Karlsruhe Institute of Technology

Autonome Lernende Roboter (ALR)
Prof. Gerhard Neumann

Project Type

- ☑ Master Thesis
- ☐ Bachelor Thesis
- ☑ Research Project

Supervisors

☞ Niklas Freymuth
@ niklas.freymuth@kit.edu
☞ Maximilian Hüttenrauch
@ maximilian.huettenrauch@kit.edu

Difficulty

Algorithmic

Math

Application

Training Swarm Systems with Curriculum Learning and Graph Neural Networks

Description

Swarm systems are groups of many actors that act in a collaborative fashion. In nature, such systems appear in the form of bee swarms, ant colonies and migrating birds. In all these cases, the individual actors act in simple ways, yet the swarm as a whole often exhibits surprisingly complex behavior.
The field of Swarm Reinforcement Learning (RL) [2] attempts to replicate this notion of simple actors that work together to solve tasks that would be too difficult for each individual agent. Here, individually acting agents need to collaborate to maximize a shared reward. An example can be seen in Figure 1, where a number of actors (blue) chase and eventually catch an evader (red) that is much faster than any individual agent.

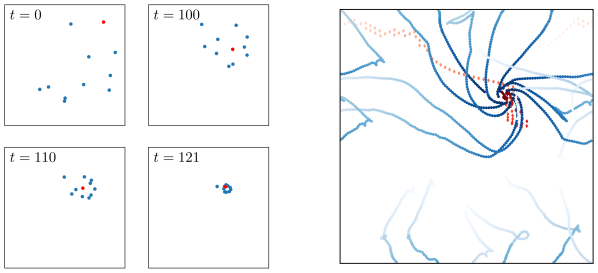

Figure 1: A swarm of agents (blue) collaborating to catch an evader (red).

While current methods in Swarm RL showcase the usefulness of this collaborative problem solving approach, they often suffer from insufficient communication between agents. Additionally, collaborative tasks are inherently difficult to learn, as they require multiple agents to interact in just the right way to make progress.
In this work, we want to tackle both these problems. We will phrase the communication between agents as a message-passing problem on graphs, where the nodes are the agents that communicate along the edges. This can be realized using Graph Neural Networks [1], that, as the name suggests, are neural networks that act on graphs as inputs. Additionally, we will employ Curriculum Learning [3], which is a learning paradigm that starts with simple tasks and then progressively increases the difficulty to lead a learning system towards otherwise too-complex behavior.
The result will be a framework that allows multiple freely communicating agents to learn increasingly complex behavior to solve harder and harder tasks.

Tasks

- Literature Review: Get familiar with Swarm RL, Graph Neural Networks and Curriculum Learning approaches
- Algorithm Design: Combine these ideas to create an algorithm that allows for increasingly complex communication between agents in a swarm.
- Evaluation: Evaluate your algorithm on simulated swarm systems and compare it to existing approaches.

References

[1] Michael M Bronstein, Joan Bruna, Taco Cohen, and Petar Veličković. Geometric deep learning: Grids, groups, graphs, geodesics, and gauges. *arXiv preprint arXiv:2104.13478*, 2021.

[2] Maximilian Hüttenrauch, Sosic Adrian, Gerhard Neumann, et al. Deep reinforcement learning for swarm systems. *Journal of Machine Learning Research*, 20(54):1–31, 2019.

[3] Sanmit Narvekar, Bei Peng, Matteo Leonetti, Jivko Sinapov, Matthew E Taylor, and Peter Stone. Curriculum learning for reinforcement learning domains: A framework and survey. *arXiv preprint arXiv:2003.04960*, 2020.