Durham University
Department of Psychology

Dr. Marco Bocchio
Dr Jasmin Strickland
Dr Ulrik Beierholm

NeuroAI: linking neural circuits and artificial intelligence

Background

Understanding how the brain learns and processes information remains one of the central challenges in neuroscience. Biological neural circuits can rapidly adapt to new environments, integrate diverse sources of information, and generate flexible behaviour. By contrast, artificial intelligence (AI) systems often require very large datasets and can struggle to generalise knowledge or adapt to changing conditions. Identifying the principles that allow biological neural networks to learn efficiently may therefore provide insights that can inform the design of more flexible AI.

The emerging field of **NeuroAI** seeks to bridge neuroscience and artificial intelligence by using biological neural circuits to inspire the design of artificial learning systems, while computational models help generate mechanistic hypotheses about how the brain processes information.

Aims and Methods

This project will **investigate how neural circuits represent and transform information, and how these biological principles can inform the development of AI**.

A central component of the project involves **studying neuronal activity using electrophysiological recordings**. Students may record in vivo neuronal activity in mice using **high-density electrophysiology (Neuropixels probes)**, which capture the activity of hundreds of neurons simultaneously in behaving animals. Alternatively, students could use **patch-clamp electrophysiology in brain slices, potentially combined with optogenetics**, to study synaptic organisation, excitability, and plasticity of individual neurons.

A second component involves **analysing these recordings and building computational models of neuronal activity**. Such models can be used to infer the mechanisms that govern interactions within neural circuits.

Finally, insights from these analyses can be used to **develop AI inspired by the organisation and dynamics of biological circuits**.

The project is flexible and can be adapted to the student's background and interests. Students with a computational background may focus primarily on analysing neural datasets and developing computational models or AI architectures. Students with a background in biology or psychology may be more involved in experimental work and data collection. Students interested in interdisciplinary approaches are also encouraged to combine experimental and computational components within the same project.

Relevance

This project lies at the intersection of neuroscience and AI. It aims to uncover principles that govern both biological and artificial learning.

Training

The candidate will receive interdisciplinary training spanning neuroscience and computational approaches. Depending on the focus of the project, this may include experimental techniques such as electrophysiology and optogenetics, analysis of large neural datasets, and computational modelling approaches used in neuroscience and machine learning.

Suitable for

PhD and MSc by Research (MRes) students.

References and Further Reading

Hassabis, D., Kumaran, D., Summerfield, C., & Botvinick, M. (2017). Neuroscience-inspired artificial intelligence. Neuron, 95, 245–258.

Richards, B. A., et al. (2019). A deep learning framework for neuroscience. Nature Neuroscience, 22, 1761–1770.

Li, Q., Sorscher, B., & Sompolinsky, H. (2024). Representations and generalization in artificial and brain neural networks. Proceedings of the National Academy of Sciences, 121, e2311805121.