NE593 Project Guidelines

Overview

- Work in a team (2 or 3)
- Deliverables

		Score weight
Check in	(5 min)	15%
Presentation	(20 min)	45%
GitHub repository with code & slides		40%

Timeline

Choose topic	April 2
Project Check in	April 16
Presentations	April 28, 30

Candidate Project Ideas and Topics

Artificial Neural Models

- Take a deeper dive into the Hopfield model (original paper or Kleinfeld paper). Understand the role of energy. Explain it. Apply it to an example.
- Describe another type of RNN (for example a long short-term memory or LSTM network). Explain it. Apply it to an example.
- Choose another deep neural network (DNN) architecture. Explain it. Apply it to an example.
- Implement OpenClaw (**be careful!**). Tell us about it. Make it do something interesting for the class.

Biophysical Neural Models

- Study the Izhikevich neuron. Simulate and understand the dynamics.
  *Izhikevich, E. M. Simple model of spiking neurons. IEEE Trans Neural Netw **14**, 1569–1572 (2003).*

- Study nested gamma-theta rhythms. Simulate and understand the dynamics. *Borges, An Introduction to Modeling Neuronal Dynamics, Chapter 34: Nested Gamma-Theta Rhythms*.
- Study a biophysical model of a neuron. Simulate and understand the dynamics.

Read and report on a published, peer-reviewed scientific paper

- Consider one of the papers below describing connections between artificial neural networks and the brain. Explain the main points to us (in the limited time we have available). Implement a simulation / model / concept in Python related to the paper.

Papers about Artificial Neural Models

  - Fan, F.-L., Li, Y., Zeng, T., Wang, F. & Peng, H. Towards NeuroAI: introducing neuronal diversity into artificial neural networks. *Med-X* **3**, 2 (2025).
  - Wurman, P. R., Barrett, S., Kawamoto, K., MacGlashan, J., Subramanian, K., Walsh, T. J., Capobianco, R., Devlic, A., Eckert, F., Fuchs, F., Gilpin, L., Khandelwal, P., Kompella, V., Lin, H., MacAlpine, P., Oller, D., Seno, T., Sherstan, C., Thomure, M. D., Aghabozorgi, H., Barrett, L., Douglas, R., Whitehead, D., Dürr, P., Stone, P., Spranger, M. & Kitano, H. Outracing champion Gran Turismo drivers with deep reinforcement learning. *Nature* **602**, 223–228 (2022).
  - Cohen, Y., Engel, T. A., Langdon, C., Lindsay, G. W., Ott, T., Peters, M. A. K., Shine, J. M., Breton-Provencher, V. & Ramaswamy, S. Recent Advances at the Interface of Neuroscience and Artificial Neural Networks. *J. Neurosci.* **42**, 8514–8523 (2022).
  - Laydevant, J., Wright, L. G., Wang, T. & McMahon, P. L. The hardware is the software. *Neuron* **112**, 180–183 (2024).
  - Willett FR, Kunz EM, Fan C, Avansino DT, Wilson GH, Choi EY, Kamdar F, Glasser MF, Hochberg LR, Druckmann S, Shenoy KV, Henderson JM. A high-performance speech neuroprosthesis. Nature. 2023 Aug;620(7976):1031-1036.

Papers about brain rhythms

  - Lundqvist, M., Miller, E. K., Nordmark, J., Liljefors, J. & Herman, P. Beta: bursts of cognition. Trends in Cognitive Sciences 28, 662–676 (2024).

- Singer, W. & Effenberger, F. Oscillations in Natural Neuronal Networks; An Epiphenomenon or a Fundamental Computational Mechanism? *Hu Arenas* **8**, 846–868 (2025).
- Vinck, M., Uran, C., Dowdall, J. R., Rummell, B. & Canales-Johnson, A. Large-scale interactions in predictive processing: oscillatory versus transient dynamics. *Trends in Cognitive Sciences* **29**, 133–148 (2025).
- Effenberger, F., Carvalho, P., Dubinin, I. & Singer, W. The functional role of oscillatory dynamics in neocortical circuits: A computational perspective. *Proceedings of the National Academy of Sciences* **122**, e2412830122 (2025).
- Buzsáki, G. & Vöröslakos, M. Brain rhythms have come of age. *Neuron* **111**, 922–926 (2023).