Agricultural Drone Survey Application

Research Manual

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Abstract:

Similar to the evolution of most emerging technologies, applications for Unmanned Aerial Vehicles (UAVs) or 'Drones' are now abundant in comparison to what was once considered a singular intended purpose. UAV technologies have now begun revolutionising industries, careers and have even created new jobs. Areas as diverse as property management and humanitarian aid are now benefiting from UAV technologies in countries around the world. For example, in Rwanda drones deliver blood transfusions to a network of 21 clinics each day. However, UAVs as we know them do not have such humble beginnings. UAVs were originally developed and used by the United States Military as a method of surveillance at the turn of this century. With such questionable roots embedded in the technology's history it wasn't until 2015, when the United States Federal Aviation Administration(FAA) authorised 100s of exceptions for recreational and commercial use, that the name 'Drone' consequently became a household name. Agricultural UAV Systems have been at the forefront of this technology's evolutionary path and Agricultural UAV System aims to explore why and what areas are yet to be discovered.

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Section 1 - Introduction

The purpose of this research document is to investigate the history of UAVs, different UAV craft, the legislation surrounding them, their application in and outside of the agricultural industry and possible solutions to problems the agriculture industry faces.

UAVs or drones are often referred to as Unmanned Aircraft Systems (UAS), Remotely Piloted Vehicles (RPV), Remotely Piloted Aircraft (RPA) and Remotely Operated Aircraft (ROA). At their essence, a drone is a flying robot that can be controlled remotely or fly autonomously. Software used to control flight plans work in conjunction with multiple sensors and GPS. While they originated from a military background, their use has expanded into commercial, scientific, logistics, recreational, construction and other areas such as drone racing. Many industries have sought out to utilise UAVs in ways which have previously challenged their industry.
Over the past decade the use and production of UAVs has increased dramatically due to a FAA 'Modernisation and Reform Act' which set a deadline of September 2015 for the agency to establish regulations to allow the use of commercial drones. In December 2015 the FAA announced that all UAVs weighing more than 250 grams flown for any purpose must be registered with the FAA. The FAA issued 1000 drone permits in 2015, this number more than tripled to 3100 permits in 2016 and has continued to grow since.

The Agricultural industry was among the first to take advantage of new legislation. Farmers have started using drones to monitor land and to treat crops. Previously, depending on the size of the farm and the treatment being applied, this was carried out by the use of a tractor and attached spraying apparatus, dedicated spraying vehicle or an agricultural light-winged crop duster. Although the industry was taking advantage of the space above us before the introduction of UAVs, it is believed there are still many areas in agriculture which drones are yet to be utilised.

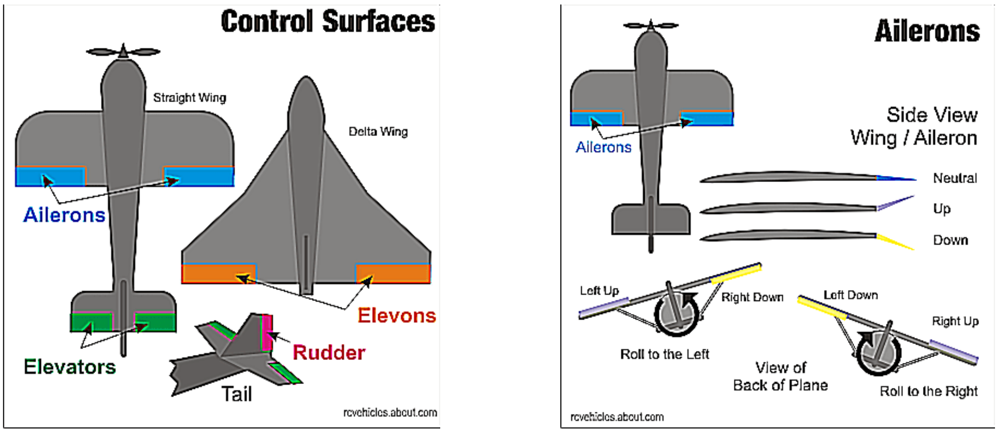
Section 2 - UAV Craft:

2.1 - Fixed-Wing

A fixed-wing drone is a rigid airfoil structure that gains lift by means of forward moving air passing under its wings [1]. A propeller attached to a small combustion engine or electric motor are generally used to generate this upward thrust [2]. These craft are usually made from lightweight durable materials like foams, rubbers, plastics and fiberglass [3].

