Designing an autonomous surveillance drone infrastructure with facial recognition



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*Abstract*— the use of drones in the modern world has been increasing. From the little drones children play with in their backyard and parks to their distant cousins in warfare, movie making, nature observing, and the list continues to increase. As the uses of drones becomes more normalized in everyday life there has been a demand for harsher laws to prevent unlawful uses of our beloved toys (S. McNeal 2015). These laws mean there are restrictions on who can fly certain drones and where drones can be operated. This paper presents a demonstration of the capabilities of facial recognition on a Tello drone and outlines possible use cases. Three main algorithms that have been trained, tested, and contrasted. The application of this project ranges from allowing law enforcement agencies and search & rescue agencies to employ the help of autonomous drones with facial recognition for law keeping and searching for people of interest in urban areas. But also, for the purpose of film making, vlogging and new reporting. Drones remain a tool that is accessible to all and this paper aims at justifying why this decision is the right one for the future development of all mankind.

Keywords—law enforcement, facial recognition, autonomous drones, restrictions, results, infrastructure.

# Introduction

## Rational/benefits

Drones have always been and will always be a a controversial topic of discussion especially when considering their use in warfare as according to a paper by (O’Dwyer & Coymak 2019), “Armed drones are now a key component of military strategy”. Unless new insight into their use case is introduced. In order for this to happen, drones, need to offer more, they need to become sophisticated. There is a lot of research into drones for warfare but there is less research into drones for domestic use and when domestic use is the case; “The campaigns mounted by privacy advocates oftentimes make a compelling case about the threat of pervasive surveillance (S. McNeal 2015). The argument that stems from a fear of lack of privacy. The very privacy that is already challenged by the use of CCTV surveillance systems.

In the defence of drones, cameras “provide safety and security for the wider law-abiding public (Muthusenthil B et al 2018) and It is believed that drone surveillance would further improve this statistic.”

Furthermore, surveillance systems have been proven to significantly reduce crime rates (Brandon C et al), an example case study being Lewisham, UK, at a station car park, in 4 months vehicle crime had reduced by 75% from 24 to 6. Hence the inclusion of surveillance drones is deemed necessary and justifiable as a paper by (Dilshad, N. et al) titled “Application and Challenges in Video Surveillance via Drone: A brief Survey” highlights the limitations of CCTV, namely: limited area coverage, no location sharing and lack of tracking capabilities.

## Choice of research topic

To counteract this negative stigmatism behind drones, the aim of this project is to make drones more accessible and common place while also promoting the significant benefits and use cases they will introduce even to the lives of the average person.

Using machine learning principles, computer vision and emerging technologies that allow the capture of various types of information, this is achievable.

Facial recognition, as it suggests is the ability to recognise faces much like people recognise one another. It is a type of biometric security along with voice recognition, fingerprints and eye retina or iris recognition. Such algorithms are already used in various systems across the world such as in cameras for detecting where faces are located and for unlocking phones.

The use of facial recognition in drones is a significant benefit because with the aid of machine learning and computer vision we can make drones act autonomously in response to what they perceive. Or otherwise return information or trigger other actions.

Said action could range from setting up a drone to take your picture when it detects a smile or throw an alert when a face is recognised. This can be useful when trying to find someone in a crowd or keep track of a actor’s face/head when making a movie as a camera pans around them.

When vlogging a hike in the mountain, abroad or everyday life, drone would enable hands free recording. Police could use drones when tracking criminals during a highspeed chase as this would be cheaper than using

helicopters and quieter too. Search and rescue agencies could use them in forests and at sea as they would save manpower, put less people at risk, be cheaper and more deployable than government UAVS (reference paper on drones used for detecting drowning victims).

The average homeowner can also use such drones for looking for things lost in their home or around their property. In Amusement parks, drones with facial recognition would be perfect for looking for lost kids and reuniting them with parents remotely.

The drones could be used in warzones for quick and easy data capture, interviews and without needing to risk reporter lives.

On private property, the drones can be used for 24/7 surveillance and the list goes on.

In addition, when considering search and rescue operations, research by (Dilshad, N. et al) showed that when comparing the efficiency and accuracy of detecting a missing or lost person in an image by UAV quadcopter versus manual visual search by a human, the drone excelled in all 3 main characteristics that were focused on, prevision, recall and speed. For evaluation, a total of 49 high-resolution colour images from the HERIDAL dataset were used. This dataset was accumulated from multiple locations in regions of Herzegovina (BiH) and Dalmatia (Croatia) by several UAVs (e.g., DJI Mavic Pro 3 or Phantom 3) on relative elevations of 30m to 60m. The image resolution is about 12 Mega Pixels, i.e., 4256 by 2848 pixels, to be exact, describing enough clarity and details. The experimental results show that the respondents failed to spot all 104 targets in the selected pictures. The average recall and average precisions were 80.43% and 90.98%, respectively.

