CLOC mentored project descriptions summer 2024

Topic description

Neuroscientists can gain insight into how the brain works by manipulating it in precise ways. Optogenetics is a very popular, relatively new technology allowing the activation of neurons which can be genetically targeted. Typically, researchers have done this with "open-loop" control, delivering a pre-defined stimulus to the brain, but more sophisticated and precise is "closed-loop" control, which rather varies the stimulus in real time to achieve a desired neural activity pattern—much like cruise control accelerates the car as needed to reach a target speed.

Our lab has already applied basic methods from control theory to do real-time optogenetic control in mice, but there are plenty of potential extensions to this work. PhD student Kyle Johnsen is recruiting students for multiple projects that require varying skill levels in neuroscience, programming, control theory, and biomedical engineering. Below is a list of possibilities—if you are interested, reach out to Kyle (kjohnsen@gatech.edu) to discuss possibilities in more detail. A minimum 10 hrs/week commitment is expected. And at least for larger projects, candidates who can commit to more than 1 semester will be preferred.

Potential projects

- Implementing factor-based SNNs in Brian/Cleo
  - Recovering latent neural dynamics from simulated data by running (RNN-)PSID / IPSID
- Estimating oscillatory information in real time, for the purpose of closed-loop control, as in this paper.
- Extend the light propagation capabilities of the Cleo simulator. We especially would like to interpolate Monte Carlo simulation results for different beam types.
- Pioneer system identification methods in the spirit of PSID to identify natural vs. unnatural states to achieve "within-manifold control"
- Paving the way to implement performant code *once* and use in multiple contexts (e.g., Python, C# (Bonsai), MATLAB, C++)
  - Julia
  - C++ and SWIG
- Simulating the "crosstalk" of excitation light on opsins when doing fluorescent microscopy and optogenetics simultaneously (See Sridharan 2022 Fig 6)
- Integrating model-predictive control into `ldsCtrlEst` (following `lqmpc` as an example)

- Implementing a model of the CA3 region of the hippocampus (Kopsick et al.) in Brian and simulating closed-loop optogenetic experiments on it using Cleo.
- Adding calcium indicator or voltage indicator models to Cleo

Potential skills required or to be learned

- General neuroscience, e.g., neurons, hippocampus, cell types, synapses
- Ability to extract relevant details from scientific publications
- Computational neuroscience: spiking neural network models
- Scientific Python coding, including source control (Git/GitHub), math (NumPy), and figure generation (matplotlib)
- High-performance software engineering
- Specific familiarity with Brian and Cleo Python packages
- Control theory: linear dynamical systems, model fitting, optimal control, etc.
- Ability to work efficiently as a team: communicating, dividing tasks, and taking responsibility
- Ability to explain research and present progress effectively to other students and supervisors