Initial Plan

Drone Transportation Protocol for High Traffic Areas

CM3203 – One Semester Individual Project
40 Credits

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Project Description

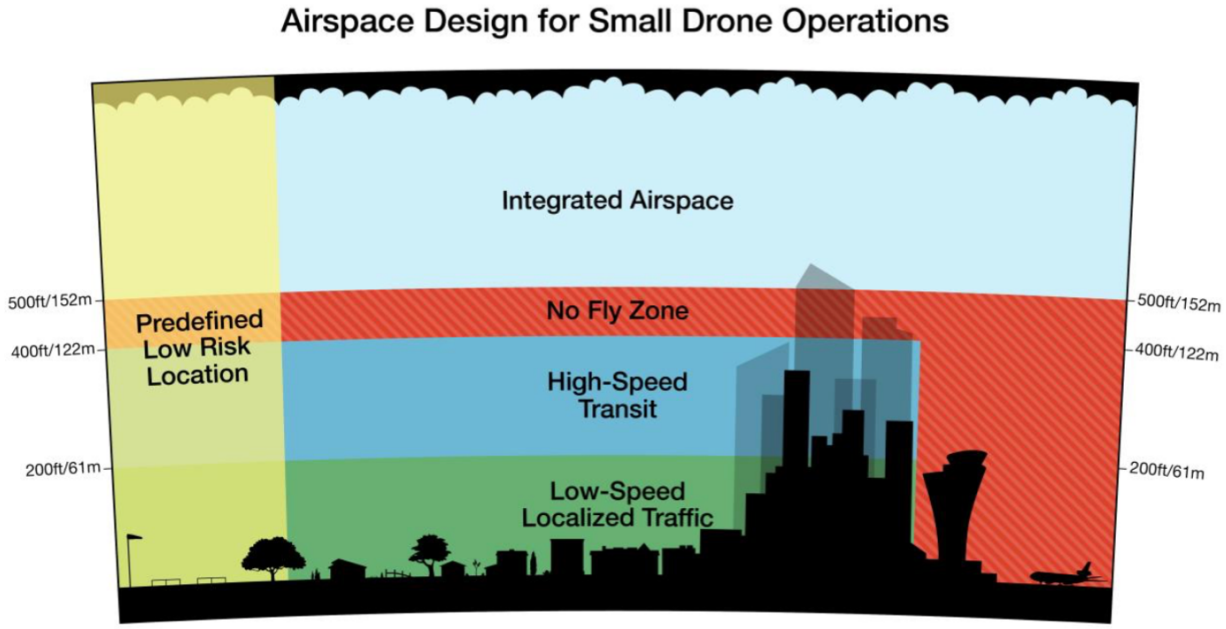
Autonomous drone transportation is currently a huge area of interest that is being explored by companies including Amazon and Google, and it will likely change the way that the delivery, surveying and other functions of these businesses will operate in the near future.

For my project I propose implementing a Drone Transportation Protocol that could potentially allow hundreds of drones to navigate shared airspace safely, efficiently and autonomously. I plan to explore how game theory can be utilised to develop efficient (i.e. minimal collision avoidance required) non-collaborative route planning. My aim is for the protocol to fit into the 'Better' category class (See Drone Classification section below). This will require the protocol to facilitate autonomous control and collaborative Sense and Avoid (SAA) technology.
To test and validate this protocol I will develop a virtual testing platform that will be able to simulate drone journeys and gather performance metrics.

As there is currently no legal framework within which totally autonomous drones can operate in the UK, I will use Amazon's recently proposed regulations to guide the standards that I will hold my drone protocol to. Amazon's proposal is covered in *"Revising the Airspace Model for the Safe Integration of Small Unmanned Aircraft Systems"* [Appendix item A] and *"Determining Safe Access with a Best-Equipped, Best-Served Model for Small Unmanned Aircraft Systems"* [Appendix item B].
Amazon's proposal covers two main points:

1. How vertical airspace should be treated to enable the safest possible drone operation.
2. Different levels of drone classification which state the operational limits applied to drones in relation to area type the drones are flying above.

Airspace Classification
Below is Amazon's diagram detailing their suggested airspace design:



