Decoding Drosophila's Visual Neuron Function Using Connectomics

Melvin Osei Opoku[1] Arie Matsliah[2], Bella Brezovec[2], Mala Murthy[2]

1. Department of Biomedical Engineering, University of Florida

2. Princeton Neuroscience Institute, Princeton University

Background

FlyWire, the first neuronal wiring diagram of a whole adult brain[1], has enabled us to measure the connectivity of every neuron in the drosophila (fruit fly) brain. In this study, we demonstrate that by conducting computational analyses of FlyWire Connectome data and integrating it with existing experimental functional data, we can investigate the anatomical structure-function relationships of Lobula Columnar (LC)11 neurons involved in small object detection.

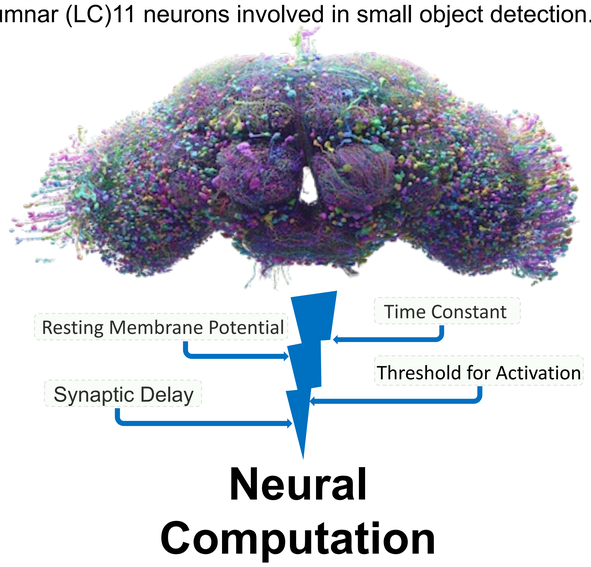
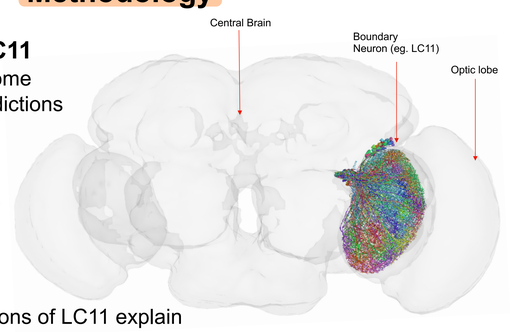


Figure 1: Visualization of the complete connectome of the Drosophila brain, showcasing intricate neural pathways and structures visualized using Codex, a tool for the FlyWire Connectome project. This image highlights the unknown parameters unique for each neuron.

Methodology

Functional Data on LC11

- Predates Full Connectome
- Structure-Function predictions



Objectives

- Does the upstream neurons of LC11 explain its activation and tuning?
- Does the downstream neurons of LC11 explain behavioral activity linked to it?

Why LC11?

- Links reported between LC11 activity and behavior are not clear
- The relationship among anatomical, molecular, and functional properties of object detection circuitry is not understood

Figure 2: Animation of 61 LC11 neurons in the right optic lobe of a female Drosophila brain, visualized using Codex, a tool for the FlyWire Connectome project.