Figure 1: Fixed-wing AgEagle EX-60 Drone. Source: ageagle.com

These drones use similar principals as fixed-wing aircraft to manoeuvre during flight. Ailerons, rudders or elevators on each control surface pitch up or down in order for the craft to ascend, descend and bank left or right [4]. Fixed-wing drones have been recorded flying at speeds of up to 179km/h [5]. These drones are popular due to their ability



Figures 2 & 3: Fixed-wing Ailerons and Control Surfaces. Source: liveabout.com

to fly at higher altitudes than conventional multi-rotor drones. This makes them particularly useful for surveying and payload delivery. Their design generally makes this type of drone more efficient allowing them to travel further distances and for longer periods of time [1].

2.2 - Multi-Rotor

Multi-rotor UAVs consist of a body and anywhere from 3 and 8 rotors. Each rotor is attached to a dedicated motor which propels air beneath the drone causing lift [6].

"If you want the drone to tilt on one side, two of the rotors will begin spinning faster on one side, creating more lift. In doing so, some of the upward lift becomes more of a sideways force, causing the drone to move forward or backwards. In the same manner, different prop speeds will spin the drone." [6]

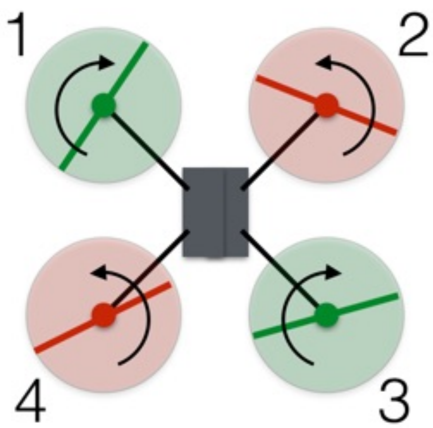


Figure 4: Directional rotary motion. Source: wired.com

Drones tend to use the same types of batteries that our phones, tablets and laptops use and for similar reasons, weight and efficiency. Lithium ion and lithium ion polymer batteries use liquids and solids or gels respectively. Although lithium ion batteries are cheaper and have greater energy density they also pose a higher risk to explosion and are significantly more difficult to produce. In comparison, lithium ion polymer batteries are lighter, have a longer life span but are more expensive [7].

Lithium ion batteries	Comparing category	Lithium ion polymer batteries
3.7 V	Voltage	3.7 V
Relatively heavy	Weight considering voltage vs. discharge rate	Light
Liquid	Electrolytes Type	Solid, polymers
Shorter than	Life	Longer than
Higher than	Risk	Less than
Limited	Product design	More freedom
Cheap	Price	Expensive
Galaxy smartphone, notebook, electric vehicle	Example products	Drone, iPod, iPhone

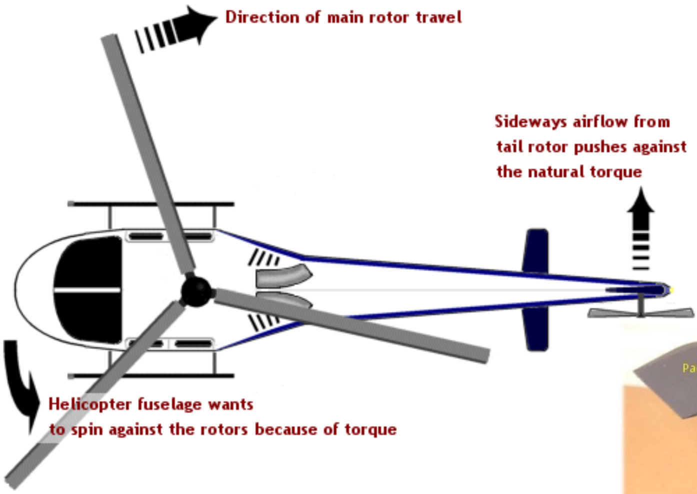
Fig 5: Lithium Ion VS Lithium Ion Polymer Batteries. Source: Drones as Cyber-Physical Systems (2019)