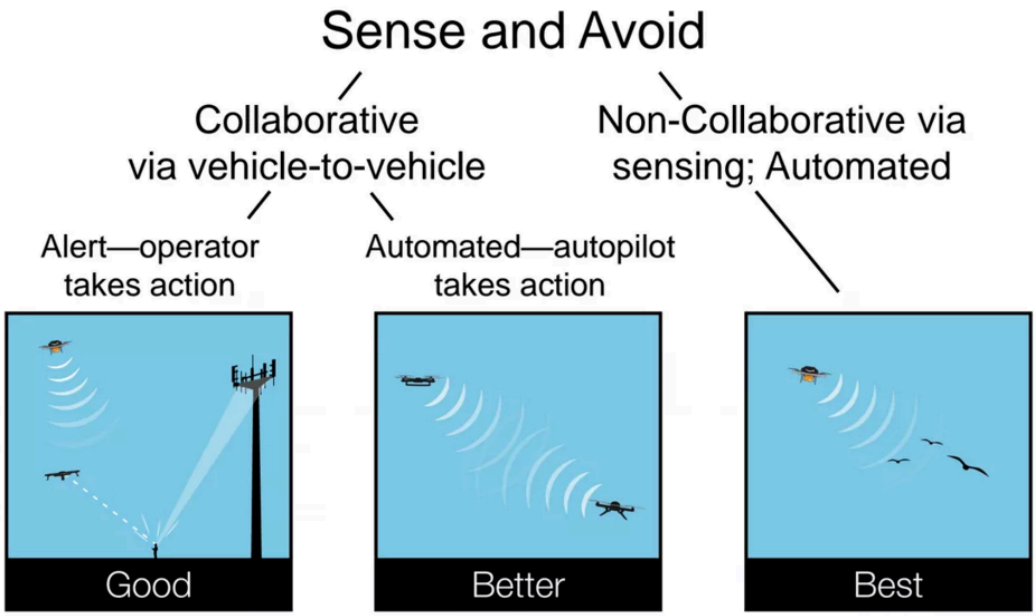
Amazon suggest segregating airspace based on vertical height and ground area type:

- Height:
  - **Ground level to 200 feet** is reserved for Low-Speed localised traffic.
    - Lesser-equipped drones and non-transit operations (such as surveying or video/photography operations) are permitted in this airspace.
  - **200 feet to 400 feet** is reserved for High-Speed transit.
    - Well-equipped drones are permitted in this airspace.
  - **400+ feet** is a No Fly Zone for drones.
- Ground Area Type:
  - **Restricted Areas**, such as airports or government space, will not allow drone operation.
  - **Predefined Low Risk Zones**.
    - Areas where special restrictions are established in advance. These areas may be used for activities such as drone research or drone recreation.
  - **Urban, Suburban and Rural Areas** affect which classes of drones can operate in that area and the limits of their operations.

<u>Drone Classification</u>

Amazon suggest classifying drones into four categories based on their ability to automatically Sense and Avoid (SAA) obstacles:

- **Basic**
  - Radio controlled drones.
  - Zero SAA technology.
- **Good**
  - Ability to announce identity, location and activity to other drones via Vehicle-to-Vehicle (V2V) communication.
  - Ability to alert operator when manual action is needed.
    - Sense-only technology.
- **Better**
  - Autonomous control.
  - Capable of collaborative SAA via V2V communication.
    - Ability to autonomously avoid other drones and ‘smart-enabled’ obstacles.
- **Best**
  - Autonomous control.
  - Capable of collaborative SAA.
  - Capable of non-collaborative SAA.
    - Ability to autonomously avoid any other obstacles, e.g. birds.



[Appendix item C]

Amazon has suggested comprehensive limitations on which classification of drone is permitted to operate over different ground area types, however I plan to deviate from these for my project. For my project I will make the assumption that the 'Better' classification of drone is safe to operate in urban areas up to 400 feet outside of the line of sight of the operator.

Project Aims and Objectives

This project has a very broad scope, so for each objective I will have primary areas of focus and secondary aims which I will consider throughout the project and hopefully explore given the opportunity.

Project Objectives

1. Develop a Drone transportation protocol that utilises non-cooperative route planning.

- Primary Aims:
    - Implement non-cooperative route planning techniques that utilise game theory to minimise collisions of single destination drones (i.e. drones that start at point A and finish their journey at point B).
    - Identify safe operating limits, such as maximum speed and minimum proximity of drones.
- Secondary Aims:
    - Facilitate multi-destination drones and non-linear journeys (e.g. the journey of a surveying drone).
    - Explore centralised route planning as an alternative to non-cooperative route planning.

2. Develop a drone communication protocol that enables V2V SAA collision pre-emption.

- Primary Aims:
    - Identify a viable technology for wireless communication between drones which has suitable characteristics, such as acceptable range of communication and power consumption.
    - Implement a communication protocol that determines appropriate action required for V2V SAA collision pre-emption and does not result in deadlock.
- Secondary Aims:
    - The protocol should be able to resolve situations when it encounters drones running unknown protocols, while considering the correct level of 'politeness' for the protocol to adopt.
    - Explore safeguards that can be taken against malicious drones that attempt to obstruct or redirect the drone's journey in some way.
    - Appropriately respond to 'emergency service' requests.

3. Develop a virtual drone testing platform that will enable testing and validation of the developed communication and transportation protocols.

- Primary Aims:
    - Develop a simplified model that can gather performance data on implementations of the drone transport protocol.
    - Develop a model that can test the communication protocol against failure.
- Secondary Aims:
    - Demonstrate the implemented drone protocol running within the virtualised testing platform. i.e. the testing platform will be able to emulate the code written to run on the drone.

Non-goals

- I do not plan to explore or implement any non-collaborative Sense and Avoid technology, required for the 'Best' drone classification.
- I do not aim to have a demonstrable physical drone, my project will be based entirely around software implementations and virtual demonstrations.