The maximum number of false detection’s was 8, mostly relating to animals, clothes, and several other objects. The manual search took almost 42 minutes for each person. Conversely, automatic search by drones took much less time [6]. This research proves that the technology is there, and drones are more than capable of being used for surveillance.

## Aim, objectivs and hypothesis

* Accurately and autonomously identify and follow a specific target of interest based purely on face recognition data.
* Create a method to remotely send new targets of interest to the drone
* Apply machine learning techniques to train models that can recognise specific faces for the drone to look for
* Compare, contrast, and evaluate the performance of the different algorithms used for face recognition on the drone.
* Ensure that the drone can always be controlled remotely should a problem arise

“Drones that utilise Machine Learning and Computer vision are capable of being programmed to demonstrate more complex behaviours and achieve higher consistent results while excelling at repetitive tasks than drones that are controlled remotely by a human operator”

# Background conte

# xt

## Drones for surveillance

According to Imperial War Museums, the first pilotless vehicles were developed in Britain and the USA during the first world war, with Britain’s Aerial Target, a small radio-controlled aircraft being tested in March 1917. However, it was not until 1935 that the word DRONE was first used, during the inter-war period and 4 years before the second world war. Inspired by one of the models being developed at the time by the British, the DH82B Queen Bee. (Imperial War Museums, 2022)

In modern times there are many definitions of the word drone, however, the earliest definition defines them as

“an Unmanned aerial vehicle that is automated”.

The basic requirements of a drone are; a power source, motors, ESCs, propellers, a frame and lastly, a flight controller to send low level instructions to the components and connect them all together.

The capabilities of a drone are purely dependent on its components. Where a more sophisticated drone will typically have, multiple sensors capable of acquiring accurate information from its surroundings and then passing on that information to a base station or and acting on it.

Autonomous drones, need to make efficient use of these sensors to perceive the world around them and act on it. As these sensors allow the drones to interact with the world as well as interfere with it and recognize that a change has taken place. Therefore, it is evident that without utilizing these sensors, an autonomous drone is not feasible.

While sensors that receive information from the world have been around for a longer time than drones, we are only recently seeing their use for face recognition in autonomous drones. As Hsu Hwai-Jung, stated that their findings suggested that the current face recognition technologies are capable of recognizing faces on drones with some limits in distance and angle (Hj Hsu et al 2015).

It is currently, 2022, almost a decade has past yet drones are still not more commonly used despite their capabilities. It is apparent therefore that a more common, higher level use case for autonomous drones in civilian space would warrant and promote increased development of technologies that make drones more suitable to be used commonly.

This makes it aparaent that it is up to the developers of now to drive the narrative that we are ready to have personalized autonomous drones much like we have autonomous cars. The first self-sufficient and truly autonomous cars appeared in the 1980s, with Carnegie Mellon University’s Navlab and ALV Projects in 1984 and Mercedes-Benz and Bundeswehr University Munich’s Eureka Prometheus Project in 1987(Wikipedia 23, 2022). Yet it wasn’t until Elon Musk’s package of these prior achievements in the form of a Tesla followed by the launch of the first Tesla Product, the Roadster sports car in 2008 (Tesla, 2022), that we are now seeing them become common place.

Van Brummelen states, “in general, robust, and reliable perception (through sensors), and localization and mapping are required to make accurate and reliable decisions for vehicle control” (J. V., B et al 2018). To create a reliable autonomous drone we thus require sensors that will acquire the specific information necessary for making the drone functionally autonomous. With that in mind, the key aspects of an autonomous drone are:

1. A method to perceive and interact with the world
2. Means for always monitoring the state of the drone
3. What to do when interacting with objects of interest

As early as 1918, the best tool for the job of remotely viewing the world has been a video camera created by John Logie Baird in 1918 (McLean, 2013) and with the introduction of open cv in 1999, it is possible to interact with a “video frame” and draw on top of it when something is detected in a frame using machine learning.

## Public opinion of Autonomous drones

There is a lack of information on attitudes to autonomous drones in the United Kingdom however according to a new study published by (Mariam. M), opinions towards remote drones is positive. The research dubbed “Project XCelerate” Consortium led by BT [12] and Altitude Angel [11] showed results demonstrating that 68% of the British public believe that drones would positively impact their lives while nearly 49% said they would be optimistic or excited about the potential drone technology holds.

Furthermore, the research showed that people were hopeful to see drones in riskier jobs such as firefighting (76%) and inspecting infrastructure (70%). Whereas 2/5 of the sample size would like to see drones employed in order to extend human capabilities and tackle problems such as tracking criminals (65%) and investigating crimes(73%). These statistics support the implementation of autonomous drones with surveillance capabilities because this would be necessary for the various tasks that people are hopeful to seem them employed in.

On the other hand, 38% of the sample size expressed some concerns for the use of drones in the UK with 46% of adults arguing about drone misuse and public safety and another 48% arguing about privacy alongside personal data and private property being the primary concerns. Arguably, according to the results, public opinion could be due to public misconceptions as 47% of the sample size were found to believe that drone usage remains unregulated.

