Ministry of Higher Education and

Scientific Research

University of Babylon

College of Basic Education

Department of Computer and Mathematics

Specialization/ Computers

UAV Navigation and Formation Based on Computer Vision

A Project

Submitted to Council of the College of Basic Education/ University of Babylon in Partial Fulfillments of the Requirements for the Degree of Bachelor in Basic Education/ Computer and Mathematics/Computer

By

Haneen Mohamed Abdel-Zahra

Sahar Hamed Abbas Hassan

Supervised by

Prof .Maysoon Khazaal Abbas Maaroof

2022 A.D 1443 A.H

بسم الله الرحمن الرحيم

((خَلَقَ الْإِنْسَانَ مِنْ صَلْصَالٍ كَالْفَخَّارِ))

صدق الله العظيم

الرحمن 14

Dedication

Our dear parents

Our supervisor in search

Ins .Maysoon Khazaal Abbas Maaroof our strong self

Acknowledgements

OUR grateful to my parents and teachers.

They have given me a lot of help in our education. Without them, our would not be

where today. We also thank my friends who supported me when we needed it

Special thanks to (Prof.Maysoon Khazaal

Abbas Maaroof) our mentor for supporting me in my research.

Table of Contents

Abstract

An unmanned aerial vehicles (UAV) has been increasingly popular in the past decades, and UAVs have been widely used in industrial inspection, remote sensing for mapping & surveying, rescuing, and so on. Nevertheless, the limited autonomous navigation capability severely hampers the application of UAVs in complex environments, such as GPS-denied areas. Previously, reprojecters mainly focused on the use of laser or radar sensors for UAV navigation. With the rapid development of computer vision, vision-based methods, which utilize cheaper and more flexible visual sensors, have shown great advantages in the field of UAV navigation. The purpose of this article is to present a comprehensive literature review of the vision-based methods for UAV navigation. Specifically on visual localization and mapping, we will have an insight into the prospect of the UAVnavigation and the challenges to be faced.

The reproject motives learn how to control the drone the algorithms used in the programming of the drone Increasing understanding about this new technology Knowing is Python suitable for controlling a drone, or is it more complicated.

chapter one

Theoretical Work

chapter one
Theoretical Work

An unmanned aerial vehicle

1.1 Introduction

An unmanned aerial vehicle (UAV) is an aircraft which can fly without a human pilot aboard. Nowadays, more and more UAVs are recruited for civilian applications because of its high mobility and flexibility. However, in some complex environments, the UAV cannot precisely perceive the surrounding environment and act properly due to the limitations of communication and perception ability of traditional sensors. Although a lot of effort has been spent on overcoming these weaknesses, a more efficient and effective method still needs to be developed. Therefore, the high-performance autonomous navigation capability is of great significance for the development and application of UAVs.

1.2 overveiw of project

As stated before, the goal of this systematic mapping project is to provide an overview of the current reproject on the topic of computer vision in autonomous UAVs. This way, we will obtain a broad view of navigation and flight control operations in which computer vision is relevant. Consequently، it will be possible to address future in-depth studies for the development of autonomous aerial robots،and, particularly, assistant UAVs.

first question aims to discover the number of works about the use of computer vision in autonomous UAVs that have been published and the forums in which these papers are most frequently published.

The second question concerns the idea of grouping articles according to the type of operation for which computer vision is used. Four main categories related to navigation, stability and maneuver control, guidance or tracking, and obstacle detection and avoidance are considered. This enables us to know on what areas the reproject is principally focused, and allows us to carry out a more in-depth analysis of the remaining questions.

One of the most determining aspects is to discover for what type of UAV platform each proposal has been designed and validated. This is precisely the goal of the third question. In addition، by considering the first classification on the use of vision, we can get an idea of which type of UAV is most frequently used in each operation. number, localization, and orientation of the cameras will be analyzed at this point in order to draw conclusions about the main features of the vision systems commonly used in each navigation and flight control area.

The last reproject question is related to the kind of tests carried out to validate the proposals; flight، experimental, and simulation trials, or a combination of them.

The idea is to perform an analysis of the kind of tests most frequently performed for each main category considered [1].

1.3 project Strategy

A project string was defined in order to automatically find articles that use computer vision technologies for the autonomous navigation and control of UAVs by using terms related to the two main concepts: UAV and vision .contained words related to autonomous aircraft, while the second was defined by employing terms related to computer vision. Table shows the definition of the project string, in which the Boolean OR was used to join terms and synonyms, and the Boolean AND was used to join the two main parts.

1.4 The aim of this project

The aim of this project article is to provide an overview of the most important efforts in the field of computer vision for UAVs, while presenting a rich bibliography in the field that could support future reading in this emerg-ing area. An additional goal is to gather a collection of pioneering studies that could act as a road-map for this broaden reproject area, towards autonomous aerial agents.

Since the field of computer vision for UAVs is very generic, the depicted work will focus only in surveying the areas of: (a) flight control or visual servo- ing, (b) visual localization and mapping, and (c) target tracking and obstacle detection [2],It should be highlighted that this article classified the aforementioned categories following the Navigation - Guidance - Control scheme. The big picture is to provide a significant insight for the entire autonomous system collecting all the pieces together.

The concept of navigation monitors the motion of the UAV from one place to another processing sensor data. Through this procedure the UAV can extract essential infor- mation for it's state (kinematics and dynamics – state estimation), build a model of its surroundings (map-ping and obstacle detection) and even track sequential.

1.5 UAV navigation

UAV navigation can be seen as a process that robots make a plan on how to safely and quickly reach the target location, which mostly relies on current environment and location. In order to successfully complete the scheduled mission, a UAV must be fully aware of its states, including location, navigation speed, heading direction as well as starting point and target location. To date, various navigation methods have been proposed and they can be mainly divided into three categories: inertial navigation, satellite navigation, and vision-based navigation. Nevertheless, none of these methods is perfect; therefore, it is crucial to adopt an appropriate one for UAV navigation according to the specific task [3].

The vision-based navigation proves to be a primary and promising reproject direction of autonomous navigation with the rapid development of computer vision.

First, the visual sensors can provide abundant online information of the surroundings; second, visual sensors are highly appropriate for perception of dynamic environment because of their remarkable anti-interference ability; third, most of visual sensors are passive sensors, which also prevent the sensing system from being detected. Europe and the United States have already established reproject institutions, such as NASA Johnson Space Centers (Herwitz et al. 2019). MIT (Langelaan and Roy 2018), University of Pennsylvania and many other top universities are also vigorously developing reproject on vision-based UAV navigation and have incorporated this technology into next generation air transport systems, such as NextGen and SESAR shown as Figure 1 [4].

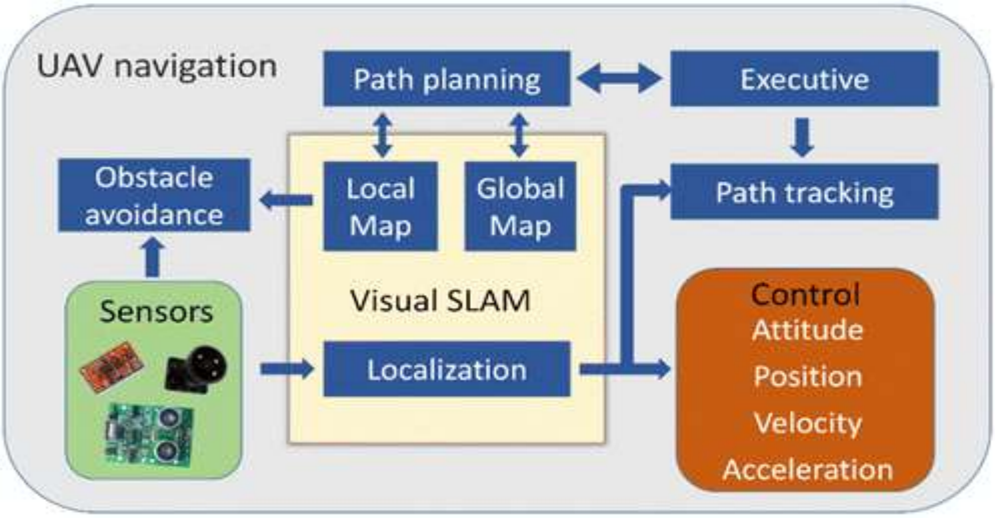


Figure 1. Vision-based UAV navigatio

The complete illustration of vision-based UAV navigation is With inputs from exteroceptive and proprioceptive sensors, after internal processing of localization and mapping, obstacle avoidance and path planning, the navigation system will finally output continuous control to drive the UAV to the target location.

