FlyBrainLab: a Complete Programming Environment for Discovering the Functional Logic of the Fruit Fly Brain

https://flybrainlab.fruitflybrain.org

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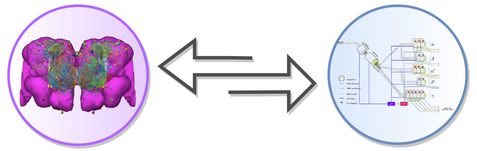
Introduction

- The era of connectomics/synaptomics ushered in the advent of large-scale availability of highly complex brain data.
- Currently, software used by neuroscientists is either for visualizing anatomical data, or for simulating brain circuits, but to construct executable circuits from brain data takes extra effort to move data between incompatible software.
- FlyBrainLab provides a complete programming environment supporting visualization of brain circuits chosen at will (left) and creation of circuit diagrams that can be immediately compiled for program execution (right), thus facilitating the construction, comparison and validation of the plethora of emerging executable brain circuit models of the fruit fly nervous system.

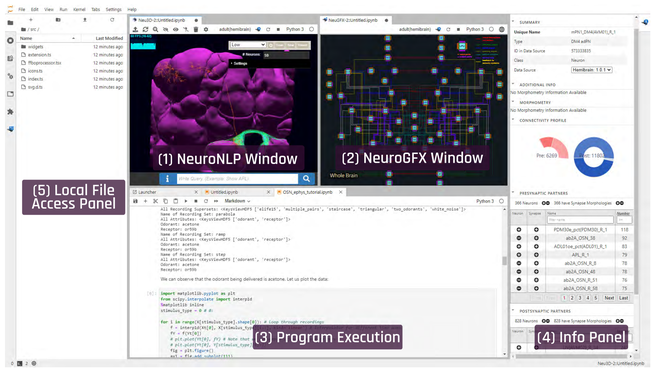


3D Exploration and Visualization of Fruit Fly Brain Data

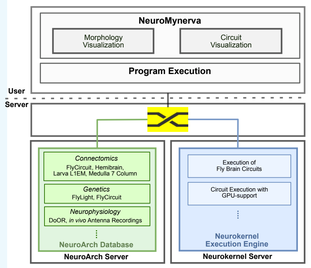
Interactive Exploration of the Functional Logic of Executable Circuits

Software Architecture and User Interface of FlyBrainLab

NeuroMynerva User Interface



Main Components of the Software Architecture



In addition to the NeuroMynerva front-end, the main FlyBrainLab back-end components include:

- the **NeuroArch Database** that integrates and stores anatomical, genetic, neurophysiology datasets, and the associated circuit models.
- the **Neurokernel Execution Engine** that supports the execution of fruit fly brain circuits on GPUs.

FlyBrainLab tightly integrates 3D exploration and visualization of fruit fly brain data, and creation of executable circuit diagrams followed by an interactive exploration of the functional logic of executable circuits.

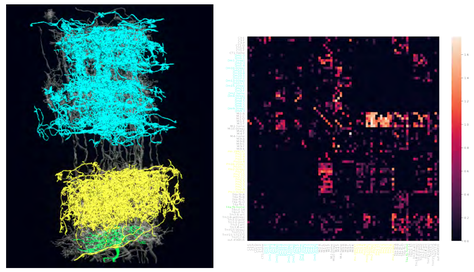
Creating Executable Circuit Models from Fly Brain Data

Building Fly Brain Circuits with English Queries

The NeuroNLP natural language query interface is designed to accommodate users with widely different expertise. A layperson can perform sophisticated database queries with only knowledge of fly brain neuroanatomy. For example, to query the neuron circuit involved in visual motion detection:

```
1) "show T4a in column home"
2) "color lime"
3) "add presynaptic neurons"
4) "color grey"
5)    "add presynaptic $Dm$ neurons with
more than 5 synapses"
6) "color cyan"
7)    "add presynaptic $Pm$ neurons with
more than 5 synapses"
8) "color yellow"
```

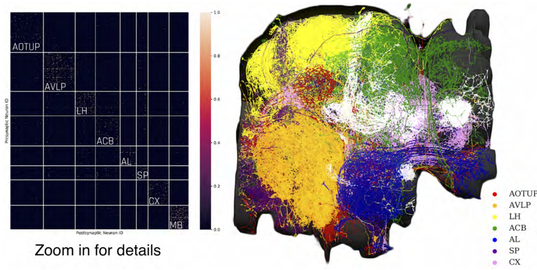
The resulting circuit is visualized (left), and the connectivity matrix of the queried circuit can be easily retrieved (right).



