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Project Summary

Cooperative optimal target tracking for fixed-winged aerial robot networks with connectivity constraints

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Mission planning and task allocation for a collaborative drone network is a problem that appeared in the early 2010 and lead to an active research field. This thesis focuses on a subproblem of the domain: long-distance collaborative flights. It contributes to the control of flying ad-hoc networks: mesh networks that are created without any prior infrastructure.

This thesis was carried out in partnership with the AgEagle company. Their most recent drone, named the eBee VISION is a fixed-wing, high-endurance intelligence, surveillance, and reconnaissance drone meant for observing distant targets.

One known limitation of this drone is its communication range. To tackle this limitation, multiple drones can be leveraged to create a relaying network that will forward the live video capture back to the operator.

The main question is therefore to design control strategies to address a multi-objective optimization problem, namely accomplishing the best topology for efficient data forwarding, and navigate the drones close to the targets for efficient target tracking.

Constraints for these controllers include maintaining a connected network to prevent the loss of a drone and respecting the dynamics of fixed-wing drones.

To this end, five controllers were developed by employing different approaches including heuristic-based intuition, general convex optimization, and receding horizon to include further dynamic constraints on the drones. Algorithms were also modified to consider robustness by implementing decentralized or distributed solving principles.

When implementing the distributed Model Predictive Controller (MPC), a novel technique has been developed to select the links that will optimize the overall connectivity of the graph. This technique builds upon the eigenvector associated with the algebraic connectivity eigenvalue. This new method enables a distributed algorithm to change its topology proactively with minimal communication and optimize the connectivity of the whole graph.

To test those algorithms, an elementary simulator was developed, with a user-friendly interface in Pyrthon. This enabled the fast development of these algorithms and proper visualization tools as can be seen in Fig. 1.

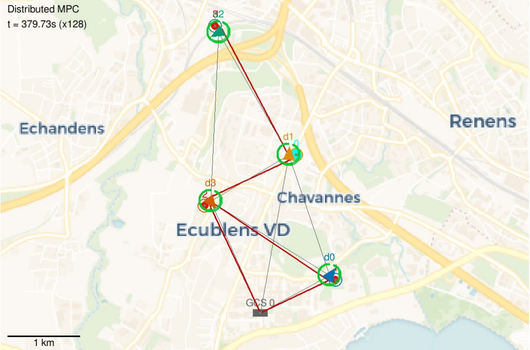

Figure 1 Screenshot of the developed controller

A benchmark on randomly generated environments, assessed through four metrics (overall cost, algebraic connectivity, distance to main target, and computation time), showed the predominance of distributed MPC for this family of problems. Figure 2 shows the distribution of the cost function values for different approaches defined for the overall optimization problem and proves the better performance of optimization-based controllers, and distributed MPC, in particular.

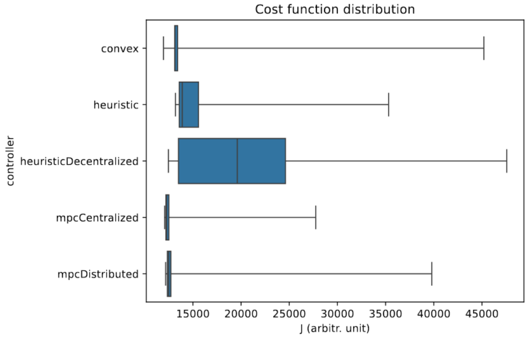

Figure 2 Cost function distribution for a single run on same environment for different controllers (smaller is better).

One of the controllers was implemented into the drone codebase and Software-in-the-Loop (SITL) simulations were performed to assess the robustness of the method in a more realistic setting. Upon successful testing of the algorithms, real flights were rolled out and demonstrated the controller performance with three drones tracking a target out of range for a single drone.