1.6 UAV sensing

Normally, UAVs obtain states of their own and information of surroundings from both exteroceptive and proprioceptive sensors. The traditional sensors used for navigation are mainly GPS, axis accelerometer, gyroscope, and inertial navigation system (INS). However, subjected to the operating principle, they are prone to affect the performance of navigation and localization. On one hand, one of the great drawbacks of GPS is its reliability, whose localization accuracy is positive correlation to the number of available satellites (Araar and Aouf 2018). On the other hand, due to the propagation of bias error caused by the integral drift problem, (Herwitz et al. 2019)

INS would result in loss of accuracy to some extent. Meanwhile, small errors of acceleration and angular velocity are continuously incorporated into the linear and quadratic errors of velocity and position, respectively More or less, the defects of traditional sensors constraint the UAV in both production and life applications[5].

Therefore, reprojecters are being more concerned about the use of novel methods to enhance both the accuracy and robustness of UAV's state estimation. Ideally, we can obtain better pose estimation by multiple sensor data fusion (Carrillo et al. 2019), which incorporates advantages of different types of sensors. Nonetheless, limited to the specific environment (for example, GPS-denied area) and payload of the UAV, it is assumed to be unnecessary and impractical for some small UAVs with multiple sensors. Therefore, a more general approach is expected to enhance the UAV's environmental perception ability. Visual navigation is using visual sensors. Comparing to the GPS, laser lightning, ultrasonic sensors, and other traditional sensors, visual sensors can acquire rich information of surroundings, involving color, texture, and other visual information. Meanwhile, they are cheaper and easier to deploy, so vision-based navigation has becoming a hot spot in the field of reproject. As shown in Figure 2, visual sensors typically include the followings: (a) monocular cameras, (b) stereo cameras, (c) RGB-D cameras, and (d) fisheye cameras.

Monocular cameras are especially suited for applications where compactness and minimum weight are critical, in addition to that, lower price and flexible deployment make them a good option for UAVs. However, monocular cameras are not able to obtain depth map (Rogers and Graham 2020). A stereo camera is actually a pair of the same monocular cameras mounted on a rig, which means that it provides not only everything that a single camera can offer [6].

But also something extra that benefits from two views. Most importantly, it can estimate depth map based on the parallax principle other than the aid of infrared sensors (Seitz et al. 2016). RGB-D cameras can simultaneously obtain depth map and visible image with the aid of infrared sensors, but they are commonly used in indoor environment due to the limited range. Fisheye cameras are a variant of monocular cameras which provide wide viewing angle and are attractive for obstacle avoidance in complex environments, such as narrow and crowded space .

The rest of the paper is organized as follows: First, in Section 2, we introduce three different kinds of visual localization and mapping methods. Next, in Section 3, we provide a review on the obstacle detection and avoidance technique in autonomous flight. Then, in Section 4, we focus on the path and trajectory planning approaches. Finally, in Section 5, we make a conclusion, together with further discussion on specific challenges and future trends of vision-based UAV navigation.

1.7 Visual localization and mapping

Considering the environment and prior information used in navigation, visual localization, and mapping systems can be roughly classified into three categories: mapless system, map-based system, and map-building system (Desouza and Kak 2002) (Figure 2).

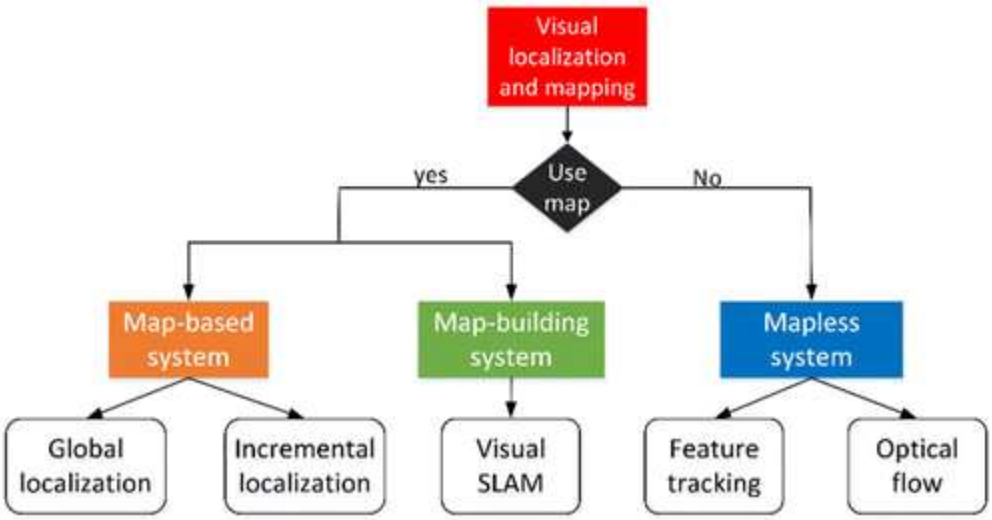


Figure 2. .Visual localization and mapping systems

Figure 2. Typical visual sensors. (a) monocular cameras, (b) stereo cameras, (c) RGB-D cameras, (d) fisheye cameras.

1.8 Mapless system

Mapless system performs navigation without a known map, and UAVs navigate only by extracting distinct features in the environment that has been observed. Currently, the most commonly used methods in mapless system are optical flow methods and feature tracking methods.

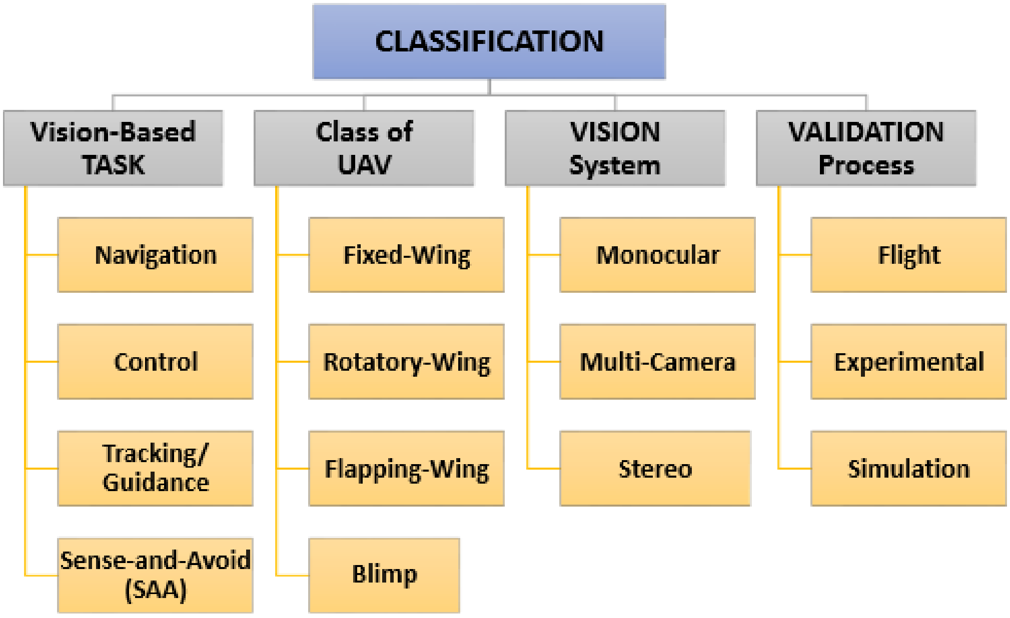


Figure 3. Classification scheme.

