

NeuroML: decoding and controlling neuronal cultures

PhD research pipeline for a learning controller in the closed loop between a neuronal culture and a computer.

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Role: author of the research and the code

BACKGROUND

A neuronal culture on a multielectrode array is stimulated and recorded through a computer. In common setups a threshold detector decides when to stimulate. The research question is whether a learning controller can replace this detector without exceeding the time budget of the loop, which is 50 ms.

SOLUTION

- An adapter layer converts every data source into one recording format. Open datasets, the simulator and, later, lab data connect through a single adapter and a single configuration.
- 26 feature extractors, some offline and some online. Latency is measured for every online feature.
- A simulator with known ground truth, so decoders can be checked before they are used on real cultures.
- Every number comes with a confidence interval, and the criterion is fixed before the measurement. No conclusions are drawn from fewer than five cultures.
- Reproducibility through explicit seeds and configurations, every run in Docker.

RESULTS

- Spike inference from calcium imaging on real data (CASCADE): correlation 0.549 [0.517; 0.610], classical method 0.067.
- Decoding the stimulus from the response in the simulator: F1 0.754 [0.703; 0.805].
- The full loop stays within the 50 ms budget for up to 128 channels.
- Pong with a culture model (12 cultures, 3,000 steps each): 21.2 missed balls per 1,000 without plasticity, 32.1 with a stationary paddle. With STDP plasticity switched on, play got worse in 11 of 12 cultures.
- Burst suppression as a function of stimulation frequency reproduced after Wagenaar et al. (2005). The remaining deviation is narrowed down to one testable hypothesis about the geometry of the culture model.
- Over 700 tests. Negative results are documented as thoroughly as positive ones.

TECHNOLOGIES

Python · NumPy · SciPy · scikit-learn · Brian2 · Spiking neural networks · Closed-loop control · Docker