The Hive: A Cooperative Drone Swarm for Protection and Reconnaissance

Resilient Multi-Agent UAV Coordination for Coverage, Scouting and Counter-UAS

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Context

This project is carried out in collaboration with Försvarsmakten. Recent conflicts have shown both the breadth of unmanned systems now in use and the importance of applying the right capability at the right time, with awareness of possible countermeasures. AI for cooperative unmanned systems is of broad interest, and this project explores it through prototypes and concept demonstrators built in simulation.

The scenario centers on a **home base** that must be protected and supported by a fleet of cooperating drones. Some drones maintain protective coverage over the base, a *dome*, while others perform reconnaissance of the surrounding area. The central idea is the **hive**: the base and its swarm treated as one system, in which the swarm acts as a single coordinated entity rather than a set of independent units, so that coverage is maintained continuously, situational awareness is shared, and threats are handled faster and more robustly than any single operator or drone could manage alone. When a drone is lost or must return to base, the hive self-heals by re-tasking the remaining units and dispatching replacements.

Students work primarily in simulation, selecting one or more of the available simulators and a subset of concrete swarm capabilities to design, implement and evaluate. The project is deliberately open-ended: the goal is a compelling proof-of-concept for one or more capabilities, evaluated against clearly defined scenarios. It is large enough for **multiple groups to work on different parts of the same hive in parallel**.

Some collaboration between groups will be needed where decisions affect everyone: a shared scenario, a common hive interface, and shared conventions when using the same simulator.

The project groups will take the InDefense specialisation: LiU's elective specialisation in defence innovation, offered within a number of project courses and developed together with Försvarshögskolan. Students work on a real total-defence challenge with mentors from the defence side and innovation support from LiU Innovation.

Goal

The goal is to design, implement and evaluate a proof-of-concept for a cooperative drone swarm that protects and supports a home base. The swarm should act as a single coordinated entity that (1) maintains protective coverage over the base, (2) performs reconnaissance of the surrounding area, and (3) responds autonomously and resiliently to threats such as hostile drones, including self-healing by dispatching reinforcements when swarm members are lost. Within this overall vision, the group selects a subset of concrete capabilities, grounds them in a literature study, implements them in a chosen simulation environment, and evaluates the resulting techniques on well-defined tasks and scenarios.

Task suggestions

- **Scope and plan:** Select a subset of the swarm capabilities listed below that the group wants to realize, and define concrete scenarios and evaluation metrics for them (e.g. detection rate, coverage, intercept success rate, time-to-reinforce, robustness to losses).
- **Literature study:** Survey the state of the art for the selected capabilities (e.g. multi-agent coordination and swarming, task allocation, coverage/patrolling, autonomous navigation and mapping, counter-UAS, reinforcement learning vs. planning-based control).
- **Choose a simulation environment:** Evaluate and select one (or more) of the available simulators (see References) based on fidelity, sensor support, multi-agent capabilities and ease of integration. Set up a reproducible scenario with a home base, friendly units and hostile drones.
- **Implement and evaluate:** Implement the selected capabilities, integrate them into coherent swarm behavior, and evaluate the chosen techniques against the defined scenarios, comparing alternative approaches (e.g. learned vs. classical) where relevant.

Candidate swarm capabilities (select a subset)

- **Base surveillance:** persistent monitoring and situational awareness over the home base.
- **Scouting and mapping:** send drones further out to build a full 3D map of the surroundings while staying undetected, using terrain to hide in advantageous spots and acting as a mobile sensor network.
- **Self-healing coverage:** detect gaps in the dome and fill them, maintaining required capability where it is needed as drones are lost, recharged or re-tasked.
- **On-leash escort:** when a group leaves the base, assign drones to follow it from above, providing overwatch and a live feed.
- **Counter-UAS engagement:** detect a hostile drone near a protected asset and intercept it, using a planning-based or a reinforcement-learning-based controller, or comparing the two.
- **Reinforcement dispatch:** when a defending drone is neutralized during an intercept, dispatch reinforcements from the hive to restore the defense.
- **Perimeter search:** after a threat is detected, search the perimeter and known area around the base for additional hostiles.

- **Your own idea:** propose an additional swarm capability relevant to the scenario, then agree the scope with the supervisor and the customer before committing to it.

References

Simulation environments

- CARLA-Air: open-source air-ground simulator with drone/quadrotor support, rich sensors (LiDAR, cameras, radar, IMU, GPS) and dynamic weather.
- teapotlaboratories/drone-sim: photoreal drone simulator flown over ROS 2 (Unreal Engine 5 + Cosys-AirSim rendering, PX4 SITL flight, ROS 2 Jazzy control interface).
- Cosys-AirSim: actively maintained fork of Microsoft AirSim for multirotor and multi-agent simulation with photorealistic sensors.
- gym-pybullet-drones: lightweight multi-quadcopter Gymnasium environment for RL and control research.
- OmniDrones: Isaac Sim platform for multi-rotor reinforcement learning, with ready-made multi-agent tasks.
- Crazyswarm2: ROS 2 stack for large quadcopter swarms, with both a simulator and a path to real Crazyflie hardware.
- PX4 SITL + Gazebo: software-in-the-loop flight stack with multi-vehicle support, close to real autopilot behavior.
- *Arma 3* (with modding / scripting): a game engine option for representing terrain, ground units and drones in a tactical setting (integration effort and licensing to be assessed).

Techniques and background

- *Swarm Intelligence: From Natural to Artificial Systems*, by Bonabeau, Dorigo & Theraulaz (foundational text on swarm behavior).
- *Multi-Agent Reinforcement Learning: A Selective Overview of Theories and Algorithms*, by Zhang, Yang & Başar.
- *QMIX / VDN*: value-decomposition methods for cooperative multi-agent reinforcement learning.
- *Multi-Robot Task Allocation: A Review of the State-of-the-Art*, by Khamis, Hussein & Elmogy.
- *Counter-Unmanned Aircraft Systems (C-UAS)* surveys on detection, tracking and neutralization of hostile drones.
- *Coverage path planning and cooperative multi-robot patrolling* literature for area surveillance.
- *YOLO*-family object detectors and vision-based detection and tracking.