Generally, we can divide the optical flow techniques into two categories: global methods (Horn and Schunck 1981) and local methods (Lucas and Kanade 1981). As early as 1993, Santos-Victor et al. (1993) invented a method imitating the bee's flight behavior by estimating the object movement through cameras on both sides of a robot. First, it calculates the optical velocity of two cameras relative to the wall, respectively. If they are same, the robot moves along the central line; otherwise, the robot moves along the speed of small places forward [7].

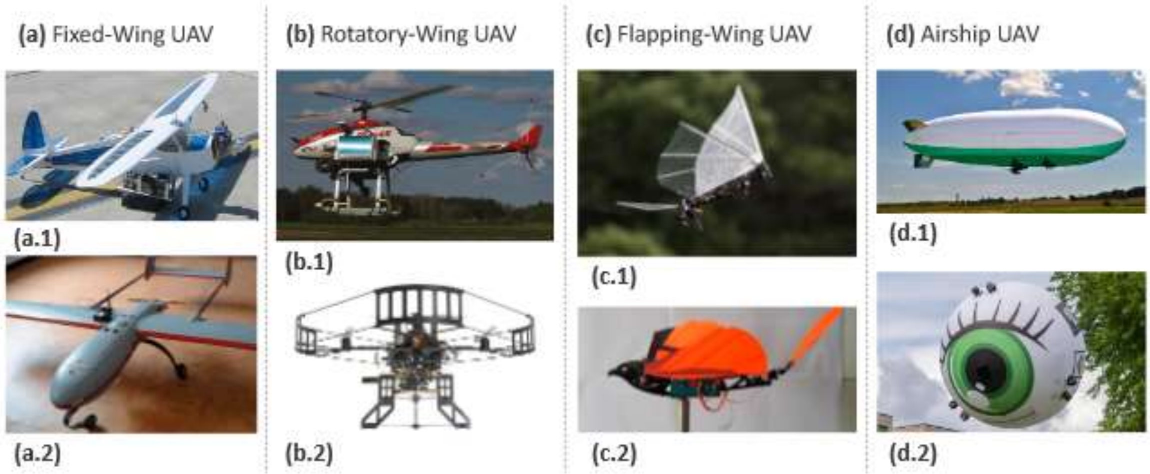


Figure 4. Type of dron.

However, it is prone to have a poor performance when navigating in texture-less environment. Since then, we have witnessed great development of optical flow approaches and also made several breakthroughs in detection and tracking fields. Recently, a novel approach has been proposed for scene change detection and description using optical flow.

Moreover, by incorporating inertial measurement unit (IMU) with the optical flow measurements (Herissé et al. 2019), reprojecters have achieved hovering flight and landing maneuvre on a moving platform. With dense optical flow calculation, it can even detect movements of all moving objects (Maier and Humenberger 2017), which plays an important role in high level tasks, such as surveillance and tracking shooting.

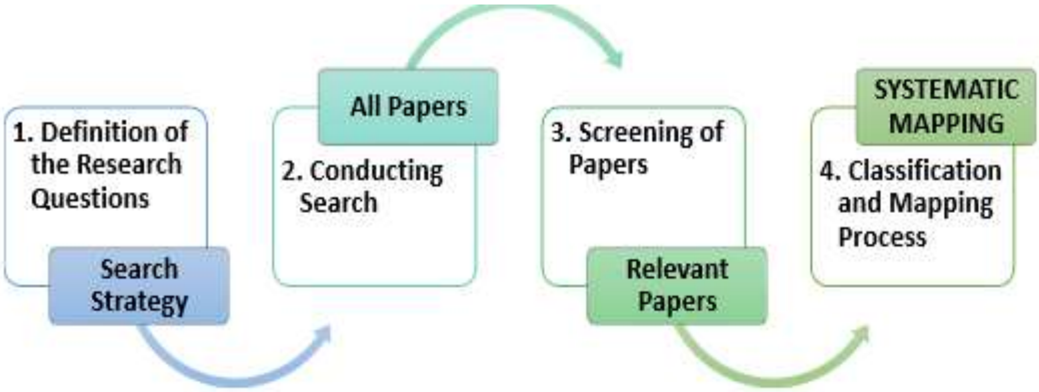


Figure 5. Systematic mapping

The feature tracking method has become a robust and standard approach for localization and mapping. It primarily tracks invariant features of moving elements, including lines, corners, and so on and determines the movement of an object by detecting the features and their relative movement in sequential images (Cho et al. 2013). During the process of robot navigation, invariant features that have been previously observed in the environment are likely to be reobserved from different perspectives, distances, and different illumination conditions [8].

They are highly suitable for navigation. Traditionally, natural features used in localization and mapping are not dense enough to avoid obstacles. Li and Yang (2003) proposed a behavioral navigation method, which utilized a robust visual landmark recognition system combining with a fuzzy-based obstacle avoidance system for obstacle avoidance.

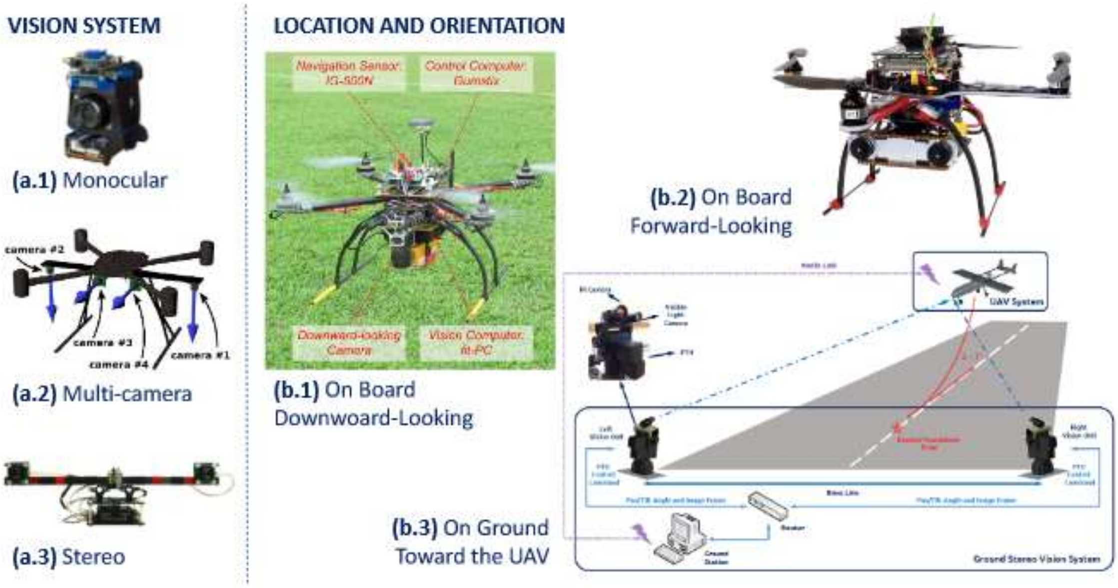


Figure 6. Classes of vision system and examples of configurations (location and orientation

chapter two

Components An unmanned aerial vehicle (UAV)

chapter two

Components An unmanned aerial vehicle (UAV)

2.1 Components of a Quadcopter

Unmanned aerial vehicle – Aircraft without a human pilot onboard. Control is provided by an onboard computer, remote control or combination of both Unmanned aircraft system – An unmanned air- craft system is an unmanned aircraft and the equip- ment necessary for the safe and efficient operation of that aircraft. An unmanned aircraft is a com- ponent of a UAS. It is defined by statute as an aircraft that is operated without the possibility of direct human intervention from within or on the aircraft [(Strohmeier et al. 2017) Micro Aerial Vehicle – A small sized unmanned aircraft system running from battery power and which can be operated and carried by one person. Collision Avoidance – Sensors on the unmanned aircraft detect adjacent air users and alert either an automated on-board system or the remote pilot of their presence and the potential need to take avoiding action Fail-Safe – A design feature that ensures the sys- tem remains safe in the event of a failure and causes the system to revert to a state that will not cause a mishap [9].

