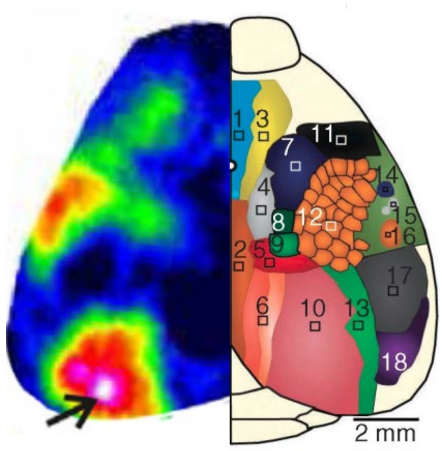
Bridging Function and Anatomy in Wide-field Calcium Imaging Data - Masters Project

Multiple experiments carried out in the Neuronal Circuit Dynamics Lab acquire in vivo full brain wide-field optical recordings of mouse cortex activity during behaviour. The measurements are mesoscopic, i.e. cover many cortex regions but without cellular resolution. Each recorded pixel carries signal averaged over multiple neurons. Such recordings can uncover context- and task-specific activation patterns in mouse brains. However, the spatiotemporal characteristics of wide-field signals are not fully understood. We seek a talented and motivated student to help analyze existing data sets and study the following questions: (1) She or he will use unsupervised machine learning tools to identify effective functional areas, as well as construct mappings between functional and anatomical areas. (2) The student will use information-theoretic metrics to study the information content in wide-field recordings, as well as identify the information overlap between pixels, functional and anatomical areas. (3) It has been hypothesized that wide-field signals in the cortex may loosely follow local propagation laws similar to those of water waves. The student will propose a few model propagation laws, fit them to the data, and then assess and report on the plausibility of this hypothesis.

Requirements: Experience in programming (Python/Matlab), statistics and/or machine learning.
Research Group: Laboratory of Neural Circuit Dynamics (Prof. Fritjof Helmchen) at the Brain Research Institute, University of Zurich (Irchel Campus, building 55).
Contact: Philipp Bethge (bethge@hifo.uzh.ch)



Exploration of Hypothetical Astrocyte Functions – Semester Project

Alongside neurons, mammalian brains also contain glial cells in comparable quantities. Glial cells in the past have been mostly neglected by computational neuroscience, but recently a specific type of glial cells called astrocyte has gained increasing attention regarding cognitive functions. Classically, astrocytes have mainly been attributed auxiliary functions in the brain, such as mechanical support, homeostasis, and management of the blood-brain barrier. As recent literature suggests that astrocytes may take an active part in neuronal computation, experimental efforts are underway exploring the exact nature of neuronal-astrocytic interactions, for example underlying memory. In this project we explore the potential effect of neuronal-astrocytic coupling computationally. The student will construct a simple top-down hypothetical neuronal-astrocytic model, and investigate the effect of different neuronal-astrocytic coupling functions on the dynamics and memory-capacity of the model. The student will also design a metric to categorize the effective observed dynamics and thus report the set of astrocytic models, for which the dynamics is distinguishable from purely neuronal models.

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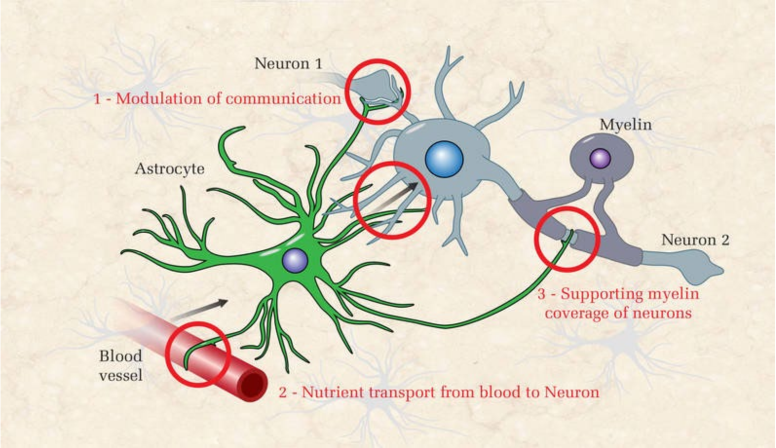

Model-Based Estimators of Functional Connectivity for Calcium Imaging Data – Masters Project