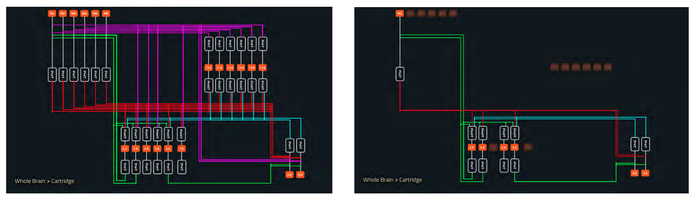
Exploring the Structure of Fly Brain Circuits

FlyBrainLab provides a set of utilities for exploring the structure of fly brain circuits.

To explore the structure of densely-connected brain circuit at the whole-brain level, we invoke an algorithm provided in the utilities library to extract 8 densely connected neuron groups (left), and pseudo-color the neurons of each group (right).



Interactive Exploration of Executable Circuit Models

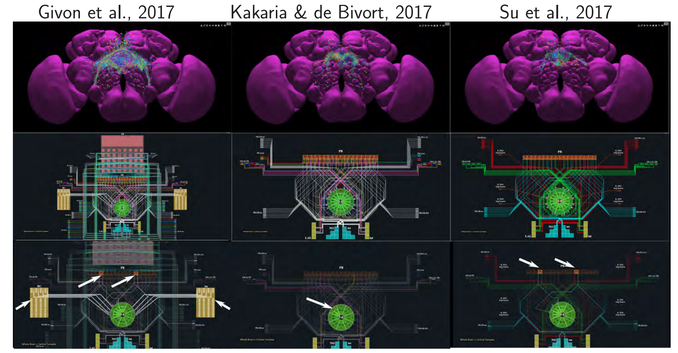


Interactive circuit diagrams in the NeuroGFX window supports 1) arbitrary reconfiguration, for example, by "silencing" some of the neurons of the "wild type" circuit (left), and 2) by executing the resulting circuit (right) on the Neurokernel Execution Engine.

To accelerate the discovery of the functional logic of fruit fly brain circuits, FlyBrainLab offers a workflow and tools for every step involved in automating the construction of executable circuits from fruit fly brain data.

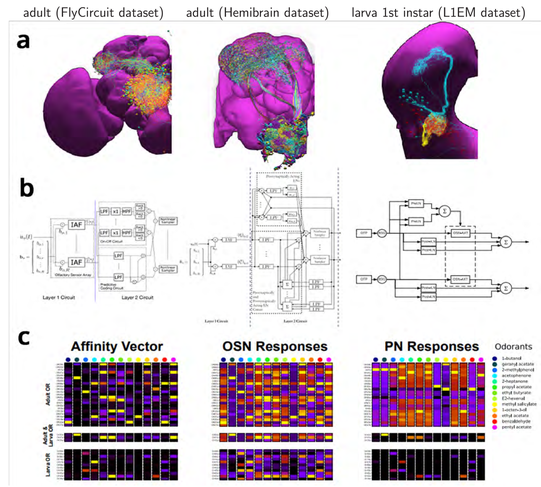
Comparison of Models Developed by Different Researchers

Three models of the central complex from the literature are compared. The graphical comparison in the FlyBrainLab highlights the differences in 1) the components each model derives from the data (first and second row), 2) the assumptions made, *e.g.*, how visual inputs are mapped into the circuit (third row), and 3) the responses of the circuit models when presented with the same visual input (not shown).



Comparison across Datasets and Developmental Stages

FlyBrainLab supports the comparison of models developed on different/new datasets and on datasets obtained at different developmental stages of the fruit fly. The discussion below focusses on the computational principles underlying the circuit model.



Here we provide an I/O characterization of neural circuits in the early olfactory system. We applied a model developed on the FlyCircuit dataset of the adult fly (with inferred synaptic connections), and compared it with the model evaluated on the Hemibrain dataset of the adult and L1EM dataset of the 1st instar larva (both with exact synaptic connectivity information). (a) visualization of neural circuits in the early olfactory system, (b) circuit diagrams depicting the early olfactory system circuit motifs, (c) steady-state circuit responses.

FlyBrainLab simplifies the process of model comparison, a critical but often neglected step in the neuroscience literature when creating new models of brain circuits and evaluating their functional logic.

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