4th year project
Automated Drone Air Traffic Control System

Research Document

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Abstract

With the advent of drone technology, there is a growing opportunity for the usage of drones for taking part in delivery systems.The purpose of this project is to create an application that would function as a form of traffic control system for a drone or fleet of drones, for the purpose of carrying out deliveries. This could include food delivery services (Just Eat) or packages(Amazon). The ideal usage for this technology would be the use of automated drone systems, to allow drones to carry out deliveries safely and efficiently, without the need for individual operators for individual drones.

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1. Introduction

With the advent of drone technology, there is a growing opportunity for the usage of drone systems for basic delivery systems. This could include food delivery services (Just Eat) or packages(Amazon)(Gelinas, 2019). The ideal usage for this technology would be the use of automated drone systems, to allow drones to carry out deliveries without the need for individual operators for individual drones. The purpose of this project is to create an autonomous drone traffic control system that would be able to control a fleet of delivery drones.

The research for this project will involve taking a look at some of the different types of drones available, and their suitability for the purposes of delivery systems. The research will also include looking at current real world air traffic control systems and deciding how to implement them for drone based flight. The legal aspects of automated drone systems will also be studied. The development languages and the possible platforms upon which the project can be developed will also be considered.

2. Overview

2.1 What are Drones?

In aviation and spaceflight, a drone is the vernacular term given to any form of unmanned air vehicle (UAV) or unmanned spacecraft (Howell, (2018). This term is open to interpretation, and there is some argument to be made for what is and is not classed as a uav (Villasenor, 2012). Drones can vary wildly in function and design, but for the purposes of this project we can look at the two main types of drones used recreationally and commercially, with a view towards the ideal type for a delivery system.

2.1.1 Fixed wing drones

Fixed wing drones resemble traditional airplanes in that they consist of a winged structure. Fixed wing drones are unable to take off and land vertically and need some form of runway to do so. They have no hover capability, so can not maintain a stationary position in flight. The use of a fixed wing however, allows them to utilise lift to increase the efficiency of their flight. This allows them to stay in the air for a longer period of time than other types of drone and so cover much larger distances. This makes them ideal for mapping and surveillance purposes (Jojo, 2020).

Fig 1. Fixed wing drone [Mark14]

2.1.2 Multi Rotor Drones

Multi Rotor Drones are the most common type of drone used commercially and at an enthusiast level. They are most commonly used for aerial photography and surveillance. They are the easiest and cheapest drones to manufacture. The stable nature in flight afforded by the ability to hover make them the easiest to pilot. The downside of these drones is that they do not have a wing structure and so a lot of energy goes into keeping the airborne, leading to much lower flight times than fixed wing drones at around 20-30 minutes.

Fig 2. Multi rotor drone [Jojo20]

2.1.3 Drones for Delivery Usage

The ideal drone type for a delivery type drone would be a multi rotor drone. Its ability to hover, as well as take off and land vertically, would make it ideal for delivery of items to specific addresses and as it would not require a runway it could land in a much wider range of locations. It would be ideal for usage in localised areas such as towns or cities due to the limited flight time and high population density. Though the benefits to the environment as well as from a cost saving (Yoo, W. et. al. (2018) perspective are clear for this form of delivery over traditional forms, there is an even greater environmental benefit to rural drone delivery over traditional forms (Park, J. et. al., 2018).

2.2 Traditional Air Traffic Control

2.2.1 Air traffic control in Ireland

Air traffic control in Ireland is overseen by the Irish Aviation Authority (IAA). The IAA manages the safe and orderly flow of traffic throughout Irish airspace, as well as at the nation's three national airports of Dublin, Shannon and Cork. It is the responsibility of the IAA to keep aircraft at a safe distance from each other, both in the air and on the ground, as well as organising them for optimised landing and take off along arranged flight paths(IAA, 2020).

There are several types of air traffic control undertaken by the IAA.They are:

Aerodrome control
Known commonly as tower control, it is the most visible and well known type of traffic control. The IAA is responsible for providing tower control at the state's three airports. From

the tower, it is the controllers duty to guide all aircraft operations within the airport control zone and on the ground at the airports.

Approach radar control
The approach controller is responsible for arriving aircraft with 30-40 miles of the aerodrome. They sequence traffic for arrival and line them up with the runway. They ensure the standard separation of 5 nautical miles and under certain circumstances, 3 nautical miles. This reduction in separation is permitted under international standards at busy airports to increase the efficiency and capacity of these airports. Dublin airport is one such airport that qualifies under these conditions. The controller uses techniques such as speed control and changes in altitude and direction measured using radar vectoring to ensure separation and sequencing.