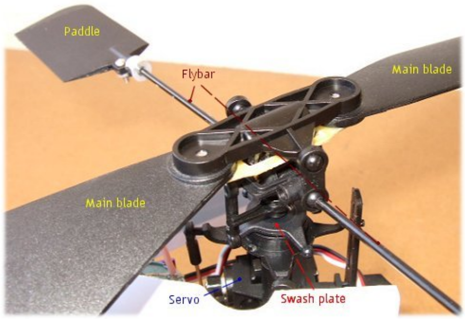
Multi-rotor drones are popular due to seamless flight control and their ability to move seamlessly through 3D space. This allows for unmanned quick launch times and easier landings. Hoovering and camera stabilisation are two key reasons people choose mutlirotor drones over fixed wings. Unfortunately multi-rotor drones are not very efficient and only have a maximum flight time of 20 to 30 minutes. This is largely due to the fact that they use multiple motors and have smaller rotors[1].

Fig 6: DJI MG-1S Agricultural Sprayer. Source: geekerhertz.com (2017)

2.3 - Single-Rotor Copter

A single-rotor copter uses an individual rotor to gain altitude and a tail rotor to control its heading or direction. The design of these types of UAV are typically based on manned helicopters [8]. They’re said to be particularly dangerous due to their sharp blades/rotors and because of this they’re notorious for being difficult to control, costly as well as difficult to repair [9]. Due to the fact that a





single-rotor copter uses one large blade opposed

Fig 7 & 8: Single-Rotor Pitch and Heading. Source: RC-Airplane-World.com

to several smaller rotors for creating lift, they have longer flight times and the ability to carry larger payloads for extended periods of time. Fewer motors means greater efficiency and because a single-rotor copter can be equipped with a gas engine opposed to an electric it extends these flight times further [8].

Fig 9: Single-Rotor Eagle Brother Spraying Drone. Source: auav.com.au

Although this type of UAV amounts for a lesser percentage of the drone market they still hold their place in niche areas. They're commonly used with Aerial LIDAR laser scanning because of their ability to hold heavy payloads and have been popular among military and navy units [8][9]. The single-rotor copter remains popular but among fewer skilled pilots.

Fig 10: Single-Rotor Heli Skeldar V-200. Source: naval-technology.com

Section 3 - Modern Applications:

3.1 - Aerial Surveying

Aerial surveying is the capture of data from ground points so analysis can be carried out on the topography of selected areas [10]. *"Before the introduction of small UAVs for aerial photogrammetry, planes, helicopters and metric cameras were used. Not only was this costly, it was also complex due to the images being taken from high altitudes. UAVs have made aerial mapping more affordable, faster and precise"* [11]. UAVs have made working environments safer for several industries such as Quarrying, Waste Management and Environmental protection due to their ability to provide real-time aerial imaging [10]. Image processing software is used with Global Positioning Systems(GPS) to stitch together both 2D and 3D maps or models. The introduction of UAVs into aerial surveying has reduced cost and made the process more accessible to a greater audience [10].