Autonomous system – Operations of a unmanned aerial system wherein the unmanned aerial system receives its mission from either the operator who is off the unmanned aerial system or another system that the unmanned aerial system interacts with and accomplishes that mission with or without human- robot interaction.

Autonomy – A unmanned aerial system's own abil- ity of integrated sensing, perceiving, analyzing, communicating, planning, decision-making, and acting/executing to achieve its goals as assigned by its human operator(s) through designed Human- Robot Interface (HRI) or by another system that the unmanned aerial system communicates with. UMS's Autonomy is characterized into levels from the perspective of Human Independence (HI), the inverse of HRI.

Environment – The surroundings of a UAV. The environment can be aerial, ground, or maritime. It includes generic and natural features, conditions, or entities such as weather, climate, ocean, terrain, and vegetation as well as man-made objects such as buildings, buoys, and vehicles. It can be static or dynamic, can be further attributed in terms of its complexity, and can be described as friendly/hostile [10].

2.2 Drone Parts Overview Along

All drone parts and components are vital to a smooth and safe flight. Knowing the parts of a drone will give you extra confidence while flying. You will also know which components to inspect on a regular basis and the drone parts which are easy to replace or upgrade.

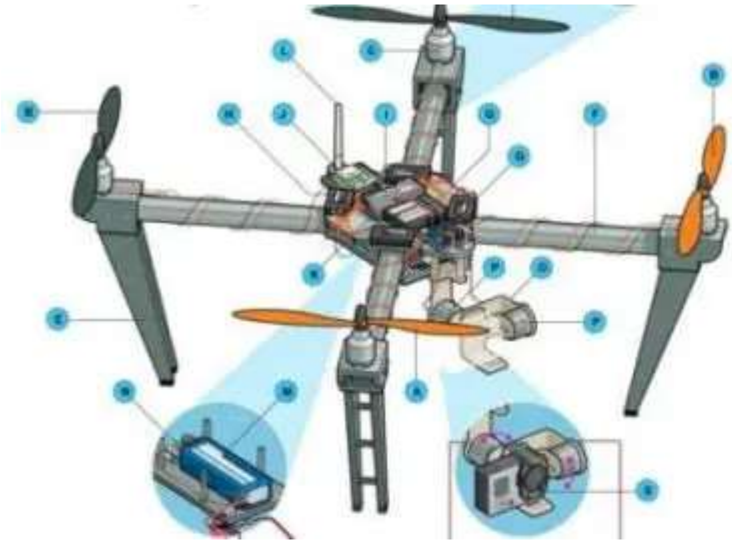


Figure 7. Drone Parts Overview Along

2.3 A. Standard Prop

•While some drones like the DJI Phantom look more or less the same from any angle, there is a front and back .

•The "tractor" propeller are the props at the front of the quadcopter. These props pull the quadcopter through the air like a tractor .

•Most drone propellers are made of plastic and the better quality made of carbon fiber [11].

•You can also buy drone prop guards which you need especially if

This is also an area where we are seeing plenty of innovation. Better prop design will assist with giving a better flying experience and longer flight times .

•There is also some big innovation towards low noise uav props .

•Tip: Always good practice to inspect your props before flying and carry an extra set in case you notice some damage on a prop. Never fly with a damaged or bent prop.

B. Pusher Prop

•The Pusher props are at the back and push the UAV forward hence the name "Pusher props". These contra-rotating props exactly cancel out motor torques during stationary level flight. Opposite pitch gives downdraft. Again, can be made of plastic with the better pusher props made of carbon fiber. You can also purchase guards for the pusher props.

2.4 C. Brushless Motors

•Practically all the latest drones use a brushless electric "outrunner" type, which is more efficient, more reliable, and quieter than a brushed motor .Motor design is important. More efficient motors save battery life and give the owner more flying time which is what every pilot wants .

Figure 8. Drone Brushless Motors Along

DJI developed and patented a new curved magnet which fits perfectly around the motor allowing the motor to run more efficiently .

•Tip: Examine the motors regularly. Make sure they are clean and free from dust. Get to know how your drone sounds. Listen to it. Most of the sound comes from the motors. If it doesn't sound right, then examine your drone. Fly a couple of feet off the ground and close to you and see if one of the motor is failing. It's not a bad option to have a spare motor or 2 **[12]**.

2.5 D. Motor Mount

•Sometimes built into combination fittings with landing struts or can be part of the UAV frame ..

•Tip: Check the motor mounts and areas close to the motors for stress cracks. If you find stress cracks and your quadcopter is under warranty, then you can send it back and have it fixed. Alternatively the manufacturer may have some strengthener motor mounts .

•Tip: When you first receive your new drone, it is also a good to examine areas around the motor mounts or where screws are used. Sometimes, screws can be wound in too tight and actually can crack the frame. It maybe just a hairline crack but these won't fix themselves.[James Careless. 2005]

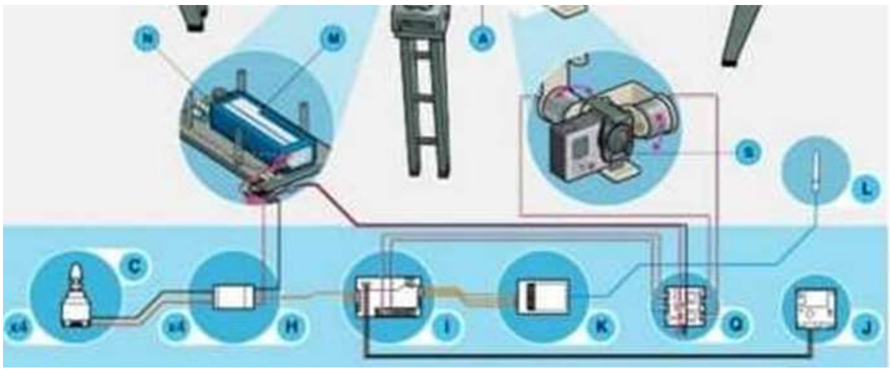


Figure 9: Motor Mount UAV frame

2.6 E. Landing Gear

Drones which need high ground clearance may adopt helicopter-style skids mounted directly to the body, while other drones which have no hanging payload may omit landing gear altogether **[13]**.

Many fixed wing drones which cover large distances such as the Sensefly eBee, Trimble UX5 or the 3DR Aero-M don't have landing gear and land perfectly fine on their belly .[Jason Blazakis. 2004]

•Most drone has a fixed landing gear. However, the best drones will have retractable landing gear giving a full 360 degree view .