Area radar control
Area radar control performs a similar function to approach radar control, though the range is increased. The busier an area is or becomes, more radar positions are added to reduce the individual controller’s workload. Each sector has a capacity to ensure controler do not become overloaded. In Dublin, controllers handle traffic up to 24,000 feet, whereas in Shannon they handle traffic up to 66,000 feet.

2.2.2 Separation Standards

The IAA applies separation standards to keep the aircraft in it’s controlled airspace at a minimum safe distance from each other. There are different standards set depending on the type of aircraft. For instrument flight rules aircraft, the minimum vertical separation is 305 meters and the horizontal separation is 5 nautical miles or 9260 meters.

For visual flight rules aircraft, the aircraft operate on a see and be seen ruleset and are free to set their own minimum flight separation.

Aircraft are also allowed to fly no lower than 305 meters above ground level in built up or residential areas, and no lower than 152 meters in non built up areas. For helicopters a blanket lower ceiling of 152 meters applies.

2.2.3 Airways

The majority of civil air routes are flown along airways, normally these are 10 nautical miles wide with midpoints defined by point-source radio navigation aids spaced close enough for accuracy in line with specifications. Each airway has a type of corridor that is a rectangle in cross-section and is well above ground level. The airspace within the Airway is controlled and traffic is separated by being assigned different heights by Air traffic control. They are generally made up of route segments linking two waypoints (Gunston, B. 2004, p.34).

2.2.4 Air Traffic Control for Drones

Much like in traditional air traffic control, the creation of a system for the safe operation of drones would require the creation of safe flight “corridors” for the drones to operate within. These would need to be created in such a way that they do not interfere with the safe operation of traditional aircraft, while also maintaining a safe clearance above ground based obstacles. A minimum safe distance for drone to drone encounters would also need to be established, in order to prevent collisions. The advantage of multi rotor drones over fixed wing aircraft is that there would not need to be large conical flight corridors surrounding take off and landing sites, which would simplify the requirements versus traditional airports. Any system designed to take the role of an air traffic control system for drones would need to be aware of these corridors and their boundaries in order to direct drones safely within them. Furthermore, such a system may need to take into account any privacy concerns of landowners or residents whose land they may pass over (Foina, A. 2015)

2.3 Automated Drone Systems

2.3.1 Drone Automation

The idea behind drone automation is to attempt to remove the need for constant human supervision of individual drones at a basic level of control input. This would require the creation of a system that is capable of taking over the basic functions of the human controller. Ideally the human user of the system could tell the system where it wants a drone or drones to go, and the system would be able to get the drone/s there without issue. It would be capable of sending pathing and velocity instruction to the drone/s and have the drone respond. The drone would also need to be in constant contact with the system so as to accurately relay their positional data to the system. The system would also need to be cognisant of the drones remaining battery power and the remaining flight time this would afford as well as any effects on flight time from any load carried. There have been a number of high profile attempts to create such systems for delivery applications in recent years.

2.3.2 Amazon

Amazon is one company that has announced plans to create a fleet of delivery drones. It originally announced the plans in 2013 [Geli19], and had expected to begin operation in late 2019. Though to date, the plans have failed to materialise.

Current specifications for Amazon’s planned service include a 24km radius for deliveries, and a maximum package weight of just over 2.25kgs. The receiver of a package will also need to have a suitable space nearby for the drone to land, in order to collect the package.

2.3.3 Domino’s and Flirtey

In 2016 Domino’s pizza in New Zealand, in partnership with Nevada based Drone delivery company Flirtey, began offering a drone delivery service to a select group of customers. At the time Domino's group CEO Don Meiji said "Drones offer the promise of safer, faster deliveries to an expanded delivery area. . .Meaning more customers can expect to receive a freshly-made order within our ultimate target of 10 minutes." (Buck, 2016)

In June 2020, Domino’s carried out a drone delivery of a pizza to customers on a beach in Zandvoort on the coast north-west of Amsterdam. In the Netherlands, Domino’s delivers pizza to gps coordinates as well as addresses, and this project is aimed at looking into the feasibility of deliveries to harder to reach places that conventional delivery vehicles, such as bikes and cars, cannot reach. A spokesperson for Domino’s remarked that “When we can actually deliver with drones depends, among other things, on legislation.”(Beedham M., 2020)

2.3.4 Health Service Executive Ireland

In April 2020 the HSE in Ireland, in partnership with Manna Aero began trials on a service to deliver needed medicine to vulnerable people in rural areas. The first trials took place around Moneygall in Co. Offaly. Manna Aero claims the straight to home deliveries represent the final stage of a “closed loop” end to end system that is first for drone delivery. The system uses a mobile “command center” for the drone based at Barack Obama Plaza motorway services and is equipped to handle up to 100 deliveries per day (Molly, 2020).

