Mälardalen University
School of Innovation Design and Engineering
Västerås, Sweden

Master Thesis Proposal
Course Code: DVA502

EXPLORING MULTI-DRONE COOPERATION FOR TASK EXECUTION

Viktor Petterson
vpn19002@student.mdu.se

Fredrik Westerbom
fnl18001@student.mdu.se

Examiner: Baran Cürüklü
Mäldardalen University, Västerås

Supervisor(s): Johan Cederbladh (Primary), Lennie Carlén Eriksson (Secondary)
Mälardalen University, Västerås

Company Supervisor(s): Anna Wahlberg, Camilla Allmyr
Försvarets Materielverk (FMV), Stockholm

23rd January 2025

1. Background and motivations:

Unmanned Aerial Vehicle (UAV)-commonly known as drone-are becoming more and more frequent due to its versatility. Drones have assisted a great number of industries to solve tasks that traditionally required significant manpower, time and resources. UAVs are widely used in fields such as agriculture, logistics, surveillance, and construction. A drones ability to operate autonomously (or semi-autonomously) allow a user to perform assignments in hazardous environments, that are time-sensitive or require real-time data collection.

Modern drones can be outfitted with sensors such as high resolution cameras, Light Detection and Ranging (LIDAR), thermal sensors and together with Artificial Intelligence (AI) algorithms UAVs can identify objects and people, track movement and collect data.

Zhang et al. in [1] discuss in their review Remote Sensing Object Detection (RSOD), a technique that can be applied in multiple fields. RSOD can capture and identify objects and natural phenomena and in the study Zhang et al. list applications such as disaster management, precision agriculture, sustainable cities and communities.

Recent technological advancements in the UAV field has increased the possibility of autonomy for multiple drones where multiple drones can collaborative work to solve an assignment. This capability greatly increase their effectiveness when solving large tasks due to the enablement of division of labour, and redundancy should a individual drone fail. With further increase in the technique and UAVs abilities they will be even more suited for precise data collection and situational awareness in real-time.

This thesis will be made in collaboration with FMV. FMV is the Swedish Defence Forces (SDF) main supplier of equipment. FMV sole task is to support the armed forces with enough and correct equipment that allows the armed forces to solve its many tasks[1]. FMV gathers experts in fields such as technology, business, law and project management and makes sure that many different parts becomes a whole to deliver regardless of peace, crisis or war.

2. Problem formulation:

Hypothetical case: There has been a mass casualty incident in a remote area that is not easy accessible. A medical team leader needs to get eyes on the situation to prepare the correct response but supposed area is out of reach of any ground station. The team leader has, in his disposal, a group of UAVs that can be tasked with finding the location, send it back to the team leader, and survey the situation using the many different sensors. With the information provided the team leader can prepare the team and any other rersources needed to limit death and suffering among the patients.

The project addresses the challenge of enabling two autonomous drones to complete a mission while collaborating without requiring constant communication with a central ground station. Specifically, the problem involves designing a system where different drones are equipped with different sensors, and therefore can compliment each other.

The subsumption model assumes that intelligence is emergent, and prioritises lower level behaviour over higher abstraction [2]. This is done by letting functions that are less complex take priority over more complex one, such as sensor data and collision avoidance.

How could an adaptation of the subsumption model be applied to individual drones in a drone swarm? Here is one suggested example. Layered behaviour in individual drone:

- Safety: Obstacle and collision avoidance.
- Communication: Maintain communication with swarm members
- Task-specific actions: Perform the task-specific actions required to finish the task, such as investigating a point of interest.
- Swam coordination: Coordination, swam control and role assignments.

[1] https://www.fmv.se/

Each lower layer takes priority over next higher one. If a drone detects a collision in layer one, it will stop its task in order to avoid said collision.

To solve the hypothetical case it is assumed that the abilities in the list below are implemented

- Task Assignment: The drones receive a high-level task from the ground station. The task could consist of analysing points of interest in a given area.
- Role allocation: One drone will be responsible for identifying points of interest, while the other drone will investigate these points of interest further.
- Drone-drone communication: The drones can communicate directly with each other, without having the need to constantly contact the ground station. This could be information such as points of interest of collaborative information or status reports.

Research question 1: How will a group of UAVs receive a task without further instructions from a base station.

Research question 2: How capable are drones of cooperating when using the subsumption model?

3. Method:

The thesis report will be written continuously during the project. The following steps will be completed sequentially, but may iterate back when required:

