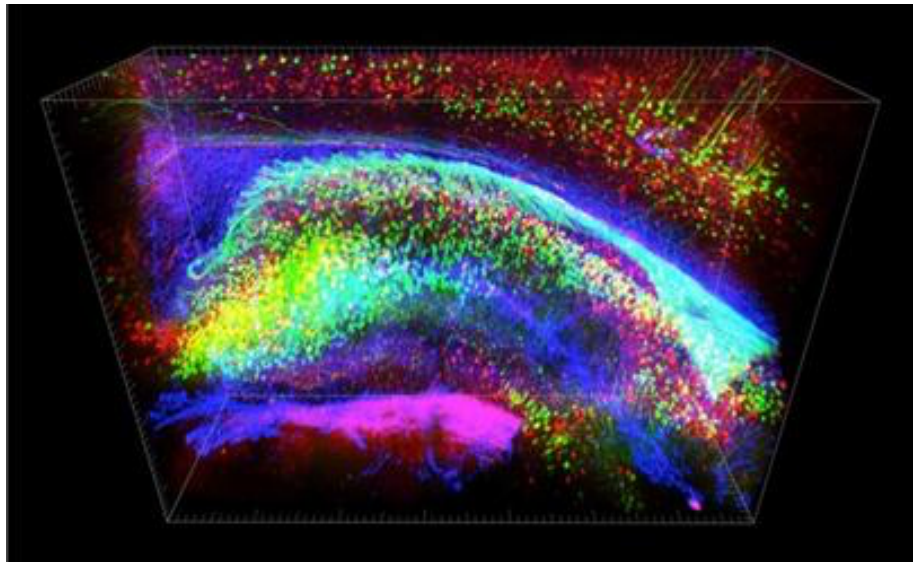
Acrylamide-hybridized

Rigid

In-situ hybridization-compatible

Tissue

h**Y**drogel



https://en.wikipedia.org/wiki/CLARITY

Significance of CLARITY for Brain Imaging

- Connectome project
  - Local circuit wiring
  - Relationships between neural cells★
- Understand neurotransmitter pathways
- Neurological diseases
  - 3D view of brain structures

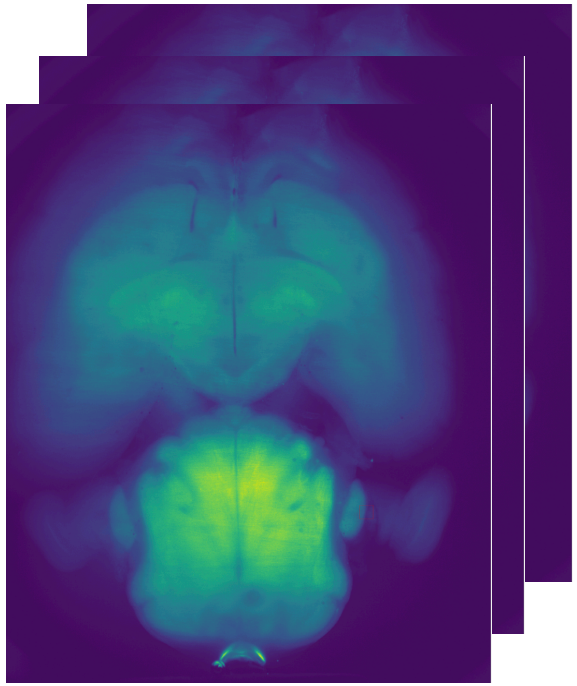
http://www.humanconnectomeproject.org/

Goal

- Develop a robust 3D CNN that can predict, with improved precision and accuracy when compared to other models, how many fluorescent neurons are present within a section of a brain imaged with CLARITY

  - Previous models: template matching, blob detection
  - Maximum accuracy achieved was ~ 59% with these techniques