2.4 Legal Issues with Automated Drones in Ireland

There are many legal hurdles to achieving a fully automated drone delivery system. Airspace has already been set aside for traditional air traffic, so drones are required to operate below this ceiling. In Ireland drones are not allowed to operate more than 120 meters above ground level. For the purpose of automation, drones would also have to operate above a safe height so as not to come into contact with buildings, and any higher buildings, antennas and other structures would need to be navigated safely. Currently existing roads would seem to be an obvious choice for this navigation, though there is a grave safety concern here from possible malfunctioning drones falling from the sky, and current Irish legislation prohibits the operation of drones within 120 meters of any person or vehicle not in the direct control of the drone operator(IAA, 2020). Furthermore, drone operators are not allowed to operate a drone outside of direct line of sight, or more than 300 meters away. This means that under current legislation, special permissions are required to allow for autonomous drone flight within Irish airspace.

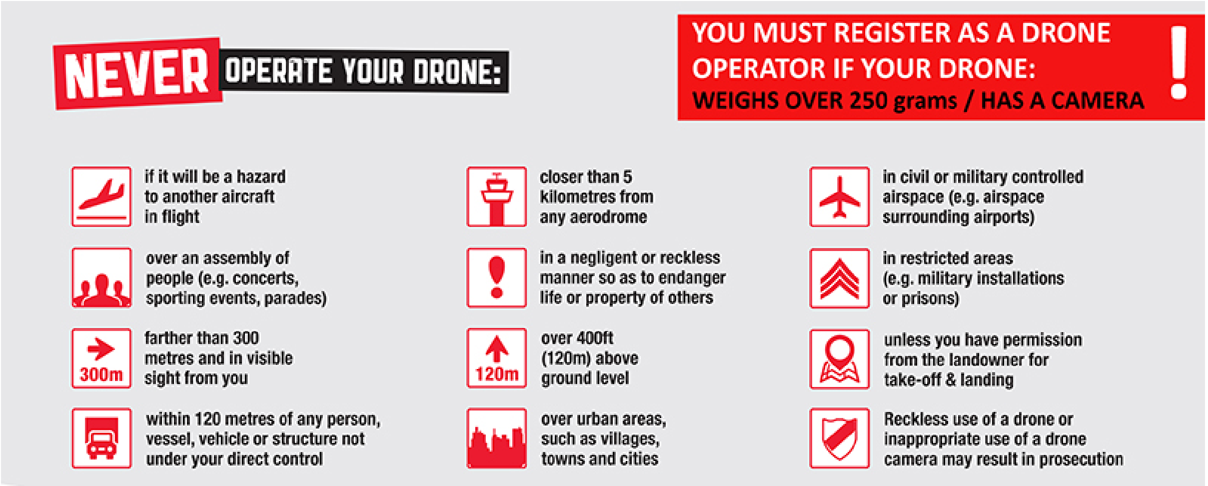

Fig 4. Irish drone operation guidelines [Iaa20]

Amazon has proposed a potential solution for these issues going forward, through the creation of dedicated "drone highways" in traditional airspace. This would allow for high speed drone flight in the airspace from 61 meters to 121 meters above ground level, with low speed localised traffic in the airspace from 61 meters to ground level (Mac, R., 2015).