Work Plan

Week Number	Drone Transportation Protocol	Drone Communication Protocol	Virtual Testing Platform	Milestones / Reviews
Week 1				Milestone: Submit Initial Plan
Week 2	Identify (with justification) operational limits (such as speed, proximity) of drones that I will adhere to in this project.			

	Identify live-state information that needs to be tracked during flight. Explore and design how Game Theory can be applied to non-collaborative route planning.			
Week 3		Compare wireless communication protocols that could be utilised for V2V SAA and determine the best choice. Plan possible SAA scenarios and design the required action that should be taken.	Prepare and set up working environment using open source code from DroneKit that I will use for programming and simulating the drones in this project.	Milestone: Have first draft of Approach section of report complete.
Week 4	Implement transportation protocol initialization step: non-collaborative route planning.			Milestone: Complete implementation of non-collaborative route planner.
Week 5		Design communication protocol interaction that takes place when drones encounter each other.	Design and implement simplified model test that can calculate success/fail rate of non-collaborative route planning method.	**Progress Review.** Milestone: Have working environment set up. Alternate plan if milestone not met: Determine testing methods that do not require DroneKit's open source software.
Week 6	Implement transportation protocol execution step: controlling the navigation from start to destination.			Milestone: Have first draft of Implementation section of report complete.

Week 7	Comment: Implementing drone control is a high risk task so I recognise that implementation may continue into week 7.		Design and implement unit tests for the Communication Protocol, which would test how the SAA technology reacts to different scenarios.	
Week 8		Implement the wireless communication protocol.		**Review before Easter break.** Milestone: Complete implementation of Transportation Protocol.
Week 9		Implement the SAA drone control code.		
Week 10			Prepare high fidelity virtualization environment.	Milestone: Complete implementation of Communication Protocol.
Week 11			Integrate Transportation protocol with high-fidelity virtual environment.	
Week 12			Integrate Drone Communication Protocol with high-fidelity environment.	
Week 13	Contingency time for unforeseen extensions to planned tasks.			**Review for final report writing.**
Week 14	Writing report.			Milestone: Draft of final report complete. Discuss in meeting.
Week 15	Writing report.			Milestone: Completed Final Report.

Background

While carrying out this project I will utilise open source projects that are relevant and useful:

- 3DR's DroneKit contains a Python based API that can control operation of the drone. It is designed to be run on companion computers that connect directly to the drone flight controller (https://github.com/dronekit/dronekit-python).
- 3DR's DroneKit-SITL (http://python.dronekit.io/develop/sitl_setup.html) is a virtual drone platform that expands on DroneCode's SITL Simulator (http://dev.ardupilot.com/wiki/sitl-simulator-software-in-the-loop/) by adding access to their Python API. I plan to utilise this to develop my Testing and Validation platform.

Ethical Issues

It is important to consider any ethical issues that may arise during my project. Although I only plan to create a virtual demonstration of my drone protocol, I will consider the ethical issues as if the project will continue development into the physical real-world testing phase.

Legal –According to the Civil Aviation Authority (CAA), the legal frameworks that govern the use of fully autonomous drones in the UK are still "evolving". It is important that drones are operated within standards that protect citizens' safety and legal rights, so for this project I will be using Amazon's drone regulation proposal to guide the legal boundaries that I need to consider during my project. When I deviate from these guidelines I will give my justification for doing so.

Safety –The safety of human life is paramount in the use of autonomous drones, and safety to property is an important consideration too. The virtual testing platform will generate models that can predict when a failure may occur, and will be used to identify and fix issues while in the virtual testing phase.

Privacy –Drones may require collected images or wireless data from external sources to operate most effectively. It is important that only the minimum amount of data that is required is collected and that sensitive data is not stored long-term without a valid reason and the appropriate permissions.

Licensing – Like Net Neutrality, the licencing of autonomous drone technology should be open to all and should not be swayed in favour of big businesses or individuals. Access should only be granted upon meeting the required legal standards. There should also be specific predefined cases where government emergency services can overrule drone operations.

Jobs –The creation of autonomous drones could impact existing jobs and affect wealth distribution. This is a huge ethical issue with unclear repercussions or solutions. If my project was being utilised by big businesses with a responsibility to their workforce, they would need to take this into consideration.

Appendix

A. Revising the Airspace Model for the Safe Integration of Small Unmanned Aircraft Systems, publish by Amazon
   https://images-na.ssl-images-amazon.com/images/G/01/112715/download/Amazon_Revising_the_Airspace_Model_for_the_Safe_Integration_of_sUAS.pdf

B. Determining Safe Access with a Best-Equipped, Best-Served Model for Small Unmanned Aircraft Systems
   https://images-na.ssl-images-amazon.com/images/G/01/112715/download/Amazon_Determining_Safe_Access_with_a_Best-Equipped_Best-Served_Model_for_sUAS.pdf

C. Diagram taken from The Verge article: “Amazon provides new details on its plan for a drone superhighway in the sky”
   http://www.theverge.com/2015/7/28/9058211/amazon-new-details-plan-delivery-drone