Anatomical Receptive Field

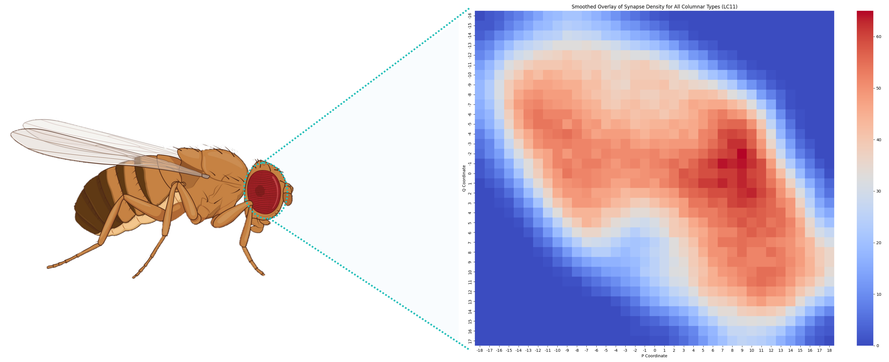
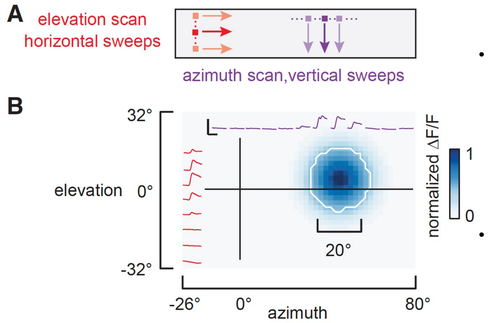


Figure 3: Left: BioRender schematic diagram of the lateral view of a Drosophila. **Right:** Mapping of all LC11 columnar inputs. Gaussian filter was applied to resulting image to generate this smooth-out figure.

Functional Receptive Field



- Average functional receptive field size was 24.1° by 18.8°

$$20\ columns \times 61\ cells = 1220\ columns$$

$$\frac{1220\ columns}{796\ ommatidium} = \mathbf{1.5}\frac{LC11}{functional\ column}$$

- Anatomical dendritic field size (70°-75° by 30°-40°)

$$\mathbf{6.5}\frac{LC11}{anatimical\ column}$$

Figure 4: A. Schematic of the experimental stimuli used to map individual LC11 receptive fields from individual cell body recordings. B. Reconstructed receptive field of a single LC11[2]

Mapping Anatomical, Functional, and Optimal Receptive Field

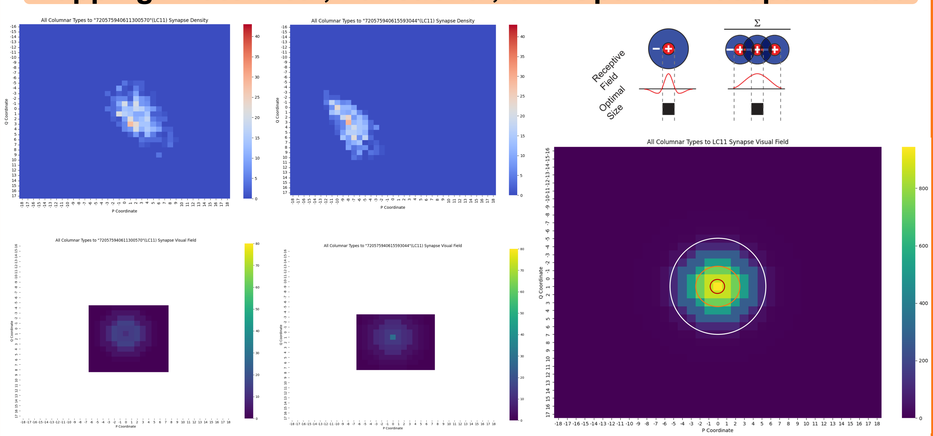


Figure 5: Top Left: Anatomical receptive field for two LC11 neurons. **Bottom Left:** An onion-ring smoothing filter was applied, which finds the center of mass, averages the values of neighboring ring columns a certain radial unit away from the center, and reassign that value to each column. **Top Right**: Schematic representation of center-surround antagonism predicted structure of LC11 neurons[3]. **Bottom Right:** Smoothed-out visual field mappings of each LC11 neuron were overlaid onto each other as they lost their spatial resolution. We predict that the red circle indicates the optimum object size (8.8-degree square object, approximately 1.7 columns), the orange circle represents the functional receptive field (24.1 by 18 degrees, approximately 20 columns), and the white circle represents the anatomical visual field (70-75 by 30-40 degrees, approximately 84-120 columns)

