Simulations for NaLoDuCo experimentation with reinforcement learning agents

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1 Motivations

In physics, engineering and robotics simulations are widely used to test, debug and optimize experiments before real wold trials. However, neuroscience experiments lack equivalent tools.

In short-duration experiments one can iterate over several experimental configurations quickly to find the best one. This possibility in NaLoDuCo experiments is drastically limited. Therefore, it is critical to have an environment to simulate in detail NaLoDuCo experiments with realistically behaving agents to allow scientists to quickly try different experimental setups. Simulations can save high costs of iterations. Every failed experiment means months of lost work, as well as the cost of caring for animals and maintaining experimental setups.

2 Proposed solution

We propose to develop a realistic, detailed simulation framework that allows scientists to pretest their foraging experiments before running them on real animals.

3 Key features of the simulation

Reinforcement Learning-Based Virtual Mice

1. We will use RL agents to simulate mouse behavior in foraging tasks.
2. Agents will be trained using prior data and reward structures that match real foraging constraints.
3. Previous work has developed RL-based foraging models (e.g., arXiv:2210.08085), which we can build upon.

Realistic Environmental and Experimental Constraints

1. The simulation will include environmental factors (e.g., food availability, maze layouts, reward schedules).
2. We will incorporate biological constraints (e.g., circadian rhythms, fatigue, adaptation).
3. The system will model sensor noise and drift to match real-world data collection.

Interactive Experiment Design and Debugging

1. Users can customize parameters of the experiment (e.g., reward schedules, number of patches, number of nets, number, resolution and positions of cameras).
2. RL agents will be visualised as realistic mice and their motion will be recorded by the different cameras, at the corresponding resolutions and frame rates. These recordings will allow to run body part tracking and pose estimation algorithms on simulated data, and test if the cameras specification and layout allows required estimation accuracy.
3. Scientists will be able to run and iterate simulations quickly, testing different hypotheses before committing to real experiments.
4. The platform will provide detailed logs, making it easier to diagnose potential pitfalls in experiment design.

Data-Driven Model Updating

1. As new foraging experimental data is collected, it will be used to update the simulation for better accuracy.
2. This allows for a continual refinement of the RL-based foraging models.

4 How can simulations help NaLoDuCo experimentation?

If I want to test if the validity of Marginal Value Theorem in a NaLoDuCo experiment setup is it better to use one or two patches?, what food reward rate should we use?, what inter-patch distance should I set?, would it be helpful to introduce predators? I could quickly address all these questions in realistically simulated the foraging experiments.

Does foraging become more efficient over time? If so, how long should an experiment be to reveal this increase in efficiency? We could address these questions with an optimal RL foraging agent.

Is an animal behavior adapting over time? To address this question I can estimate parameters of optimal RL models at different points in time and check if these parameters change significantly.