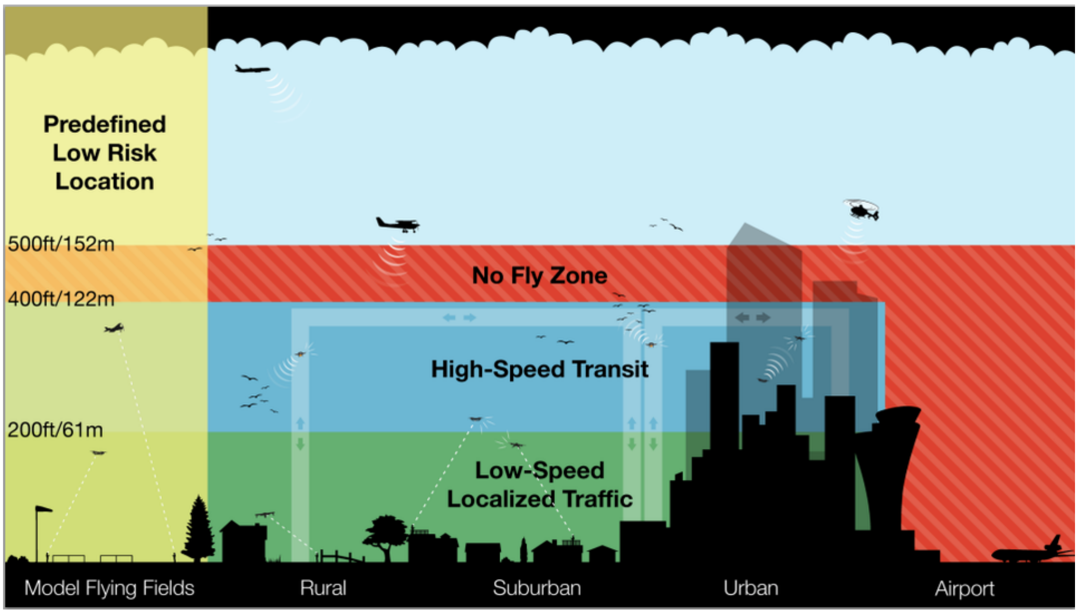

Fig 3. Amazon proposed a segregated airspace below 500 feet for the operation of drones.[Mac15]

2.5 Conclusion

Given that a delivery drone would have to be able to land in a variety of areas, the multi rotor drone type would be the most suitable type for use in a drone delivery system. The system would best function by having the ability to create corridors for drones to safely navigate through to their destinations, in a similar way to how traditional air corridors operate. One advantage multi rotor drones have over traditional fixed wing aircraft, is the ability to hover. This would allow for drones at intersections of flight corridors to stop briefly, to allow other drones crossing their paths to do so safely. This could be achieved through a first come first served system. The system would need to be in constant communication with the drones, with the drones relaying real time data on altitude, position, speed and direction of movement to the system, and the system relaying instructions to the drones on any adjustments that would need to be made to facilitate a successful and safe flight to the correct destination.

3. Technology

3.1 Possible Operating Systems for Development

3.1.1 Desktop Operating Systems

There are a variety of operating systems (OS) with which the finished application would ideally be compatible with. Microsoft's Windows is the most common platform by far on desktop devices with a 76.32% market share, followed by MacOSx at 17.65% and then Linux and Chromium, both with just under 1.6% of the market. Windows is the platform of choice for DJI drones SDK and Linux is the platform of choice for Parrot drones SDK.

Windows is a proprietary OS developed and owned by Microsoft that retails for between $USD99 and $USD199 for a licensed copy. It's immense popularity compared to other OSs make it a compelling choice for desktop application development. This popularity makes it compatible with a wide variety of software and hardware options.

Linux is a free to use open source OS which comes in a variety of distributions or "flavours" and can be downloaded to and run on most desktop devices. It is generally considered to be more lightweight than Windows and its open source nature means that the user is afforded greater control over the OS than a user using Microsoft's proprietary system (Computerhope.com, 2020).

3.1.2 Mobile Operating Systems

On mobile devices, Google's Android has a market share of 72.92%, followed by Apple's IOS with 26.53% of the market. Android has created a more developer friendly environment as anyone can download and develop for the platform using Android studio (Android.com, 2020). Applications can be written in Java and can be hosted on any site and downloaded to an Android device without needing to be accepted to Google's Play Store (Melnichuk, A., 2019).

Applications on IOS are written for the most part in Swift. App development for IOS takes place on Apple's Xcode development suite (Apple.com, 2020). Xcode must be installed on a system running MacOS, which increases the initial cost to development (Melnichuk, A., 2019).

3.1.3 OS for a Drone Control System

Given the nature of the project, the ideal OS to develop this application on would be a desktop system. A desktop system would allow for the creation of a more powerful system than on a mobile platform. Ideally the application would be able to run on multiple platforms, with Windows being ideal for its market dominance, and Linux also having value for its versatility from a users perspective. A mobile system may have value for setting up networks in remote areas, though for this project and a proof of concept, A desktop platform would be the logical option for development.

