CMPE 491 – Senior Design Project I

MoonAI

Project Proposal

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1) Web Page

- https://moon-aii.github.io/moonai/

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3) Project Description

This project aims to develop a simulation environment that models predator-prey dynamics to investigate and optimize the performance of genetic and evolutionary algorithms. Within this environment, evolutionary algorithms will be employed to optimize both population-level parameters—such as movement speed, attack range, and reproductive rate—and individual behavioural strategies. These behaviours will be represented and evolved through artificial neural networks using techniques such as the NeuroEvolution of Augmenting Topologies algorithm.

The objectives of this research are threefold:

- Developing a predator-prey simulation that can generate the data and environment required to train machine learning algorithms without requiring large amounts of real-world data and that will provide an environment that will allow us to observe the training and evolution of machine learning algorithms in detail.
- To investigate how genetic representations influence learning efficiency and adaptability in dynamic and complex environments through simulation-base experimentation.
- To evaluate the potential of evolutionary computational methods in solving adaptive behaviour modelling problems in complex systems that are challenging for traditional optimization techniques.

Problem and Motivation

- Evolutionary algorithms are particularly suitable for this problem because they do not rely on gradient-based optimization and can explore highly nonlinear, multimodal search spaces. Their population-based nature also mirrors the biological processes underlying predator–prey evolution, making them conceptually and practically appropriate for this domain.

Traditional vs. Evolutionary Approaches

- Traditional methods focus on deterministic or statistical modelling of system parameters, while evolutionary algorithms simulate adaptive evolution to discover effective solutions autonomously.
- We select NeuroEvolution of Augmenting Topologies as the primary algorithm because it evolves both the topology and weights of neural networks simultaneously, allowing the emergence of sophisticated adaptive behaviours without predefining network structures.

Planned Simulation Setup

- Environment: A 2D simulation space with time-step-based dynamics.
- Agents: Two types (predators and prey) with configurable attributes — movement speed, vision range, stamina, and reproduction rate.
- Behaviour Representation: Each agent's behaviour will be governed by a Neural Network whose structure evolves through Neuroevolution of augmenting topologies algorithm.
- Optimization Objective: Maximize survival rate, optimize population size and stability.
- Data Collection: population statistics, behaviour trajectories, network topologies, and genetic representations will be logged for analysis.

Technologies

- Simulation and Visualization: C++, Simple and Fast Multimedia library (SFML).
- Machine Learning: CUDA for calculation and C++ for Algorithm Implementation.
- Data Analysis and Visualization: Python (Pandas, Matplotlib).

Expected Contributions

- Development of a flexible and extensible predator–prey simulation framework to be able to test machine learning algorithms without real world data.
- Quantitative and qualitative evaluation of evolutionary algorithm performance under dynamic conditions.
- Insights into the impact of genetic representation and environmental factors on the evolution of complex behaviours.
- A structured comparative methodology for future research in neuroevolution and adaptive systems.

Through this study, we intend to conduct a comprehensive analysis of how genetic representations of agents and environments influence the efficiency and adaptability of evolutionary optimization processes using a simulation environment which is capable to generate data for machine learning algorithms. The outcomes will include quantitative evaluations of algorithmic performance, visual analyses of emergent behaviours in the simulation, and insights into the relationship between evolutionary parameterization and system-level dynamics.