

Capture the flag with drone swarms

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Abstract—This paper presents a decentralized control strategy for a multi-agent unmanned aerial vehicle (UAV) swarm tasked with a capture-the-flag (CTF) objective, formulated as a point reaching problem with collision avoidance. An artificial potential field (APF)-based controller is employed to generate velocity references for each agent through sums of attractive and repulsive vectors. A leader-follower structure is introduced, where the agent equipped with status is directly attracted to the drone, while the followers objective is to remain passive. This paper explores how changing the targets gps location, gives a more dynamic bypassing of leader status in between the drone swarm. This paper provides a Github repository with guidelines to launch the simulation from a containerized environment using Docker, and results from said simulations will be discussed.

Index Terms—Artificial potential fields, multi-agent systems, drone swarms, capture-the-flag, ROS2, Webots

I. INTRODUCTION

Cooperative control of multi-agent systems is a central topic in swarm robotics, with applications ranging from surveillance, exploration to transport and search tasks. A benchmark for evaluating such strategies, is capture-the-flag problems, in which agents are required to communicate their motion towards a shared objective, while avoiding collisions and adapting to dynamic changes in the goal. When implemented using UAVs, this task poses a challenge to decentralized decision making, scalability and effectiveness of the swarm.

Artificial Potential Fields (APF) provides a computationally cheap and efficient approach to decentralized motion planning, by generating control actions off of sums of attraction from targets, and repulsion forces from objects to avoid colliding with. This is a

In this paper, we formulate the multi-agent capture-the-flag (CTF) problem as a decentralized control task and propose and APF based control strategy for generating trajectories to reach said flag. A dynamic leader follower structure is introduced, where a single agent is assigned a status as leader and is directly attracted to the flag, while the remaining agents act as followers and maintain collision avoidance. This approach is implemented and evaluated in a physics-based simulation environment using Webots and ROS 2

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II. PROBLEM FORMULATION

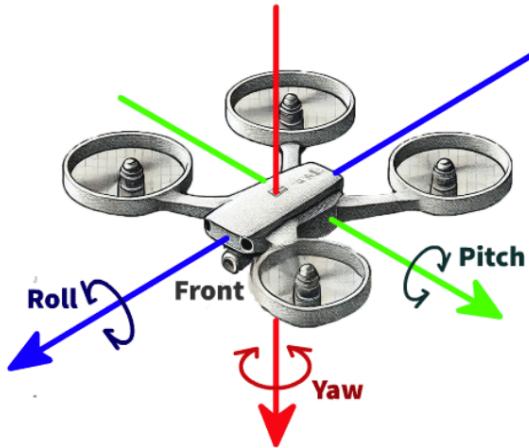
This section formalizes the multi-agent CTF task considered, and specified system assumptions, architecture of nodes and topics and control objectives. The formulation is intentionally kept at a high-level in order to emphasize coordination problem, rather than low-level vehicle dynamics.

A. Scenario description

We consider a swarm of autonomous UAVs operating in a 3D virtual world, where simulated physics are the closest approach to first principles in the real world. The collective task is to capture the flag, which is modelled as reaching a point in this space. Upon capture, the flag will respawn in a new location, represented as a vector with uniformly distributed components. This respawn mechanism, requires the swarm to adapt its behaviour. The agents are required to decide on consensus in order to reach the target efficiently, while avoiding collisions with each other, or potentially foreign objects. There is no central trajectory planner that is assumed, and each agent computes its control action independently based locally available information.

B. Agent Representation and Control Level

Each UAV is treated as an independent agent, controlled at velocity-command level. Low level attitude stabilization and motor thrust actuators are assumed to be handled by onboard flight controller and are not explicitly modeled in this paper. As a result, the controller considered in this paper generates velocity references, rather than thrust commands. This allows the paper to focus on multi-agent coordination and interaction, rather than on detailed vehicle dynamics, which would require a longer paper. Roll and pitch dynamics are neglected, but are possible to tweak as a contribution to the github project. Only planar motion and yaw regulation are considered.



C. Information Structure and Decentralization

Since control architecture is decentralized, each agent has access to its own state, and to the relative states of other agents in the swarm, in addition to the position of the flag

III. ARTIFICIAL POTENTIAL FIELD CONTROLLER

A. Equations

IV. SYSTEM ARCHITECTURE AND IMPLEMENTATION

V. EXPERIMENTAL RESULTS

VI. DISCUSSION

VII. CONCLUSION AND FUTURE WORK

REFERENCES

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