End-Stopped Inhibition

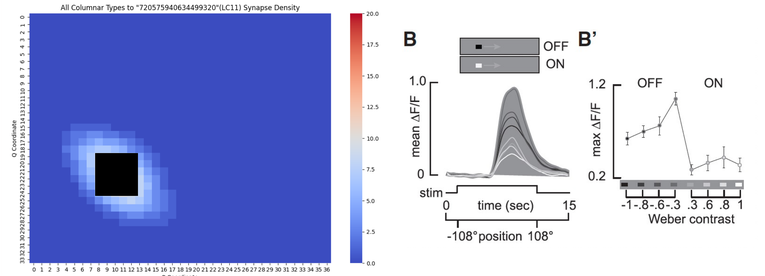


Figure 6: Right: A 30º square object overlapping the receptive field of an LC11 neuron. **B.** Neural activity of an LC11 during experiment where contrast of black object reduced from 100% to 30%. **B':** Average of maximum responses of the LC11 glomerulus to objects of varying contrast[2]

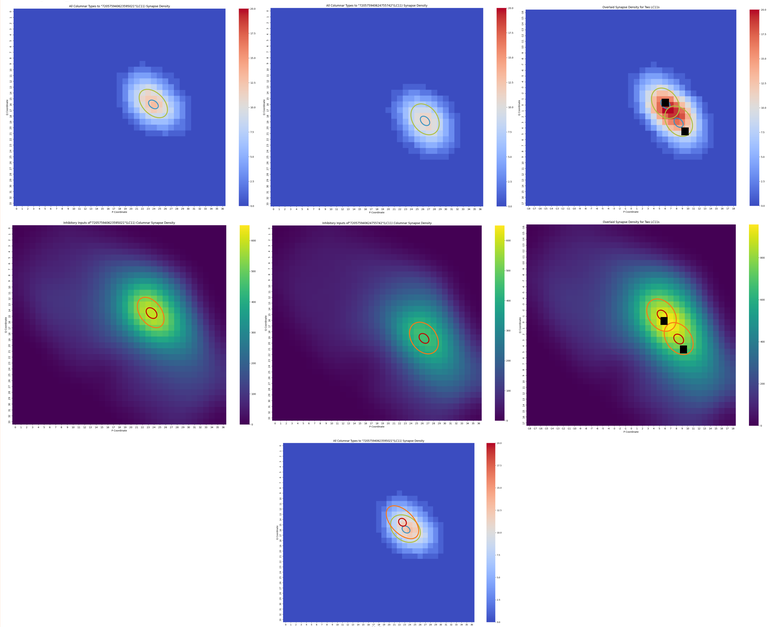


Figure 7: Top: Anatomical receptive field of two different LC11 neurons with the last image being the overlay of the two. Black dots represents an 8.8-degree square. **Middle**. All inhibitory inputs to the LC11 neurons above spatially organized. **Bottom**: Overlay of excitatory and inhibitory input

Future Directions

- Analyze downstream effect of LC11 on short-term freezing behavior of flies
- Investigate ring and center heavy patterns of LC11 receptive field
- Analyze LC10a and other neurons linked to small object detection in drosophila

References and Acknowledgments

1. Dorkenwald, S., et al (2023). Neuronal wiring diagram of an adult brain. bioRxiv. doi:10.1101/2023.06.27.546656. Accepted, Nature.
2. Janne K. Lappalainen, Fabian D. Tschopp, Sridhama Prakhya, Mason McGill, AljoschaNern, Kazunori Shinomiya, Shin-ya Takemura, Eyal Gruntman, Jakob H. Macke, Srinivas C. Turaga bioRxiv 2023.03.11.532232;
3. Tanaka R, Clark DA. Object-Displacement-Sensitive Visual Neurons Drive Freezing in Drosophila. Curr Biol. 2020 Jul 6;30(13):2532-2550.e8.

The Murthy Lab is supported in part by Princeton University. I appreciate the support of Dr. Arie Matsliah, Dr. Bella Brezovec and Prof. Mala Murthy for their mentorship