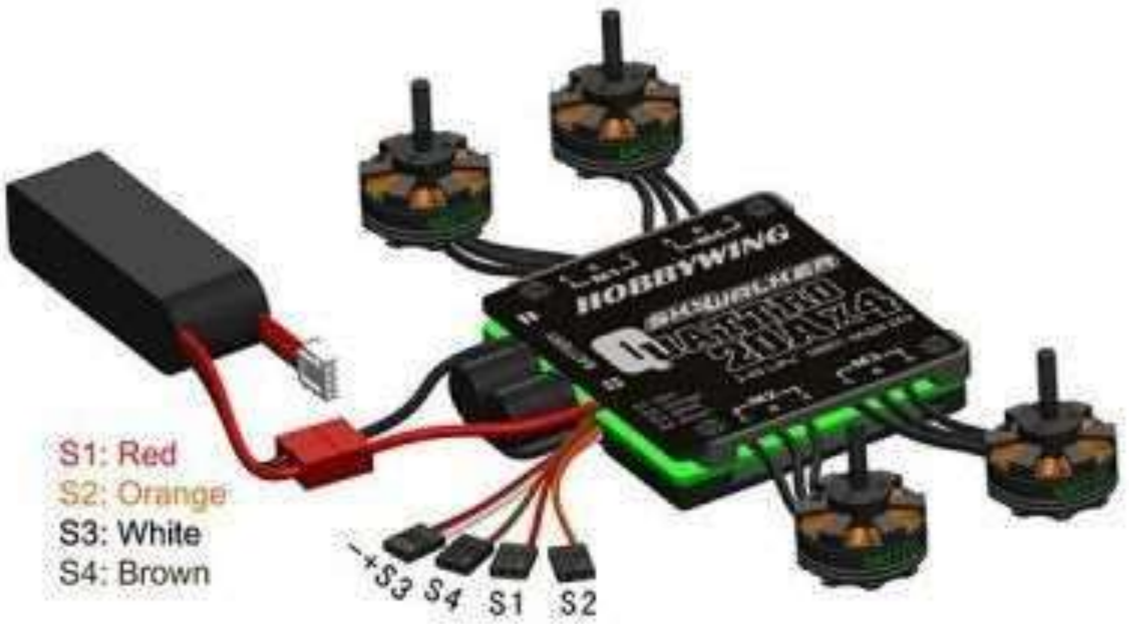


Figure 10: landing gear altogether

Retractable Landing Gear Drones

•DJI – Spreading Wings S1000+, Inspire 1

•DJI– Voyager 3, Scout x4, QR X900

•Tip: Examine your landing gear and especially if you've had a bit of a rough landing. This protects the drone, expensive camera or sensors **[14]**.

•Tip: If you can and it suits your needs, buy a drone which has retractable landing gear. Then you don't have to worry about the legs getting in the way of a great photo or video shot. With retractable landing gear, keep it clean and free from dust and dirt. In that way the landing gear doesn't seize up .[M.Angel, A.Chandnani, D. 2003]

2.6.1 F. Boom

•Shorter booms increase maneuverability, while longer booms increase stability. Booms must be tough to hold up in a crash while interfering with prop downdraft as little as possible. In many drones the boom is part of the main body. Other drone have a definite boom as a separate part .[M.Angel, A.Chandnani, D. 2003]

Figure 11: gear booms increase maneuverability

•Tip: Examine and insure that the boom has not become bent as this would effect the flying capabilities .

G. Main Drone Body Part

•

chapter three

Experimental work

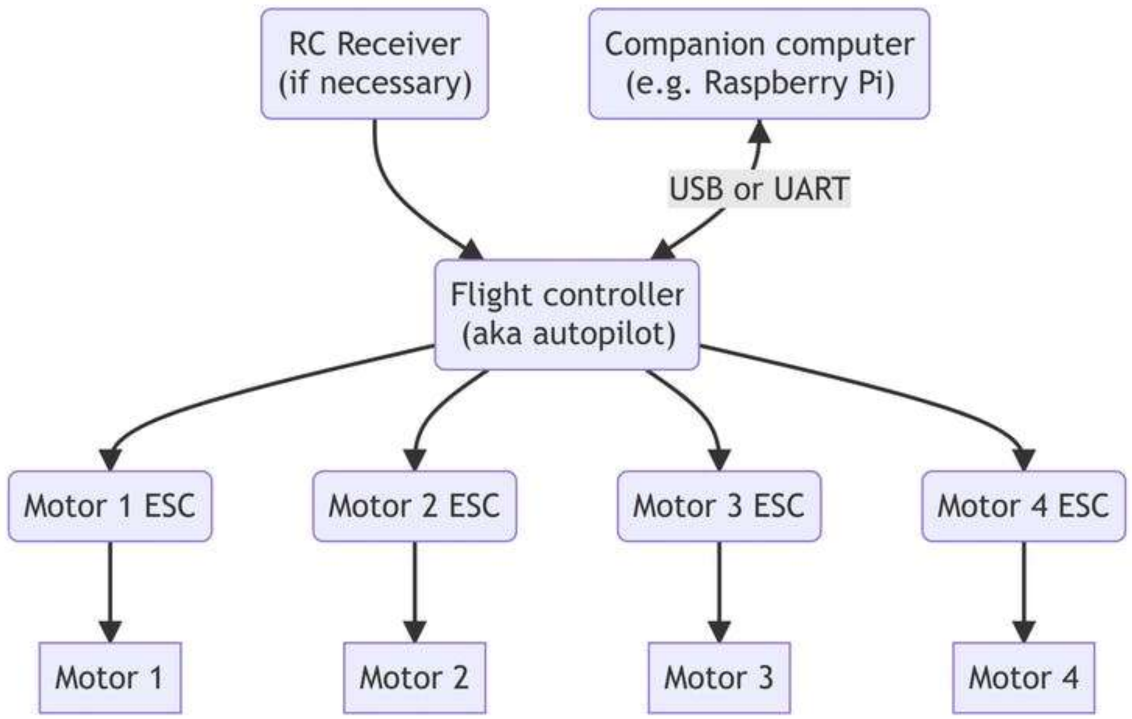
chapter three

Experimental work

Controlling a Raspberry Drone Using Python

3.1 Over the last decade, the commercial UAV industry has grown exponentially. Nowadays UAVs are being used for mapping, infrastructure analysis, navigation, food and package delivery, photography and film making, pest spraying and much more.

Also during this decade we have seen Alexa and Siri taking over our daily lives, providing automation to our day to day routine. Like dimming out the lights, playing songs, calling mom and even reading out recipes while we cook.



Step 1: Part Selection

Figure 15: RC Controller protocol

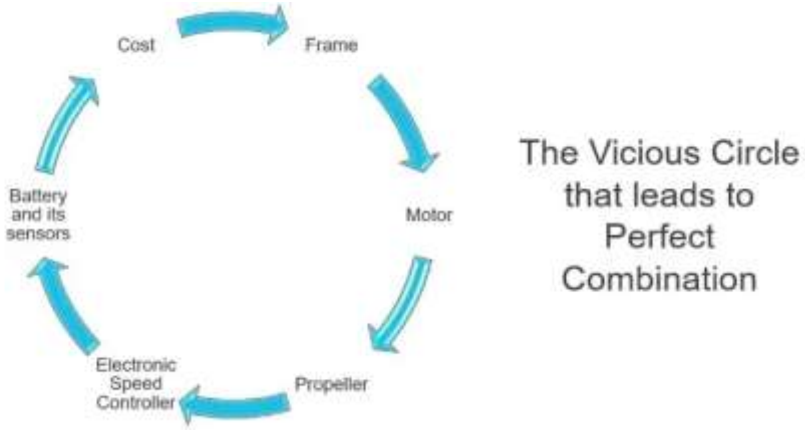


Figure 16: commercial UAV industry

First thing to do is get a ArduPilot AV.make sure it has enough room to carry Raspberry Pi (Zero/ Zero-Wireless/Model 3 B/ Model 3 B+). Literally just Google DIY Pixhawk quadcopter will help to find a lot of build guides and configuration.For those who are still curious on how to select parts, just draft up a chart and start writing down the weight of the objects that used (frame, ESC, motors, propellers, battery, Flight controller, receiver). Using the weight list verify (using motor thrust table) that combination of motor and propeller would be able to lift of the total weight at 50% throttle. If yes, then heading in the right direction.

chapter four

Python algorithms to control the drone

chapter four

Python algorithms to control the drone

4.1 **A comparison will be made between the drone control algorithms,** as the Path Algorithm is the path followed in the project with a comparison between UAV Swarm Real-Time Rerouting. The Swarm algorithm is used in several languages such as C Sharp and Java, as well as C++. It is important to know that the way The algorithm differs according to the language used as well as a number of additional points.