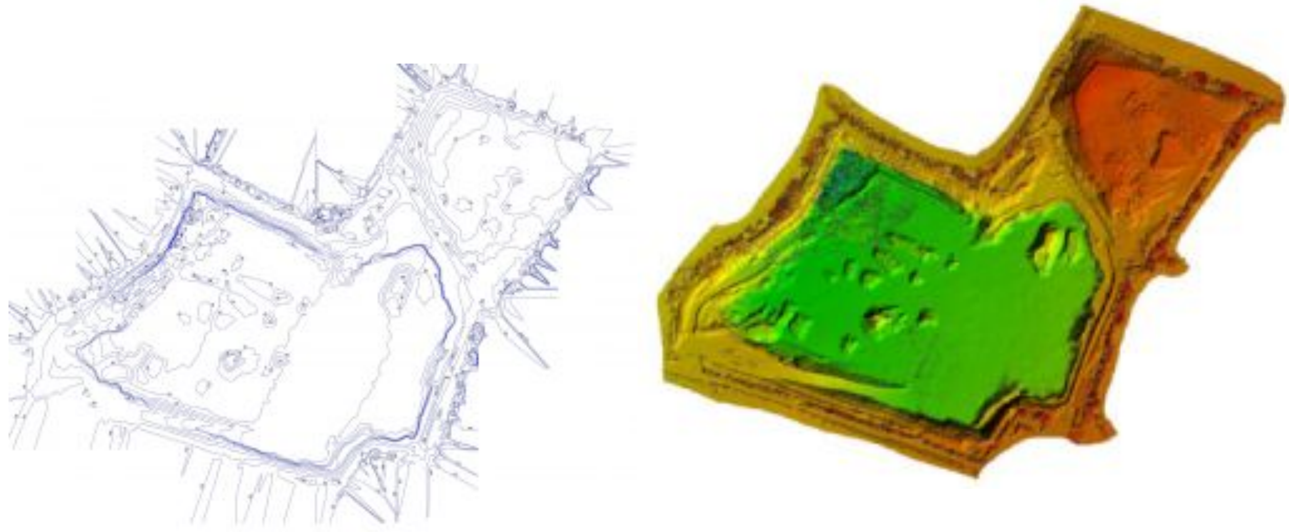


Fig 11 & 12: 2D and 3D Topography Models created by Drone Services Ireland. Source: droneservicesireland.ie/

3.2 - Weather Forecasting

Weather forecasters have used unmanned craft for collecting atmospheric data for centuries. Kites and balloons equipped with thermometers were some of the first instruments used to take atmospheric measurements [12]. Today technology has advanced but some of the methods we use to measure weather conditions have not changed greatly. Meteorologists are still sending probes into the unknown in attempts to collect data. In 2017 NASA used a remotely piloted vehicle(RPA) to collect readings like temperature, humidity, windspeed, pressure and altitude on routine flights above the clouds [13]. This data was then used to adjust and influence weather prediction models.
In 2016 NASA used drones to track hurricane Matthew in the state of Florida. The drones were used to drop sensors into the storm allowing them gather more information about the storm in real-time. *"Using drones allows scientists to tap into the low altitude area finally making weather prediction a very easy exercise especially when integrated with deep learning AI systems"* [12].

3.3 - Rescue Services

"A search and rescue drone is an unmanned aircraft used by emergency services, such as police officers, firefighters or volunteer rescue teams, ideal for searching over vast areas for missing persons…" [15]. Rescue drones are better equipped than most hobbyist drones and can be fitted with photographic measurement systems such as video, thermal or infrared cameras, airborne LiDAR and GPS. Thermal and infrared cameras are useful for detecting a persons heat signature, viewing inaccessible buildings and recognising the

presence of electric power lines. LiDAR technology is being used in times of disaster to create fast and accurate environmental information models of devastated areas [16].

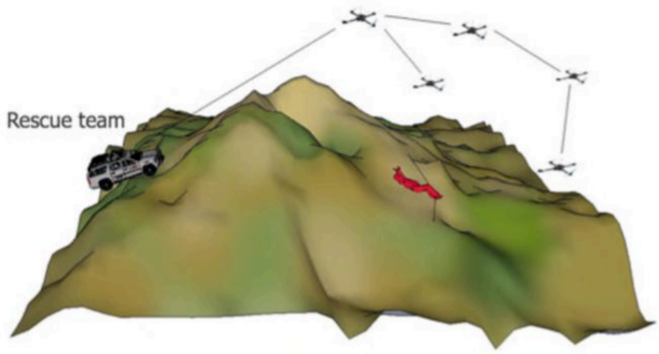


Fig 13: An Example of a rescue scenario using drones. Source: Big Data and Visual Analytics(2019)

Volunteers equipped with drones have began playing larger roles in rescue and disaster relief situations than ever before. Typically emergency departments wait for flight plan approvals to come through aviation administrations, this can be a lengthy process and has motivated volunteers to step in and put their UAVs to work while some organisations await approvals [17]. Volunteer groups like 'Humanitarian UAV Network' and 'SWARM' are international networks of experienced drone pilots honing there skills to help others.
In 2012 UAVs were used to assist rescuers after Hurricane Sandy struck havoc in Haiti and again in 2014 after a earthquake hit Yunnan, China [18]. To date drones have been used for mapping, chemical spills, emergency supplies, assessing structural damage and extinguishing wildfires.

