Project LegionAir

1st Darshit Miteshkumar Desai
University of Maryland
College Park
darshit@umd.edu

2nd Patrik Dominik Pördi
University of Maryland
College Park
ppordi@umd.edu

***Abstract*—This document summarizes the project proposal for the Swarm Robotics course Research project. The project aims to emulate a swarm formation of a roman legion where if a single comrade falls out of formation there is a readjustment of the whole formation such that the coverage can be maximized. The project's outcomes would be the application of our knowledge of drone hardware, perception, control systems, software architectures and swarm algorithms learnt during our coursework of the Robotics masters degree.**

***Index Terms*—Formation control, Coverage control,**

I. Introduction

Within our project, we aim to investigate the collaboration among a multi-agent system employing drones. Our objective is to develop a scalable decentralized algorithm capable of orchestrating a shape formation around a moving object using robot swarms.

II. Motivation

A. High-Level Motivation

Swarming behavior using vision is quite common in the animal kingdom, birds flock together while migrating to locations and maintain formation at the same time just based on limited field of view vision sensors. Our motivation is to use a similar limited FOV swarm of drones to track a mother ship drone in the center at the same time maintaining the formation while the the mother ship guides the flock to the designated target. The second stage of the project involves emulating Roman legion tactics of replacing and maintaining coverage of troops. Roman legions functioned using continuous funneling of troops to the front lines so that exhausted troops can rest or recuperate while at the same time fallen soldiers can be replaced. Our objective would be to emulate the second formation where one of the drones in the flock looses track or is sent on a scouting mission ahead, while the slower moving mother ship and it's flock reorients itself to account for the missing drone.

B. Personal Motivation

Our personal motivation stems from our shared experience in Autonomous Aerial Robotics. During this course, we discovered a common passion for UAVs. Darshit delved into object detection and tracking, while I focused on decision-making and object capturing. Recognizing the depth of these fields, we were eager to combine our ideas and expertise. To add complexity to our endeavors, we aimed to explore collaboration and emergent behavior among multiple agents. Furthermore, Darshit has access to hardware, particularly drones, which we can leverage for our pursuits.

III. Related Work

This section describes the papers we would be referring for developing algorithms and software for the whole project. For the detection and tracking part we would be using Yolov5 algorithm [1] right out of the box. We will be retraining this algorithm to do single (or multi class) identification of drones used in our project. For the tracking part we have referred the thesis of Zhu et. al. [2] which basically forms the basis of using a constant velocity Kalman filter to track a moving human in front of the drone for obstacle avoidance. We have adopted a similar tracking approach and designed a custom position based controller to test the drone to drone following functionality.

We would like to work in a moving uncertain environment with drones, this problem was addressed in [3], where they apply leader-follower consensus control and in [4] where they used a directed graph. Another idea we would like to explore is the field of flexible swarm formations [5] when the shape can alter and adjust according to commands or environment changes.

Apart from this, we have also researched on a number of papers which implement swarm algorithms on drone hardware. One such paper describes the use of Visual Inertial Odometry where the researchers [6] at GRASP Lab in UPenn use on board visual odometry estimates to guide a swarm of 10 drones into different formations. We will try to build upon that concept where we have the individual odometry poses of the drones and we use it only for individual position control, whereas the overall swarm's position control rests on the vision sensors feedback. Another paper [7] which works on a similar principle and uses only vision sensors which have a 360 degree fov around the whole environment to track all visible drones in the flocking radius. This information is then used to run a flocking algorithm.

IV. Intended methodology

The project involves using knowledge of tools from this class as well as previous courses we took during our degree program. To enumerate we have itemized the list of tools and their short descriptions and their intended purpose:

- m500 Drone: This drone is the mother ship of the formation. This drone has a downward facing fisheye camera which does Visual Inertial Odometry to find its pose with respect to a inertial frame. In our case this drone would be the only one receiving commands from the Ground station which would lead the whole flock to move just based on vision estimates of the m500 drone position.
- Starling Drone: This drone is part of the flock formation and is the flagship autonomy drones from the company MODAL AI. The drone has three types of sensors, Fisheye sensors are used for Visual odometry, The front facing RGB Hires camera's data will be used for object detection and the front facing Time of flight camera will be used to fuse detection and point cloud data to localize the target (m500 drone).
- PX4 Framework: The PX4 Autopilot Framework is the most commonly used open source firmware for unmanned vehicles. This range from ground rovers to vtol aircrafts to underwater ROVs. In our drones we plan to use it as the base control firmware upon which high level code would be written.
- ROS 1 and 2: Robot Operating System would act as a middle ware for internal communication and exchange of data within individual drones and inter drone communication of pose estimates of the mother ship between flock drones. In our case, the code right now is running on ROS1 melodic on the drones but if time permits we plan to port to ROS2 foxy for better user support.
- Yolov5 [1]: We will also use Yolov5 single shot detector for object detection. This algorithm is being used as it can be vectorized for the GPU architecture on board the drones we are using and the supporting libraries are pre installed.

Apart from the above tools, we will use GIT, ROS-Gazebo, Python packages like numpy, matplotlib, pytorch for testing and prototyping code. We plan to use C++ end to end for efficiency of running it on board the drones and to take advantage of clean C++ builds which handle memory management better then python.

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