ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Bachelor/Master Thesis

Understanding the Spatial Code in Mammalian Brain

Due to the complex circuitry and abstract functionality, understanding the computation in high-level association cortices (rather than in primary sensory cortices) in mammalian brain remains to be a challenge nowadays. Nevertheless, in the medial entorhinal cortex (mEC), neuroscientists managed to identify a few cell types that are specialised for navigation in the environment, i.e grid cells, border cells and speed cells. Most interestingly, a grid cell fires at multiple locations that form a strikingly regular triangular grid [1], which seems to suggest that the brain is using Synergetics coordinates (60 degree coordinate system) [2] rather than Cartesian coordinates during navigating. In 2014, May-Britt Moser and Edvard I. Moser were awarded the Nobel Prize in Physiology or Medicine for their discovery of grid cells [3]:

"The discovery of the brain's positioning system represents a paradigm shift in our understanding of how ensembles of specialized cells work together to execute higher cognitive functions. It has opened new avenues for understanding other cognitive processes, such as memory, thinking and planning."

The goal of this project is to build computational models that explain the acquisition of spatial triangular representations. There are two methodologies: we can either make assumptions about the connectivity pattern of grid cells based on anatomy and theory, and then wire them accordingly, cf [4] for an example on head-direction cells; or we can set up a fully connected neural network, and train it with a proper objective like path integration, cf [5]. Depending on the progress, we could further investigate into how changes of parameters in the model could affect the triangular gird (in terms of spacing, orientation and etc.), or how these spatial patterns adapt in different environments (square, circle or any arbitrary shape). Ideally, a computational model that is capable of reproducing the most significant features in mEC could contribute to our understanding of the inner working principles in association cortices.

Prerequisites: Interest in computational neuroscience and good programming skills.

Contact Information: Xun Zou, CAB J 21.3, `xun.zou@inf.ethz.ch`

[1] D.C. Rowland, Y. Roudi, M.B. Moser and E.I. Moser, *Ten years of grid cells*, Annual Review of Neuroscience, 2016
[2] `http://mathworld.wolfram.com/SynergeticsCoordinates.html`
[3] `https://www.nobelprize.org/prizes/medicine/2014/press-release/`
[4] H.J. Page, D. Walters and S.M. Stringer, *A speed-accurate self-sustaining head direction cell path integration model without recurrent excitation*, Network: Computation in Neural Systems, 2018
[5] C.J. Cueva and X.X. Wei, *Emergence of grid-like representations by training recurrent neural networks to perform spatial localization*, arXiv, 2018