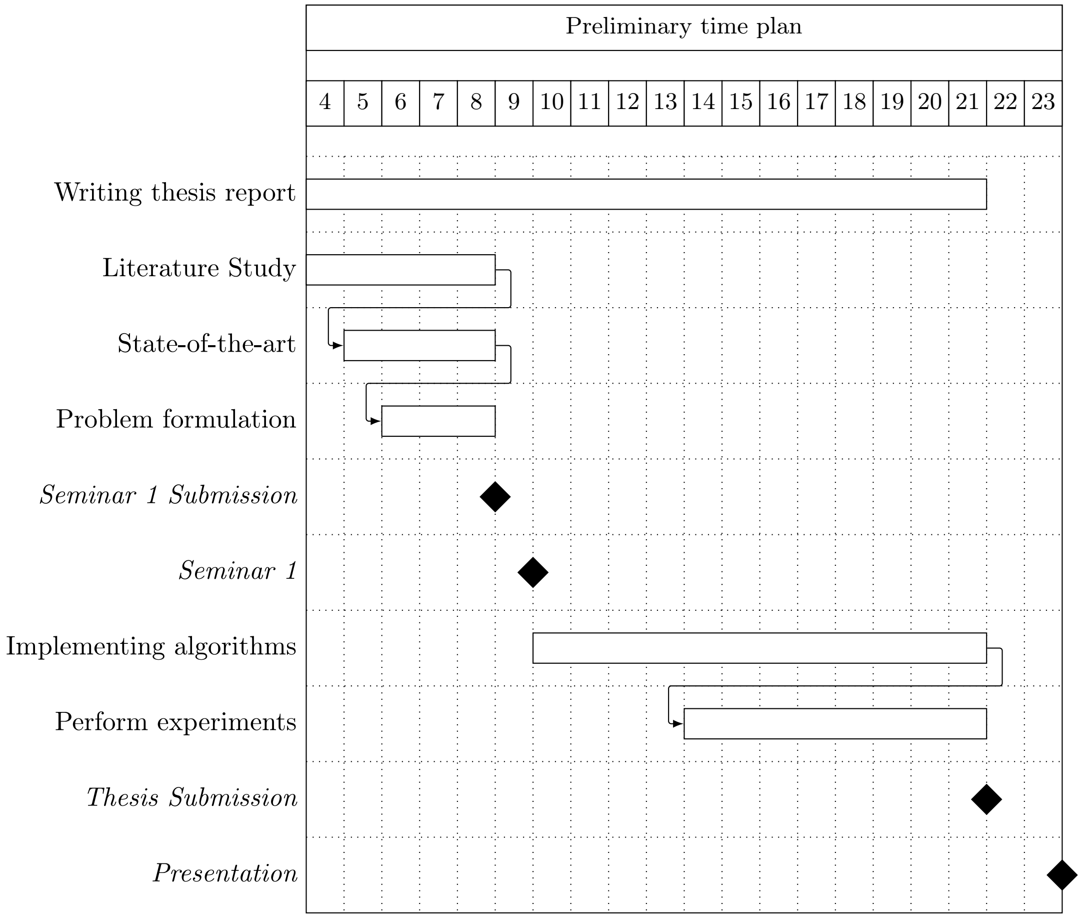
- Literature study
- State-of-the-art
- Problem formulation
- Algorithm implementation
- Algorithm behavioural simulation
- Perform Real Experiments
- Analyse results

4. Outcomes:

This project aims to produce an algorithm capable of a high level control over drones that have inter-drone cooperation, running the subsumption architecture. It will determine if this system is beneficial for task execution in swarm behaviour.

Additionally, the design of the collaboration algorithm should be written on a high level, such that it is possible to add more drones or different sensors without breaking the algorithm.

5. Initial time plan:



6. Limitations:

This thesis will not aim to write or improve image processing techniques that allow a software to identify objects or natural phenomena. It will solely focus on the collaboration between two (2) UAVs and the implementation of either the algorithms mentioned in section 3. or similar.

Regarding the hardware, two UAVs has been ordered (components are listed in Table 1). As of now it is uncertain when they will arrive since the company tasked with building the UAVs have a great demand and potentially a backorder.

Table 1: A Bill of Materials (BOM) of the components for the UAV

Components
UAV frame T650
Motors for T650
Propellers for T650
Electronic Speed Control (ESC) 4in1
Pixhawk 6C
H-RTK F9P Helical GPS
T650 power distribution board
Intel Next Unit of Computing (NUC)
RAM for NUC 2×8
500GB SSD for NUC
FPV Camera
Thermal Camera 160×120
Thermal Camera Board
Stereo Luxonis OAK-D S2
Livox MID-360
Altitude LIDAR Sensor
5G Module M2
Radio Transceiver/Ground Control Station with 5.5" Liquid Crystal Display (LCD)
Battery 2200mAh 6S 30C
Transport Box
Drone Cover
Low Voltage Battery Buzzer
Customized 3D Printed Holders
Cables
Connectors

7. For thesis with confidential data, how will this be addressed:

Although the thesis will be in contribution with FMV who deal with classified information this thesis will not include any classified information. The authors will not have access to SDF or FMV abilities or limitations. The assigned supervisor from FMV will, in cooperation with the responsible security authority, keep a continuous dialogue and steer the authors such that any information that could be considered confidential will not be included in the final report.

References

[1] X. Zhang, T. Zhang, G. Wang *et al.*, 'Remote sensing object detection meets deep learning: A metareview of challenges and advances,' *IEEE Geoscience and Remote Sensing Magazine*, vol. 11, no. 4, pp. 8–44, 2023. DOI: 10.1109/MGRS.2023.3312347.

[2] R. A. Brooks, 'Elephants don't play chess,' 1990, pp. 3–15.