Technical Approach – CNN Training



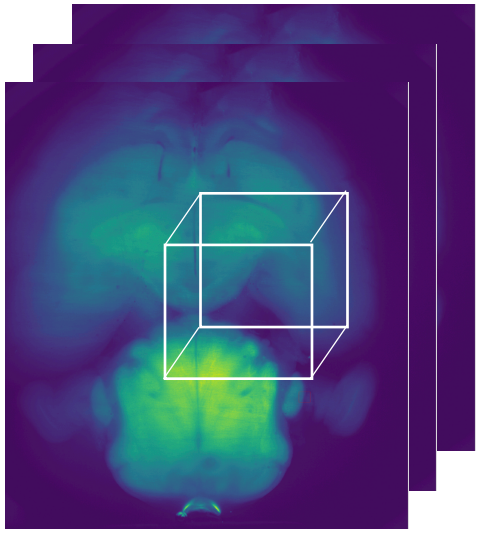
Nine 3-D CLARITY Brains Imaging Data annotated for Neurons

Neuron 12X12X12 voxels and non-neuron 12x12x12 voxels from these images are used for training

3D Convolutional Neural Network

Potentially: Data augmentation step for more training data depending on CNN performance

Technical Approach- CNN Architecture



Input: any 3 dimensional subset of a CLARITY Brain scan

Trained 3D Convolutional Neural Network

Layer 1: 3D Convolutional
Layer 2: Maxpool
Layer 3: 3D Convolutional
Layer 4: 3D Convolutional
Layer 5: Fully Connected
Layer 6: Fully Connected

Output: weighted score of 0-1 of neuron probability for each 12x12x12 voxel in input

https://www.istockphoto.com/vector/abstract-3d-cube-from-cubes-vector-outline-illustration-em1034794628-277033503

Technical Approach- Validation

- Data includes 9 whole brains
- Coarse validation: report metrics (e.g. AUC) over a few random splits of data (6 train, 3 test)
- Full Leave-one-out (LOO) Cross validation: report cross-validated metrics (e.g. AUC) averaged over 9 folds. In each fold, all but 1 brain will be used for training, and the remaining one for testing

Dependencies

Dependency	Solution	Date Expected	Date Required	Alternative	
Computing power	MARCC Access granted through Dr. Sulam	2/10	2/25	Very slow training	
Computer	Personal laptop	2/10	2/10	Desktop computer provided in Sulam Lab	
Backups	Private github code storage,	2/10	2/25	code & data also stored on MARCC	
pytorch	Install pytorch for use on MARCC	2/10	2/25	Tensorflow	
Data- Images	Downloaded off of BOSS Neurodata	2/10	2/16	--	
Data-Annotations	Provided by Dr. Sulam	2/10	2/16	--	

ALL RESOLVED

Deliverables

Minimum:

- Trained 3D CNN model (pytorch) for neuron detection
- Report in Jupiter notebook – explains training of CNN and predictions

Expected:

- Robust and validated trained model (pytorch) for neuron detection
- Packaged model with documentation –made available on the internet with equal or better performance than competing simpler alternatives

Maximum:

- Academic paper describing packaged model, training, validation
- Surpass baseline accuracy of previous models by a significant margin

Schedule

	2/9	2/16	2/23	3/1	3/8	3/15	3/22	3/29	4/5	4/12	4/19	4/26	5/3	5/10
CNN training data acquisition and preparation														
CNN-training & prelim validation														
Data Augmentation* and Re-training														
Validation														
Packaging														
Paper														

* If necessary & will need to retrain model

Milestones

Date	Milestone
3/1	CNN input script completed
3/8	Determine whether data augmentation necessary based on preliminary accuracy analysis
4/5	Model completed
4/18	Model validated
5/10	Software package completed

Management

- Meetings with Dr. Sulam every two weeks and additionally as necessary
- Code stored on github and MARCC
- Code backed up to github every week and more often with substantial improvements
- Communication through Slack/email

Reading List

Wiring and Molecular Features of Prefrontal Ensembles Representing Distinct Experiences, Ye et al., 2016, Cell 165

Building a See-through Brain- A New Experimental Approach at the Interface of Chemistry and Biology, Karl Deisseroth, 2016 Scientific American

Automatic Detection of Cerebral Microbleeds from MR Images via 3D Convolutional Neural Networks, Dou et al., IEEE Transactions on Medical Imaging

A Manual Segmentation Tool for 3 Dimensional Neuron Datasets, C. Magliaro et al., frontiers in Neuroinformatics