4.2.1:Path Algorithm

The common global path planning algorithms such as Dijkstra algorithm, A* algorithm , D* algorithm and many more have been developed to handle the path project problem for mobile robots.

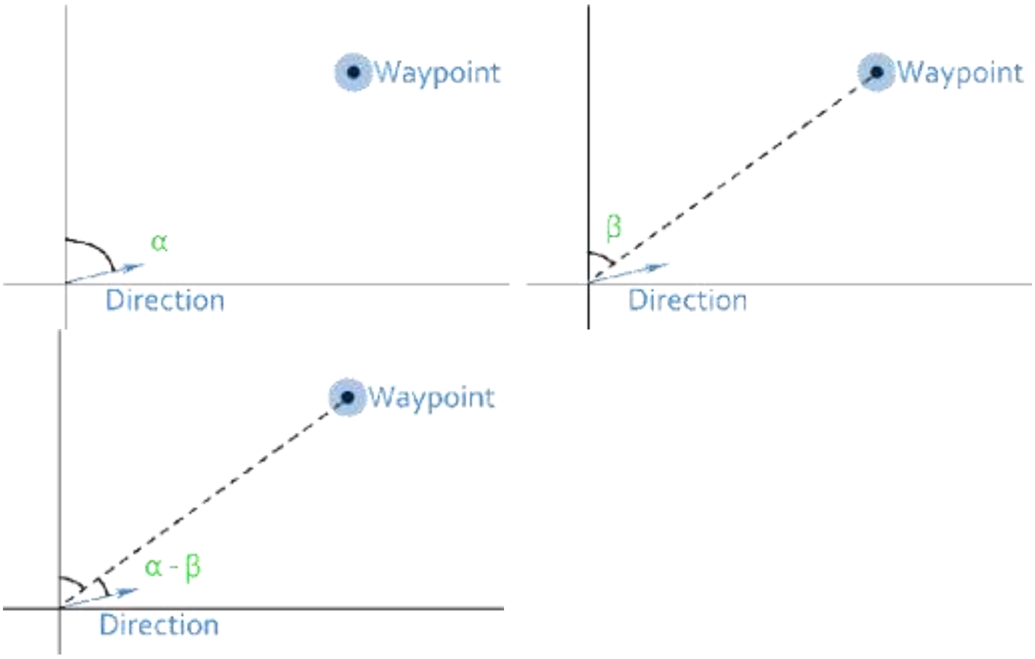
Dijkstra algorithm is an e cient breath−first project method to find a least−cost path between nodes in a graph. It was conceived by E.W. Dijkstra in 1959 [104]. The evaluation function of this method can be written as f(n) = g(n) + 0, which uses a negligible estimate of the distance to the goal. All vertices are divided into two groups, the first group is used for vertices of the shortest path, and the second group is used for vertices that have not been included yet. The initial state of the shortest path set only contains the starting point, while the another set initially includes all vertices except the initial point. Every time, a vertex closest to the starting point from the second set will move to the first set, and the path length will be minimized [20].

The path length is the sum of the weight of edge from the starting point to the node. The project ends when all vertices are included in the first set. [105–107] have presented the path planning strategy for mobile robots using with Dijkstra algorithm. The main disadvantage of this method is that it does not use the information obtained from the environment, such as the location of the goal, so it will explore in all directions (uniformed project).

As an extension of Dijkstra algorithm, A* [108] is defined as the best−first algorithm. It is the most known path planning algorithm, which can be applied to the metric and topological configuration space. The principle of A* algorithm is to evaluate each state through the evaluation function f(n), f(n) = g(n) + h(n). h(n) represents the heuristic estimate of the minimum cost from state n to the goal state, and g(n) is the current accumulated cost between the initial state to state n. Generally, the Manhattan or the Euclidean distance is used when calculating the heuristic cost. The evaluation function f(n) notably represents the minimum estimated cost from the initial state to the goal state passing through state n. A* algorithm is more e ective than the Dijkstra algorithm in path project, because it considers the location of the goal and mainly explores the goal state (informed project). Nonetheless, which may exist several states with the minimum f(n) value, which can not guarantee the optimality of the generated path. [21].

4.2.2 There also exist the extensions of A* algorithm like D* algorithm [109,110], field D* algorithm [110,111], Focussed D* [112],LPA* (Lifelong Planning A*) [113], D* Lite [114], basic Theta* algorithm [115], and Phi.[١١٦] *

D* algorithm stands for the dynamic version of the A* algorithm, which means it can change the cost of arc while operating (online replanning). The backward path is projected from the goal to the current position. Every state expect goal state to have a backpointer to the next state, so that the cost from each state to the the goal state is known. The calculation ends when the next state to be evaluated turns out to be the start state. D* algorithm is more e cient than the A* algorithm in complex environments as it can ignore the influence of local changes in the environment and avoid the cost of backtracking computation. However, the high cost of memory is the main disadvantage of D* algorithm[22].