3.2 Software Development Kits

As the application should ideally be able to work with as many different brands of drone as possible, The author has looked at the use of Developer Software Development Kits (SDKs) from the top 2 leading enthusiast brands (Global Brands Magazine, 2020) DJI and Parrot.

3.2.1 DJI Drones

The DJI Developer Software Development Kit SDK is a Windows based SDK that allows users to develop an application for the Universal Windows Platform (UWP). It allows developers to create and integrate applications that can control certain DJI drone types.

Currently supported drone types are the DJI Mavic Air and the Phantom 4 Pro V2.0. These are newer and more premium versions of the DJI drone lineup, creating a relatively high cost barrier to entry for development.

There are also 2 forms of virtualisation software available for DJI, in the form of their DJI Assistant 2 and the older DJI PC Simulator software. Both of these allow for virtual input and feedback for testing application interfacing through the API. However, they both require a physical and compatible drone to be connected via USB to the PC running the software, as the software runs the simulation in the onboard flight controller of the aircraft (Developer.dji.com, 2020).

3.2.2 Parrot Drones

Parrot's Olympe SDK provides a Python based controller programming interface. It allows for the use of both real and simulated drone flight, with the simulation being visualised through their Sphinx software running on Gazebo, a 3d visualisation tool. Olympe is available on the Linux platform and has been tested by the developers on Ubuntu 18.04 and works on Debian 9 or higher. The software is written in the Python programming language and allows the control of Parrot drones through Python scripts. The integration of the Olympe SDK with the Sphinx virtualisation software allows potential developers to use a virtual version of a number of Parrot drone types without the need for a physical drone on hand (developer.parrot.com, 2020).

3.2.3 Conclusion

Ideally, the author would like to be able to develop the application to be compatible with a variety of drone types. For the scope of this project however, as access to suitable DJI drones is not available. The application will be built and tested using a Parrot Bebop 2 drone using the Olympe SDK. Though the application will be tested using the Olympe SDK, it would ideally be as generic as possible to easily facilitate the inclusion of compatibility for other drone types in the future however.

As Olympe only runs on Linux based systems, specifically Ubuntu 18.04 and Debian 9 or higher, The application will be developed using Ubuntu 18.04 as this is the latest version of Ubuntu that is verified as compatible by the Olympe developers. As Olympe is written in Python (Developer.parrot.com, 2020), this would be the obvious choice for the development of a proof of concept application, in order to allow easier integration with Parrot API.

3.3 GUI Tools

As the Olympe API is written in Python, the project will most likely be developed using python. As such a number of Python GUI tools were looked for implementing the GUI for the project. PyQt was first looked at and some simple attempts at creating a map implementation were attempted. The process for using PyQt from the perspective of a novice was quite time consuming however, and eventually the author came across Kivy and its Garden Mapview tool, which allows for the easy implementation of Map widgets using Open Source Maps. This map creation widget is very easy to integrate into an app, though it is basic in its functionality.

4. Research Conclusions

For this project the author will be using a Parrot Bebop 2 drone, controlled through the Parrot SDK(software development kit), known as Olypme. Olympe runs on Linux, and for this project Ubuntu 18.04 will be used as it is the last Linux distribution to be tested by the Olympe developers. Parrot also provides a facility for virtual testing of the Olympe SDK through a virtualisation program called Sphinx. Sphinx uses Gazebo, 3D dynamic simulator, to simulate the physical and visual surroundings of the drone. The application will be written in Python, in order to allow for easier integration with the Parrot SDK. The Python library to be used for the GUI will be Kivy, with MapView used for the map implementation.

The application will need to allow the user to create, read (view), update and delete (CRUD) both delivery locations and also set up flight corridors for the drones to utilise. The application will also be able to allow the user to CRUD drones. The application should be versatile enough to easily facilitate the addition of various types of drones. The user should ideally be able to get visual feedback through some form of map, to allow them to be able to view the layout of the delivery network and the position of the various drones active on the network in real time.

The application will need to be able to allow for the safe navigation of drones throughout the network and to have them accurately arrive at their destinations without issue. Problems that will need to be addressed for this will include drone on drone collision avoidance, and accurate and optimum pathing to ensure that drones do not take paths that would cause them to collide with other drones, or take paths that would keep them airborne longer than their flight time allows.

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