3.4 - Telecommunications

Telecommunication technologies surround us everyday and can be considered the backbone of most modern industries. They drive the technological world we live in and are used in almost every modern device from cars to keys. Drones cannot work without telecom technologies but now the telecommunications industry is starting to employ the technologies it has been resourcing. Tower climbing is considered to be one of the most hazardous professions in the world and can cost a telecoms companies anywhere from $2000 to $5000 per climb. During routine climbs inspections are carried out on the towers, a job which is now being performed by drones. Drones are being used to take videos, photos and perform audits which are then sent to the network carriers on site and can be performed again if required, this significantly reduces risk and can save on time and cost [19]. In 2017 network giant AT&T launched flying COWs(Cells on Wings) to aid recovery after hurricane Maria hit Puerto

Rico. *"Designed to provide LTE coverage from the sky to a particular area on the ground, these flying COWs can be airborne for up to 24 hours nonstop, reach an altitude of up to 400 feet, (500% higher than a traditional mast on a terrestrial Cell on Wheels), and cover an area up to 14 square miles"* [20]. These flying COWs were used to provide connectivity and get network services back up and running for people and emergency services left without communications in the aftermath of the hurricane [20]. PwC has estimated that drone solutions in the telecommunication industry will become a 6.3 billion dollar market [19].

