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Gatsby Computational neuroscience unit

Statement of purpose

Neuroplasticity is key to understand how neurons synapse with each other to solve complex tasks. We are rich in knowledge about how neuroplasticity works at the cellular level, but how these rules allow neural circuitry to solve complex problems is still poorly understood. One example is Spike-Time Dependent Plasticity (STDP), where long-term potentiation (LTP) occurs if postsynaptic calcium levels are above a certain threshold, whereas long-term depression (LTD) occurs if calcium levels are above baseline but below this threshold (Shouval, Bear & Cooper, 2002). An interesting property of STDP is that the induction of plasticity by multi-spike protocols is not linear. The first presynaptic spikes cause more weight changes than later presynaptic spikes, which is due to the non-linear dynamics of the underlying calcium transients (Cai et al., 2007). These findings are consistent with the idea that synaptic plasticity can be interpreted as Bayesian inference and that mean synaptic changes are proportional to the uncertainty of the weights (Aitchison et al., 2021). It would therefore be interesting to build simulation models to test whether the Bayesian inference models from Aitchison et al. (2021) could be derived from known neurobiology, such as the calcium-dependent models proposed by Shouval et al. (2002). Solving theoretical questions such as this one is how we can push our understanding of neuroscience to the next level, which is what I want to do for my PhD.

I would be a great candidate to carry out a theoretical neuroscience project at the Gatsby computational neuroscience unit. I have a lot of experience in applying computational approaches to solve neuroscience problems. This expertise can be seen in two of my recent projects, my Master's thesis and my recent publication in the journal of computational biology. My master's thesis "Transient inhibition to light explains stronger V1 responses to dark stimuli" uses machine learning to do system identification of neurons in the primary visual cortex. During this research project, I've greatly improved my machine learning skills and learned how to use Tensorflow to build my own custom, biologically-inspired convolutional neural network. I've also developed a solid expertise in both visual neuroscience and electrophysiology, on top of learning how to review and understand the literature to relate my results to it. On the other hand, my recent publication "Visual perception of texture regularity: conjoint measurements and a wavelet response-distribution model" is a good demonstration of how I can apply my statistical expertise to experimental problems. This project uses Maximum-Likelihood Conjoint Measurement (MLCM), a statistical method for analyzing psychophysical data with a specific type of experimental design. While MLCM was originally designed to study one-way and two-way interactions, our study was the first to simultaneously estimate the effect of three different variables. As the group's statistical expert, I designed a new statistical framework to extend MLCM to test for three-way interactions. This work was published in the Journal of Cognitive Neuroscience, and received compliments from Kennett Knoblauch, who invented

MLCM. As my record shows, I have a solid background in computational neuroscience which is going to be a strong foundation for pursuing a PhD.

The Gatsby computational neuroscience unit would be the perfect place for me to pursue my PhD, as it is a world-renowned institute for theoretical neuroscience and machine learning. This would be a golden opportunity for me to improve my mathematical skills as well as learn rigorous theoretical machine learning. I could learn a lot from professors such as Dr.Peter Latham, who does amazing work at modeling neural computations and noise from a Bayesian perspective. The researchers at the Gatsby unit are experts at applying machine learning to theoretical neuroscience problems and I would love to learn from them. I am certain doing so would be both fascinating and propel my research career to the next level.