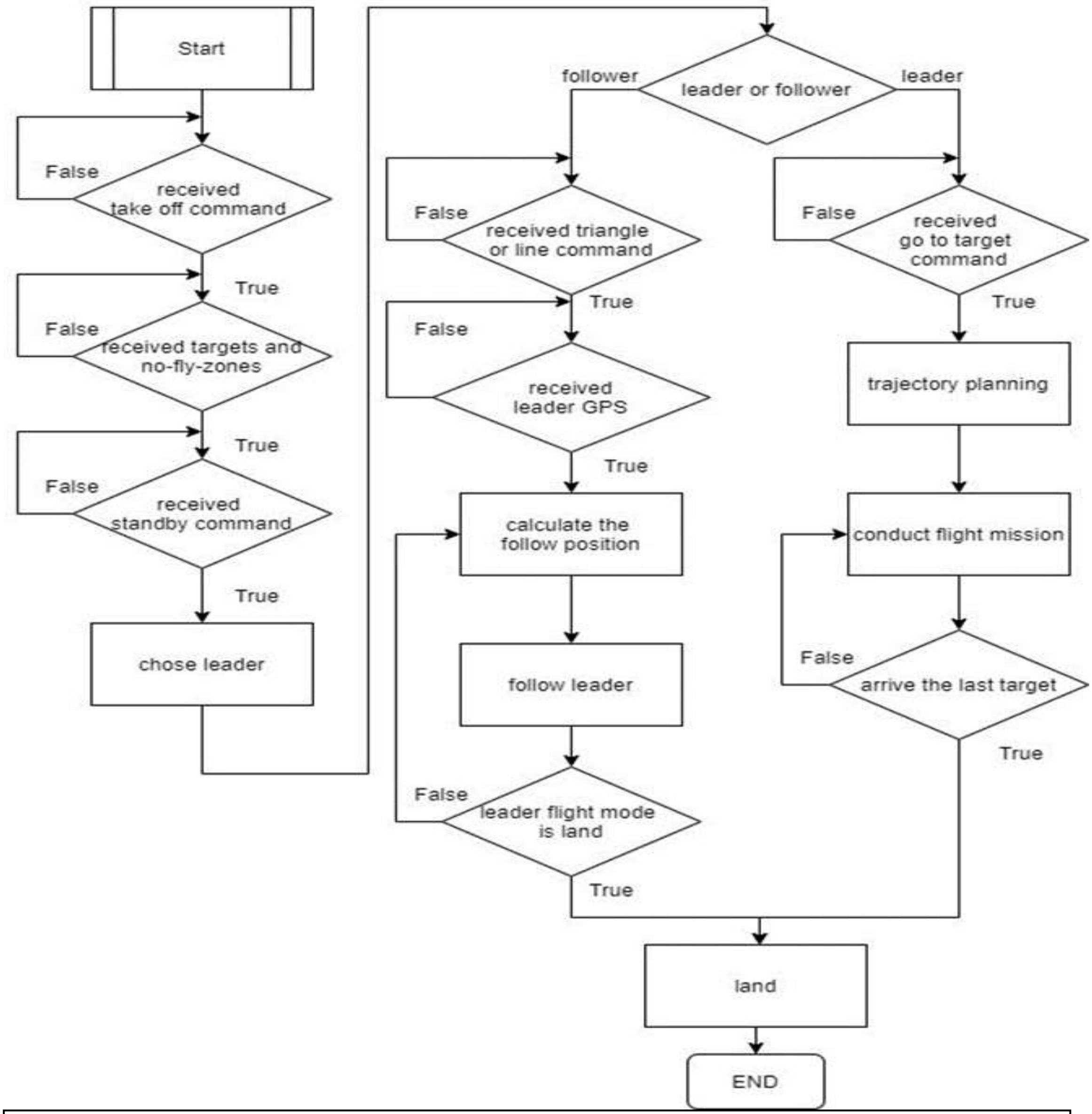


Figure 18: Lifelong Planning A-D

4.2.3 UAV Swarm Real-Time Rerouting

MAVProxy is designed as a simple GCS for any flight controller supporting the MAVLink protocol. It is a command-based ground station software for developers.

To use a graphical user interface for monitoring, it can be complemented with other ground station software applications, such as Mission Planner, APM Planner 2, or QGroundControl [21–23]. Further, it has many interesting functions, such as message forwarding from the UAV to other GCS via the User Datagram Protocol (UDP) network. This function is used to monitor the mission trajectory during flight.

The monitoring station is designed to monitor the trajectory of flight missions based on a GCS mission planner. It is a simulation tool developed as part of this project. In Figure 11, the monitoring station gathers information from MAVProxy via Wi-Fi and displays the trajectory [23].

Figure 19: UAV Swarm Real-Time Rerouting

4.2.4 Experimental Drones

Compared with fixed-wing aircraft, a quadcopter can deploy on a smaller site and does not require a runway for takeoff or landing; hence, it was chosen for flight experiments. The drones used in this project were three 450-class quadcopters, which consisted of four motors, four electronic speed controls (ESC), four propellors, and a carbon-fiber frame with a power distribution board. [Herwitz et al. 2019]. Based on this flying testbed, a Pixhawk 4 flight controller, a Jetson Xavier NX onboard computer, an Xbee wireless communication module, a 2.4 GHz receiver, and a battery were integrated into each drone, as shown in Figure 12. The total weight of the experimental drone, including a 3S 4200 mAh LiPo battery, was 1474 g, and the flight duration was about 6 min [24].

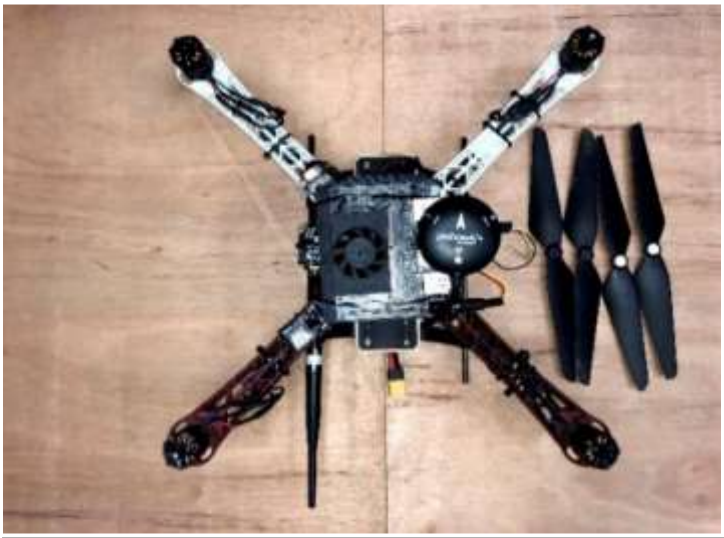
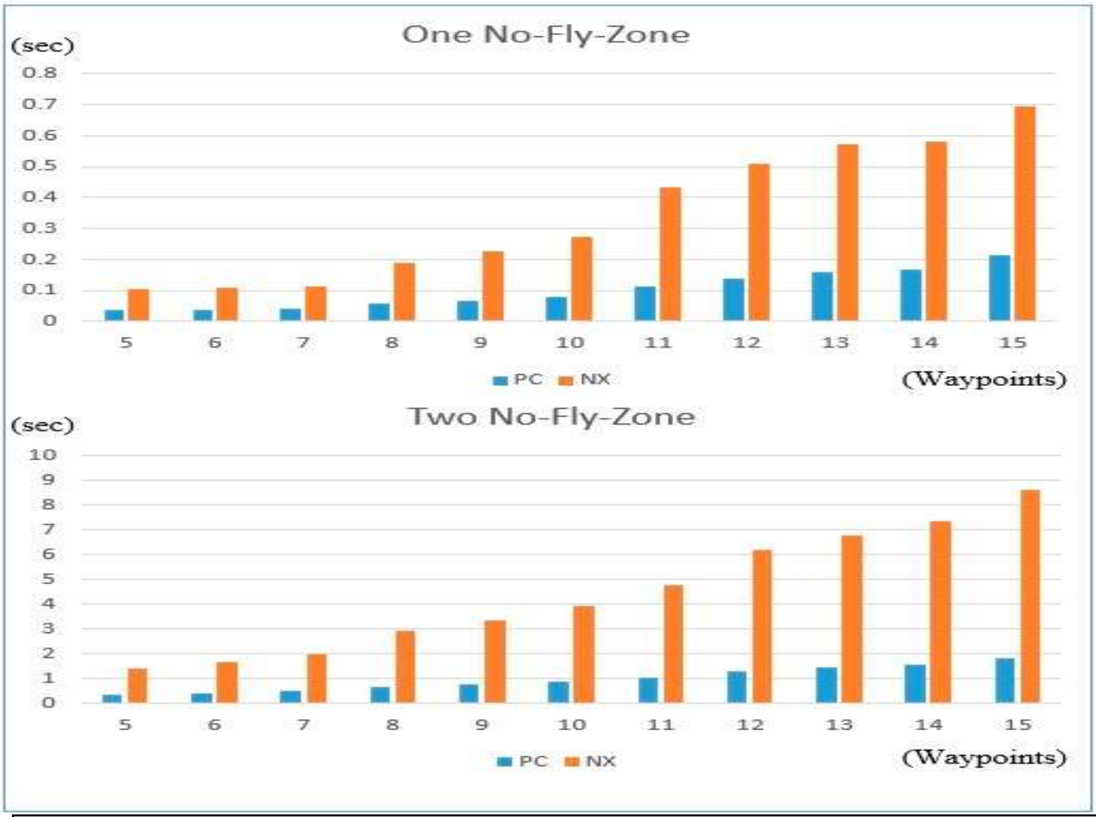