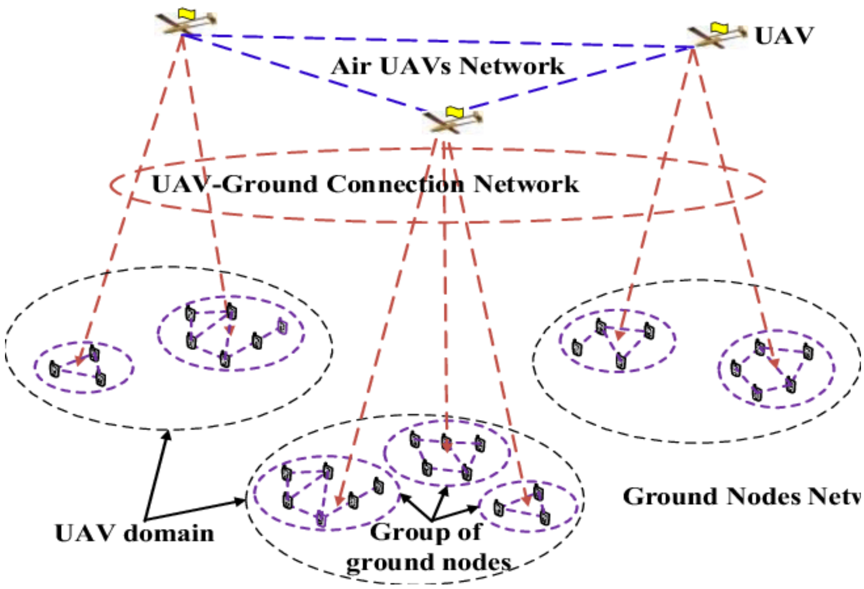


Fig 14: UAV Disaster ad hoc network. Source: ResearchGate.net

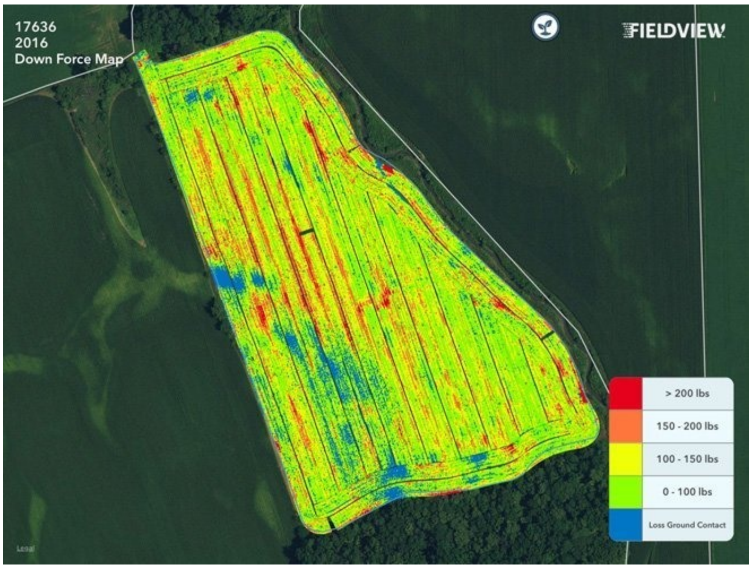
3.5 - Drone Racing

Drone racing was said to have originated in Australia and has since adapted the name rotor-cross. Pilots use first-person-view (FPV) goggles to provide them a point of view from a camera mounted to their drone. This allows users to control their drones from a distance. A racing quadcopter is substantially different from common photography drones. Built for extreme speed, agility and durability, they're controlled directly by the pilot without the use of GPS navigation or other computer assistance. With incredible acceleration and agility, they can reach a speeds of over 160 kmh.

Section 4 - UAV Agricultural Applications:

4.1 - Monitoring

In agriculture drones are being used for multiple purposes, one of the most popular appears to be crop monitoring and surveying. In these cases drones are launched with mapped flight plans programmed in order to survey an area of land. 'AV Drone Analytics' is one company which has been using drones for surveying and mapping. Their applications allow large amount of photos to be stitched together seamlessly with the use of their software. You can find a link to their website here www.avdroneanalytics.com. 'AV Drone Analytics' uses the maps created to categorise areas which can lack in nutrition. Both fixed wing



and multi-rotor UAVs are built for this purpose.
Fig 15: Down Force Map showing plant patterns. Source: avdroneanalytics.com

4.2 - Crop and Spot Spraying

Crop and spot spraying is achieved with the use of digital imaging sensors identifying areas of crops that are in need of fertilisation or pesticide control. These areas or spots

Fig 16: XAG P30 Crop spraying UAV. Source: www.xa.com

can then be treated appropriately either by the grower or autonomously with use of a UAV. 'XAG' is an example of a company currently doing this. Here's a link to their site www.xa.com. With the help of UAVs crops health can now be regularly monitored and treated accordingly where once an entire crop may have been treated to avoid the possibility of lower yields.

4.3 - UAV Herding

In countries like the United States of America, Australia and New Zealand agricultural sectors have began implementing herding with the assistance of drones. People are opting for this method due to convince and time saving measures. Farms can span to 100s of acres in size and the privilege of rounding up livestock from a remote location can be undeniably more efficient and faster compared to traditional methods. Drones are being used with speakers to simulate voices and sounds when herding. Currently there seem to be no drone applications available for autonomous herding while flight is being controlled manually via the pilot.

4.4 - Crop Sowing

Similar to drones being used with crop monitoring and spraying UAVs are also being used to sow crops. Drones are fitted with modular attachments which allow the dispersion and spreading of seed. 'CFR Innovations' is one example of a company already providing these types of services and products. You can find a link to their website here https://www.cfr-innovations.com.

Fig 17: UGS-4G Seed Distributer. Source: cfr-innovations.com

Section 5 - Parrot Anafi & SDK:

5.1 - Parrot Anafi

The Parrot Anafi is a multi-rotor quadcopter drone. It has a 21 megapixel camera capable of taking photos and videos of up to 4K resolution and is mounted to a gimbal for 3 axis image stabilisation.The camera has a 180° tilt ability and 2.8X lossless zoom. The Anafi drone has a maximum flight time of 25 minutes due to it weighing only 320 grams. Thanks to flight stabilisation features programmed within the drone, the Anafi can withstand winds of up to 50km/h and can travel at speeds of up to 53km/h in sport mode. Within the drones geofence or virtual perimeter, which can be throttled or turned off, it can fly a maximum of 150 meters high and a max distance of 4km from the pilot. This is because the transmission system used in both the drone and remote have dual band antennas, 2.4GHz and 5GHz.

