Predator–Prey Collective Behaviour under Survival Pressure

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Collective Behaviour – Project Presentation

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Outline

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Why Study Predator–Prey Collective Behaviour?

- Collective behaviours such as flocking and swarming are common in nature.
- They emerge from simple local interactions and lead to complex global patterns.
- Understanding these mechanisms is useful for:
  - biology (animal groups),
  - physics (active matter),
  - robotics (swarm systems).

Scientific Context

- **Li et al. (2023)** show that survival pressure alone can lead to collective behaviour in predator–prey systems.
- Public **GitHub implementations** and **YouTube simulations** show similar behaviours, but are costly to run and hard to explore in detail.
- **Couzin-type models** are classical rule-based models for collective motion.
- **MADDPG** is a common algorithm for multi-agent reinforcement learning.

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Our Starting Goal

- Carefully read the reference paper to fully understand the proposed model.
- Explore related work and public implementations (GitHub repositories, simulations).
- Reproduce a minimal predator–prey system inspired by Li et al.
- Study collective behaviour using simple metrics:
  - Degree of Sparsity **(DoS)**: close to 0 indicates compact prey groups,
  - Degree of Alignment **(DoA)**: close to 1 indicates coherent motion.
- Investigate the role of environmental geometry, in particular the effect of boundaries.

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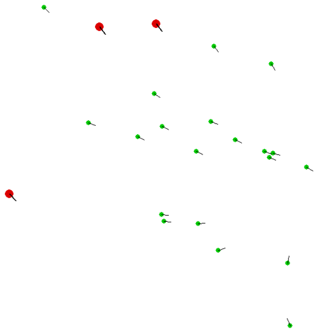
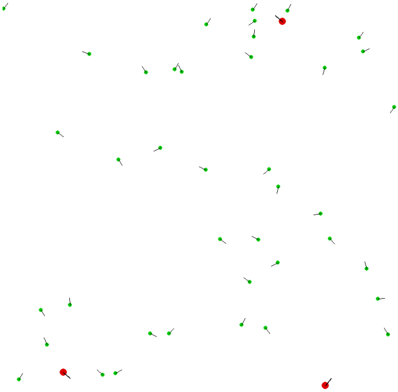
What We Achieved

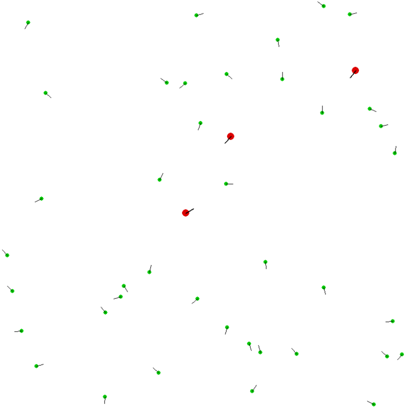
- Built a continuous 2D predator–prey environment.
- 20 prey interacting with 3 predators.
- A controllable setup to test geometry and learning effects.



Reinforcement Learning: Simulation Behaviour



Toroidal environment



Bounded environment

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Main Challenges We Faced

- Existing GitHub code: **hard to appropriate**, **too expensive to run**
- **Couzin models** and **reinforcement learning** developed in parallel
- Multiple **boundary conditions** (torus vs walls) explored simultaneously
- Strong focus on reproducing **Li et al.** results

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How We Addressed the Challenges

- Importance of **building our own environment**
- Value of **simplifying** to isolate key mechanisms
- Differences with reference results can be **informative**

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What Would We Do Differently?

- Start with a **very simple baseline model** before implementing deterministic rules and reinforcement learning in parallel.
- Conduct a **longer and more systematic literature review**, including additional papers and implementations beyond the main reference.
- Work in a **larger team**, which would have allowed better separation of tasks (environment, metrics, learning).
- Schedule **two regular team meetings per week** instead of one, to improve coordination and faster iteration.

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