Multiple measurement techniques, such as multi-fiber photometry and wide-field calcium imaging are used in our lab to acquire in vivo brainwide mesoscopic optical recordings in mice. This data can help to identify functional connections between different brain areas, and the relationship of individual brain area activity and behavioural variables such as paw or whisker movement. We are currently carrying out a study to compare the performance of most prominent model-based and model-free functional connectivity estimators using simulated and real data, with emphasis on calcium indicator-based optical imaging data. The student will help adapt a few model-based functional connectivity estimators to the calcium indicator forward model, test them against existing simulated benchmarks, as well as compare their performance to model-free estimators, which we have already implemented. Finally, the student will proceed to design fitness criteria for the above model-based estimators to evaluate and compare the feasibility of using the models to describe mesoscopic calcium imaging data.

Requirements: Experience in programming (Python/Matlab), statistics and/or machine learning.
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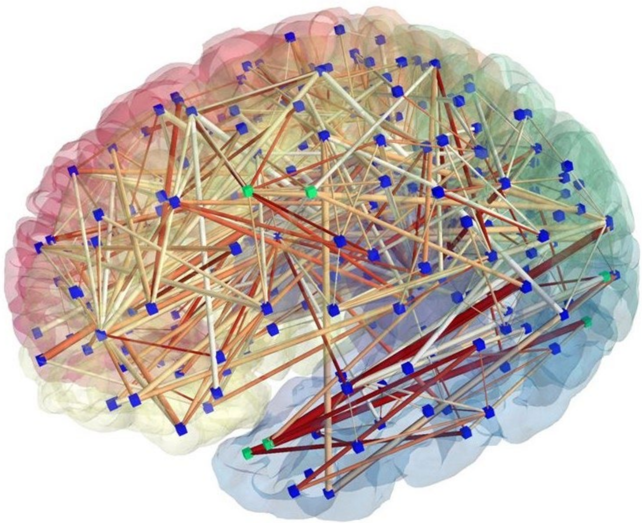

Deep Learning for Time-Dependent Behavioural Data – Semester Project

With recent advances in deep learning it is now possible to significantly automatize tracking of animal behaviour. For example, DeepLabCut (DLC) has been successfully used by many labs to automatically identify selected points in videos of behaving animal with a training set of just a few hundred human-labeled frames. The main assumption of DLC is that the features of interest can be identified from individual frames, so the algorithm considers only one frame at a time. However, there exist other tracking-related questions, such as event detection, for which the above assumption is insufficient for good performance. Several of our experiments require precise detection of the first moment in time the whiskers of a mouse touch a certain object. This task is challenging to solve on a frame-by-frame basis, since occasional false positives of touch estimation can have devastating effects on the estimate of the first touch moment. Further, our human labelers report using information from previous frames, such as velocity of the whisker or rate of change of its angle to estimate if a touch has occurred.

The student will design a deep learning pipeline which will consider multiple frames simultaneously to decide on the timing of the first touch event. The student will then apply the method to our labeled and unlabeled data, validating and optimizing the pipeline. The exact implementation details of the pipeline will be the creative work of the student.

Requirements: Experience python and Deep Learning

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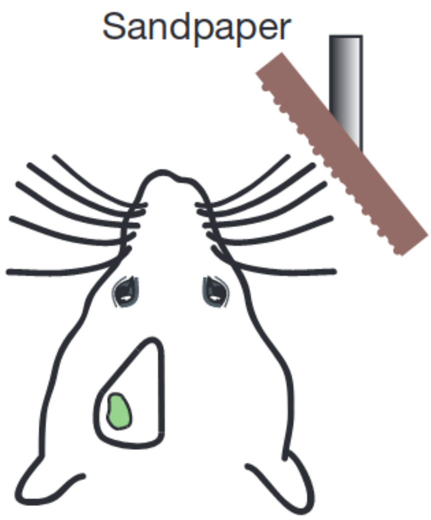

Data Compression – Paid Internship

The Neuronal Circuit Dynamics Lab is currently exploring and applying compression algorithms to reduce data amounts from video recordings and imaging measurements, which would significantly reduce the size of existing data sets and future storage requirements. For this purpose, many terabytes of new and old data (mostly videos) need to be zipped, unzipped, moved and compressed. The student will be instructed how to run some automated scripts designed in the lab to accelerate this process. The student will work closely with several members of the lab to record the current state of their data and their needs, and then proceed to implement the compression scheme.

Requirements: Responsibility and attention to detail. Knowledge of bash script and python is welcome but not necessary.

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