Fig 18: Parrot Anafi. Source: parrot.com

5.2 - Smart Features

Parrots FreeFlight 6 app allows pilots with android or iOS devices to view and control the Anafi drone in real time. The app syncs to the drone once connected to Parrot's 'Skycontroller' via USB type-C cable or over the Anafi's wifi. The app allows users to take full control of the drone, view real time feed coming from the camera, set parameters(presets) and trigger functions built into the Anafi [21].
The Parrot Anafi has some clever features for example, 'Smart RTH'(Return to Home). When the drone takes off it records it's current geo coordinates, later if the pilot decides to use this feature it autonomously returns to its take off location and at a designated altitude. If the drones battery drops below 3% the Smart RTH feature is automatically triggered.

The Anafi also features a 'Find Me' function programmed which broadcasts it's current location to your device and sounds an alarm from the drone to assist the pilot locating it [21].

The Anafi includes in app purchases which unlock AI features to enhance the users experience. The 'Follow Me' feature allows for hands free use of the drone. Once a target has been selected the drone will follow the subject and continue to capture video footage as the target moves around. The feature uses visual tracking to keep it's camera facing the subject while filming [21].

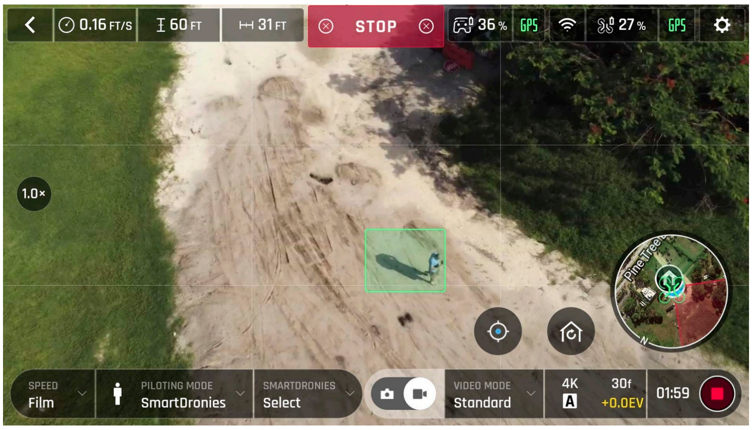


Fig 19: Follow Me Function within Parrot's FreeFlight 6 App. Source: parrot.com

Flight Plan mode allows a user to pre-program flight paths by selecting points on a map. While setting the desired altitude for each point the user can also pick a point of interest for the camera to focus on as it follows the flight path.Once the flight plan is made the drone can be launched and follow the route set out for it accordingly. The Anafi does not feature obstacle detection so this can be hazardous if executed incorrectly [21].

