UNIVERSITY OF SOUTH FLORIDA

Defense of a Doctoral Dissertation

Adaptive Multi-scale Place Cell Representations and Replay for Spatial Navigation and Learning in Autonomous Robots

by

Pablo Scleidorovich

For the Ph.D. degree in Computer Science and Engineering

Place cells are one of the most widely studied neurons in the brain hippocampus thought to play a vital role in spatial cognition. Studies show that place cell activity is highly correlated with the animal's location in an environment, forming "place fields" with smaller sizes near the dorsal pole and larger sizes near the ventral pole. Place cell reactivation during sleeping periods (hippocampal replay) has been shown to recreate routes navigated while awake and has been linked with memory consolidation processes. In this dissertation, we analyze the place cell representation from a computational point of view, with a special interest in studying how multi-scale place fields impact navigation in large and cluttered environments. The objectives are to assess how the brain may benefit from such a multi-scale representation and to extend brain-inspired spatial cognition models for controlling autonomous robots. Additionally, we show how computational models of hippocampal replay can reduce the number of trials required to learn a task by pre-exposing the agent to the environment before rewarded trials begin in reinforcement learning algorithms.

Examining Committee

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Please email for more information
pablos@usf.edu
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Publications

1) **Scleidorovich, P.,** Weitzenfeld, A., Fellous, JM., and Dominey, P. Integration of velocity-dependent spatio-temporal structure of place cell activation during navigation in a reservoir model of prefrontal cortex. Biol Cybern (accepted).
2) **Scleidorovich, P.**, Llofriu, M., Fellous, JM. et al. A computational model for spatial cognition combining dorsal and ventral hippocampal place field maps: multiscale navigation. Biol Cybern 114, 187–207 (2020). https://doi.org/10.1007/s00422-019-00812-x
3) **Scleidorovich, P.**, Llofriu, M., Fellous, JM., and Weitzenfeld, A., "A Computational Model for Latent Learning based on Hippocampal Replay," *2020 International Joint Conference on Neural Networks (IJCNN)*, 2020, pp. 1-8, doi: 10.1109/IJCNN48605.2020.9206824.
4) Cazin, N., **Scleidorovich, P.**, Weitzenfeld, A. et al. Real-time sensory–motor integration of hippocampal place cell replay and prefrontal sequence learning in simulated and physical rat robots for novel path optimization. Biol Cybern 114, 249–268 (2020). https://doi.org/10.1007/s00422-020-00820-2
5) Llofriu, M., **Scleidorovich, P.**, Tejera, G. *et al*., "A Computational Model for a Multi-Goal Spatial Navigation Task inspired by Rodent Studies," *2019 International Joint Conference on Neural Networks (IJCNN)*, 2019, pp. 1-8, doi: 10.1109/IJCNN.2019.8851852.
6) Cazin, N., Llofriu, M., **Scleidorovich, P.**, et al. (2019) Reservoir computing model of prefrontal cortex creates novel combinations of previous navigation sequences from hippocampal place-cell replay with spatial reward propagation. PLOS Computational Biology 15(7): e1006624.

Robert Bishop, Ph.D.
Dean, College of Engineering

Ruth H. Bahr, Ph.D.
Dean, Office of Graduate Studies

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