It is important to mention that the report is just one part of Project XCelerate’s broader work on the UK Government’s Future Flight Programme [13] and the findings will be leveraged to inform the consortium’s work in addressing some of the challenges surrounding the public acceptance of drones.

Nonetheless, the results of the research showed how applicable drones can be to daily lives for people in the UK and the purpose of this research is to help make this a reality. That being said, it is clear that there will have to be restrictions on the use of drones for the project to be viable and the use of drones will have to be backed by their application via a reputable agency such as the policy or search and rescue agencies that can justify their use in the public for those who are worried about their privacy being disregarded.

## Uses of autonomous drones

Plenty of research has been carried out on autonomous drones, highlighting their significance as a topic. According to “The use of drones in maritime sector-areas and benefits” by Krystosik-Gromadzińska, DNV GL is currently testing autonomous drones with hyperspectral cameras for use in ship tank inspections. The paper argues that autonomous drones for inspection in maritime conditions, ensure human safety and operational efficiency during transportation from port to ship and they also reduce the carbon footprint when used over the sea.

Other research on autonomous drones include the development of autonomous drones for delivering items that use GNSS with a compass as the main tool; with the aim of delivering medical aid to patients in emergency situations and implementation in agriculture in Indonesia. This research was carried out by (Patrik Aurello et al). The results demonstrated that the use cases are realistic and very viable as experiments showed that the average of positional deviation of landing position between the actual landing position and the desired landing position in the flight tests of flying from start to goal is 1.1125 m and for the tests that use the algorithm which uses course-over-ground, the positional deviation has average of 2.39 m. Meaning that the technology is there when developing autonomous drone that operate via GNSS.

# Report structure

Outline the structure of the rest of the report

# Literature review

# Methodology

The process with which this project was carried out began with research into available facial recognition algorithms that could be deployed in real time on the drone.

After this, three main algorithms were chosen and implemented: Dlib’s facial recognition library using SVM, YOLO and lastly, the viola jones method with haarcascade. Firstly, face detection was implemented. This would allow the drone to react when ever a face was detected in the frame. This is a necessary abstraction from face recognition as it meant that a function could be implemented such that the drone could avoid recognized faces whilst also behaving in a certain way to recognized faces.

The Dlib library came with a variety of functions that made it easy to identify faces as well as recognize a face from a target image without the need for additional training. As for the other two methods, datasets were created for training however the methods have not been modified to recognize faces that not in a known dataset. Meaning, when deployability is in question, the Dlib face recognition library is the most readily available to employ in a field due to not needing any down time for additional training for new faces. However, through testing results have also shown that the dataset used for Dlib’s face recognition algorithm is insufficient at recognizing people of BAME with the same consistency that others are recognized with, in the same lighting. This highlights a potential lack of BAME data in the dataset that was used to train the Dlib library.

Following the creation of the datasets, face recognition was tested on the drone with varying degrees of accuracy.

## Project Management

In order to manage the progress of the project. Frequent meetings were held. Where possible once a week, otherwise, once every two weeks. During the meetings, the project progress was discussed as well as objectives for the next week and any problems that asides following the meeting along with how the problems were solved.

As the project involved an autonomous drone operating primiraly on computer vision this meant specially attention had to be paid to the way in which the drone responded to what it saw. This required a lot of experimenting on the drone to see how well faces would be picked up through the camera, the distance at which faces would be detected and how well the drone could follow and keep track of a face when in motion.

As a result of assessing this only being possible through experimenting, the following methodology was deemed appropriate.

## Software Development

Methodical Analysis of what software development approach was used?

Black box and white box testing.

You should work from the

specific requirements of your project and explain how these might determine

approaches for software /IS methodologies. Where relevant, you should give

serious thought to the proper design of research and requirements capture approaches.

# Alternarive research methods

Asides from running experiments in simulation with the drone and using Virtual machines to simulate a raspberry pi communicating with a host device such as a phone or computer observations on the interaction between people and the drone will also be taken. These observations will be used to analyze public response to drones for surveillance asides from their feedback in a survey which could also be a viable option for gathering support for justification of the use of drones for surveillance. It would be interesting to see if people’s response to the surveys also matched their responses to an implementation of an autonomous drone surveilling an area.

# Design and development

# Experiments and evaluation

# Discussion and reflective analysis

# Findings and conclusion

The results of various research on existing papers shows how controversial the topic of drones is. It is very hard to design a useful drone for surveillance that will not be at the mercy of the public as the drones will have to fly low to the ground at times leaving them vulnerable to malicious actions.

Moreover, it is also hard to design a multi-functional drone as the past research in drones show that drones have to be designed as modular in order to be multi-functional in which case a universal standard will be required if the drones will be applicable to various organizations as this is the only way they can then be quickly retrofitted as necessary for each task that is demanded of them.

Furthermore, in the context of preserving the drones the only real way to protect the collective moving forward and prevent them from vandalism would be to create laws that protect both people’s privacy while also ensuring that drones are treated with the same authority and presence of the organizations that they will be created for or employed by.

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