WASP Project Course 2025

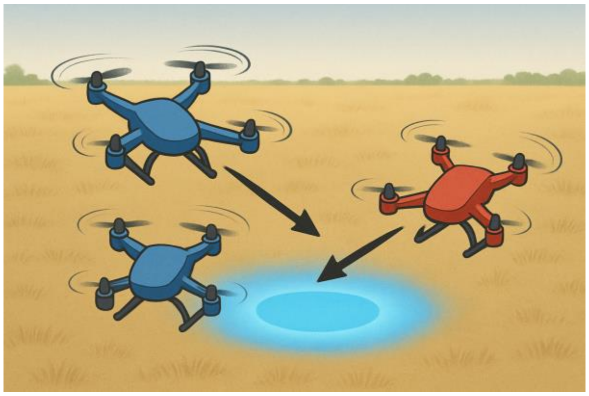
Dynamic shield defense: MARL-based countermeasure against attacking UAVs

Background

The project explores a simple dynamic shield defense game with drones [4]. The figure below illustrates the game, where the two blue drones attempt to push out the red drone from the blue hotspot on the ground. The simplest scenario includes two drones with drone A defending the hotspot from drone B trying to enter the hotspot. Drone A must physically repel Drone B from the hotspot.

Possible challenges in this project involve developing a robust autonomy framework for the drones, integrating real-time perception (possibly vision-based object detection with fallback to GPS), state estimation (possibly with dynamic factor graph-based SLAM), autonomous decision-making (potentially using Behavior Trees and Multi-Agent Reinforcement Learning (MARL)), and control strategies for interception.

The project consists of three main parts:
1) Theoretically formalizing the game as a stochastic game [5, Chapter 4].
2) Solving the game in a simulated environment, possibly BenchMARL [7], the WARA-PS core system [8], or ROS. If training MARL agents on the core system is unfeasible, work must be done to transfer the resulting policies from other simulated environments to the core system.
3) Integration of software into hardware. This includes iterating the previous parts until a satisfactory solution is obtained. One challenge for obtaining satisfiable results is the sim-to-real gap [9].



Constraints: The three Holybro drones that WARA-PS can lend out need to be operated using a drone operating license [10]. Somewhat reasonable compute power is needed for training the agents using MARL.

Participants

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Challenges to investigate

- Design a stochastic game that represents the dynamic shield defense game. Implementation efforts will include:
  - Representation:
    - Should the agents move on the real plane or the subset of whole numbers (a grid)?
  - Level of control:
    - Should the agents control position, velocity, or acceleration?
    - Potentially include orientation control in the action space to allow for active sensing in a partially observable setting.
    - What is the input to the agent policies?
  - Simulation:
    - Implementing and solving the stochastic game in a simulated environment.
  - Observability:
    - What would full observability mean in our scenario?
    - Each agent may start off knowing GPS-position of every other agent
    - What would the agents' observations be in the partial observable case? Camera data?
    - How to incorporate uncertainty and active sensing into the game?
  - Closing the Sim-To-Real gap:
    - Explore the ability to transfer policies learned in a simulated environment to reality.
  - Integration for demonstration:
    - How to integrate software and hardware to demonstrate the learned policies in the real world?
    - How to synchronize agent states in time and share information across the system?

Resources

Our identified physical resource requirements include access to the three WARA-PS Holybro drones. Additionally, we intend to leverage the WARA-PS core team, including Michael Petterstedt for technical support integrating with this hardware. Michael Petterstedt will also assist with using the core system as a simulator for the designed dynamic shield defense scenario.

Deliverables

- Theoretical design of the dynamic shield defense game as a stochastic game.
- Demonstration of the dynamic shield defense game with two defending drones successfully blocking out an infringing drone from the hotspot. The initial demonstration will take place in simulation, with a goal to reproduce the results on the real drones.

References

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Keywords

Multi-agent reinforcement learning
Navigation
Autonomous drones
Simulation