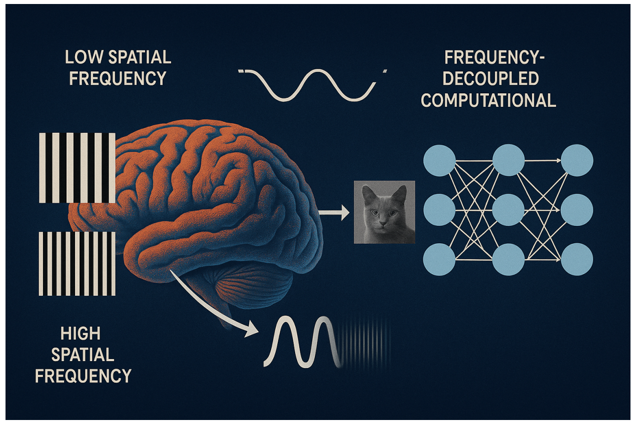
Brain's Spatial Frequency Processing and Frequency-decoupled Computational Model Development

A Project fully funded by BAP SUP, 2025-2027

Project No: 20411



Fully funded M.S. positions are available!

Project Description:

Understanding how the brain processes spatial frequencies can provide valuable insights for designing more robust computational models. To investigate this in this project, we primarily design/conduct a series of EEG experiments, we revisit the neural correlates of low and high spatial frequency processing. We aim to verify that low spatial frequencies are prioritized early (or late) in perception, while high spatial frequencies are processed later (or earlier) and provide guidance for low(high)-spatial frequency processing and final perception. This aligns with the known functional distinctions between the distinct structures (magnocellular and parvocellular pathways) in the brain. Inspired by this neurophysiological evidence, we aim to explore how these distinct processing streams could inform the design of existing layered deep learning paradigms.

To enhance computational generalization, we first introduce architectural modifications to a ResNet model, creating specialized pathways for processing different spatial frequencies. This biologically inspired approach we believe might lead to a distinct preference for high spatial frequencies and low spatial frequency processing at different stages of feedforward direction. This might be used to inform or verify some of the electrophysiological findings. The final objective of the project would be to demonstrate that networks incorporating this spatial frequency decoupling has the potential to exhibit increased resilience against adversarial perturbations such as noise, frequency filtering, and color fading. Furthermore, we aim to provide mathematical analysis to support the bold claim that cortical circuitry may be encoding innate mechanisms to guide robust perception, potentially reducing the need for extensive training data. These findings, subject to validation, can potentially open new directions for neural architecture design, leveraging principles from biological vision to improve model robustness and few-shot learning techniques.

Keywords: Deep Learning, Human Vision, EEG, Computational Neuroscience, Spatial Frequency Processing.

Project Management:

1. Prof. Suayb S. Arslan (PI), Dept. of Comp. Engineering at Bogazici University and Research Affiliate, Brain and Cog. Sciences at MIT.

Applications and Compensations: Funding is available for M.S. and Ph.D. degrees.

1. Master of Science (M.S), 40000TL + benefits
2. Philosophy of Doctorate (Ph.D), 50000TL + benefits

Bonus: Opportunity to collaborate with a research group at Korea University and Sinha Lab at MIT, with the possibility of a summer visit to these labs, contingent on the availability of external funding (e.g., TUBITAK, MIT MISTI, etc.). Guidance and help will be provided.

All applicants are encouraged to contact the PI of the project should there be any interest to engage and contribute to this new exciting field. All questions about the logistics and official applications (A resume with previous project experience and publication record) should be directed to ***suayb.arslan@bogazici.edu.tr***. The available positions will be filled on a first-come, first-serve basis upon successful fulfilment of project requirements.