Figure 20: Experimental Drones PARTS

4.2.5 Hardware and Software Performance



. **Figure 22.** Calculation time of Cython on PC and Jetson Xavier

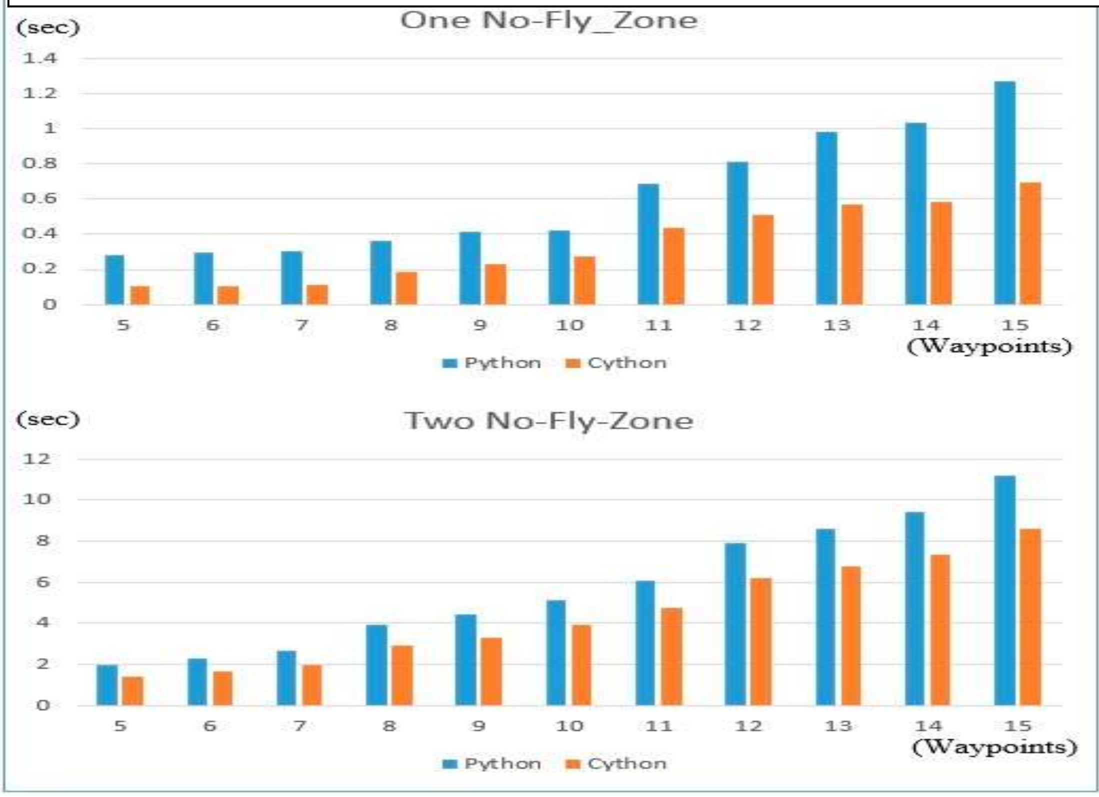


Figure 23. Comparison of Python and Cython on Jetson

chapter five

Conclusion

chapter five
Conclusion

Conclusion

In this reproject, the method of programming a Raspberry cut was identified by a computer using the Python language. Through the computer, the vehicle's flight and change of directions, descent and ascent are controlled, but there are several points that can be known at the end of the work, the most important of which is that Python is the language suitable for controlling drones because the control is using a computer. It is easier than other languages such as Java, for example, and the two reprojecters made a comparison between the control by showing the basic code and auxiliary codes such as the camera and other accessories that are present in the plane>.

Figure24: Image of uav on the building

References

References

[1] Baron, A., Kornus, W., Talaya, J. (2003): ICC experiences on Inertial/GPS sensor orientation. In: ISPRS WG I/Workshop“Theory, Technology and Realities Inertial/GPS sensor orientation”, 22-23rd September (2003),Castelldefels

[2]Caprile, B and V. Torre. (1990): Using Vanishing Points for Camera Calibration. International Journal of Computer Vision, vol. 4, pp. 127-139, 1990

[3] -David R. Fletcher. (**2002**): The Role of Geospatial Technology in Critical Transportation Infrastructure Protection: A Reproject Agenda. In: National Consortium on Remote Sensing in Transportation—InfrastructureManagement,

[4]-www.ncgia.ucsb.edu/ncrst/meetings/(2002)02CIP.

[5]-Disaster, IGARSS’06,Denver, Colorada,(2006). (to be pressed)
Wu, J; Zhou, G.; Zuxun Zhang; Jianqing Zhang. (2006)c:Texturing 3D Building Model for Photorealistic

[6]Generation, IGARSS’06,Denver, Colorada,(2006). (to be pressed) .
Wu, J; and Zhou, G., (2006)b: UAV Video System Calibration For Real-Time Generation of Orthoimage for Natural

[7] http://www.epic.org/privacy/surveillance/spotlight/0805/rsjb.pdf

[8]-Mirchandani, P. Hickman, M.Angel, A.Chandnani, D. (2003): Application of Aerial video for Traffic Flow

[9]-http://www.streambox.com/corporate/gv6170-final.pdf

[10]Jason Blazakis. (2004): Border Security and Unmanned AerialVehicles, CRS Report for Congress, Order Code RS21698, January 2. IEEE Transactions On Geoscience And Remote Sensing, Vol. 43, No. 7, July.

[11]- Zhou, G., Kenneth Jezek, W. Wright, J. Rand, and J. Granger. (2002): Orthorectification of (1960)s Satellite

[12]-International Symposium on Satellite Navigation Technology Including Mobile Positioning & Location Services Melbourne, Australia 22–25 July (2018).
[13]-Jacobsen K., 1999. Combined bundle block adjustment with attitude data. ASPRS Annual Convention (1999),
[14]-Portland Jacobsen, K.(2002): Calibration aspects in direct georeferencing of frame imagery. IAPRS, Vol. 34, Com. I, Part 1, pages 82-89, Denver
[15]James Careless. (2005): "UAV provides NOAA with airborne eye", in governmentvideo.com, September, Copyright © 2005 by CMP Information, Inc. Reprinted with permission from Government Video.(6170).
[16]- Monitoring and Management, EOM Vol. 12, No. 4, pp.10-19
[17]- Moore, M., C. Rizos, J. Wang. (2003): Issues concerning the implementation of a low cost attitude solution for anunmanned airborne vehicle (UAV), Presented at SatNav 2003 The 6th
[18]-Photographs Covering Greenland. IEEE Transactions on Geoscience And Remote Sensing, Vol. 40, No. 6,June (2002).
[19]-Robotics And Automation, Vol. Ra-3, No. 4,August (2009).
[20]-Wu, J. and Zhou, G., (2006)a: Self-adaptive Image Matching of Low-Cost Unmanned Aerial Vehicle (UAV) Video for Orthoimage
[21]Schwarz K.P., Chapman M.E., Cannon E., Gong P., (1993). An Integrated INS/GPS approach to the georeferencing of remotely sensed data. Photogrammetric Engineering & Remote Sensing, 59(11), pp. 1667-1674
[22]-Schwarz K.P., Wei M., Van Gelderen M., (1994). Aided Versus Embedded- A Comparison of Two approaches to GPS/INS Integration, IEEE PLANS, Las Vegas, pp. 314-322
[23]- Skaloud J. (1999). Problems in sensor orientation by INS/DGPS in the airborne environment, Proceedings, ISPRS

Workshop "Direct versus indirect methods of sensor orientation", Barcelona, pp. 7-15

[24]-Suman Srinivasan, Haniph Latchman, John Shea. (2004): Airborne Traffic Surveillance Systems –Video Surveillance of Highway Traffic. VSSN'04, October 15, New York, New York, USA.

[25]Tasi, Roger Y. (1987): A Versatile Camera Calibration Techniaue for High-Accuracy 3D Machine Vision Metrology Using Off-the-shelf TV Cameras and Lenses, IEEE Journal of

[26]Visualization of Urban Environment Using Video and Range Data, IEEE Tran. on Visualization and Computer Graphics (2019)(Submitted).

[27]- Zhou, G., W. Chen, J.. Kelmelis, and D. Zhang. (2005): A comprehensive project on Urban True Orthorecitification.