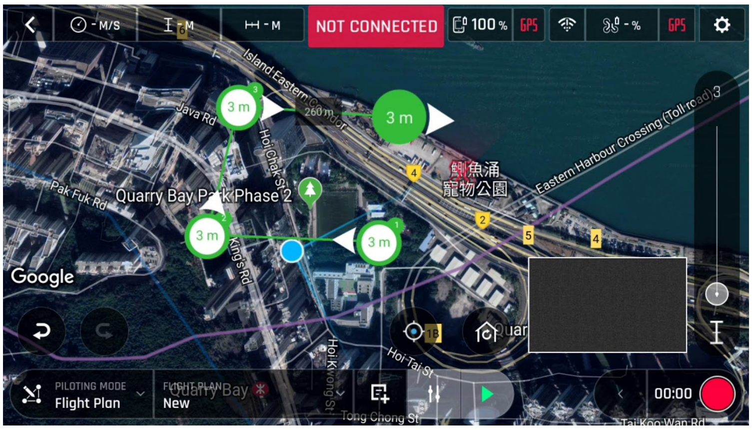


Fig 20: Flight Plan mode within Parrot's FreeFlight 6 App. Source: parrot.com

5.3 - SDK & API Set

Parrot's Ground SDK is a ready-to-compile source code for android and iOS. The SDK allows developers to create mobile applications which control and fly the Anafi drone.
The API set enables developers to exploit every feature imbedded in the drone such as presets, video feed and controller settings. The source code has been released under BSD3 licence along with it's documentation. The minimum android version required to run this source code is android 7.0(API level 24) [22].

```
/** Reference to a current drone piloting interface. */
private var pilotingItfRef: Ref<ManualCopterPilotingItf>? = null

/**
 * Called on take off/land button click.
 */
private fun onTakeOffLandClick() {
    // Get the piloting interface from its reference.
    pilotingItfRef?.get()?.let { itf ->
        // Do the action according to the interface capabilities
        if (itf.canTakeOff()) {
            // Take off
            itf.takeOff()
        } else if (itf.canLand()) {
            // Land
            itf.land()
        }
    }
}
```

Fig 21: Above itf.takeOff() function from Ground SDK which launches drone. Source: Ground SDK developer.parrot.com

Ground SDK is composed of 3 modules:

- groundsdk - Ground SDK and implementation.
- arsdkengine - SDK engines based on ARSDK
- sdkcore - Native code wrapper

Sphinx is a simulation tool used to test drone developers code on PCs. It allows users to visualise flight data at runtime, mimic drone's behaviour, create your own scenarios and more. Parrot drone firmware is ran with Gazebo to simulate a drones physical/visual surroundings and behaviour. Olympe is a python controller programming interface for Parrot drones. It can be used to connect to simulated or physical drone, send commands and check the current state. Olympe was designed to only be used with simulated drones on a PC but can be used to control physical drones also. PDrAW is a video viewing format tool used to view footage created by a Parrot drone. PDrAW is the video pipeline implementation of GroundSDK and can be used with android iOS Linux and MacOS [22].

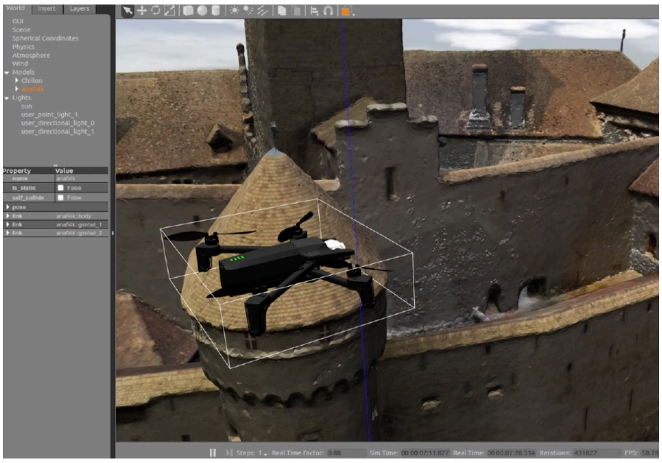


Fig 22: Sphinx virtual environment. Source *developer.parrot.com*

Section 6 - Irish Aviation Administration:

In accordance with Irish legislation and the Irish Aviation Authority(IAA), since December 2015 drones weighing more than 1Kg must be registered. Drones weighing under 1Kg but with the ability to fly over 15 meters in height must also be registered.
All drones are subject, but not limited to, the following rules and regulations. Never operate a drone; if it is a hazard to another aircraft, over a crowd of people, farther than 300 meters. within 30 meters of any person, structure or vehicle, closer than 5Km of a aerodrome, in a negligent or reckless manner, above 400 ft, over urban areas, in restricted areas, in civil or military controlled airspace, without permission from the landowner or outside of your direct line of site.[14]

Section 7 - Summary:

Following an extensive investigation into diverse areas that employ drone use, it appears there is space for further application development in the agricultural sector. Both drone and agricultural industries are continuously striving in their efforts for innovation and it appears they will continue to cross paths in the future. Drone consumer technologies have come a long way and are continuing to display new ways to tackle real world problems. In contrast the agricultural sector is constantly encountering new challenges to feed this world of innovation. In the clouded search for an impressionable tool the Parrot Anafi has answered as a very capable drone with the ability to become the platform for a real world solution. Although throughout my research I have come upon different technologies which may pose more suitable to specifics needs, the Anafi ticks all the boxes for usability in many categories.

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