

Study on Design and Simulation of a Drone (Quadcopter)

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Abstract- In the past, various industries and fields of endeavors has had a hard time in reaching certain places crucial to achieving their goals and objectives. This could be as a result of bad weather, awkward positions to reach or even places that could be dangerous for humans to access physically. For example, in the military, some enemy lines prove too difficult to conquer without mass casualty. In manufacturing, agriculture, commerce etc., poor weather and difficult positions makes accessing some places very strenuous. These were all before the advent of drones. A drone is an aerial vehicle which uses aerodynamic forces to provide vehicle lift which can be recoverable or expandable, can be piloted remotely or fly autonomously, does not carry a human operator, and can carry a non-lethal or lethal payload. Beforehand, drones were used only for military applications like spying on both international and domestic threats because they do not put the life of a pilot at risk in combat zones. Currently, the developed drones can be used in a vast number of applications, such as deliveries, policing, monitoring flooded areas etc. This project focuses on designing and developing a general-purpose drone that can be used in different applications. A quadcopter is the model of drone that is simulated on this project depicting the aerodynamics and components needed for the development of a quadcopter.

I. INTRODUCTION

For years, drones have been used for different purposes and has been of help in numerous occasions and applications. Today, these Unmanned Aerial Vehicles (UAV) have evolved becoming more popular and their applications increased rapidly in various fields. The name “drone” is said to have originated from an old English word *drān*, *dræn*, which means ‘male bee’. [1: Douglas, 2021] When we talk of drone as an electric device, it could be a missile or a remote-controlled pilotless aircraft designed to meet certain goals and objectives. According to the figure below, the estimated investment in drone hardware in government, consumer, and enterprise has been increasing since 2015.

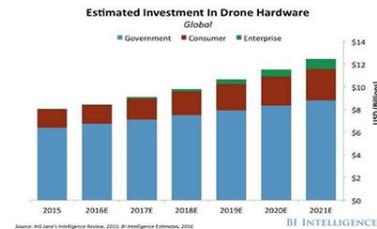


Figure 1: The Estimated Investment Growth in Drone Hardware [2: Joshi, 2019]

Undeniably, it was disclosed by research that human help is still required in order for the drone technology to start operating in new spaces. Currently, there are two types of drones. The former does not need a GPS as it hinges on a highly skilled person to keep full control of it. In other words, it relies on visual tracking in order to determine orientation as well as position. As for the latter, it contains GPS technology, which at first was reserved only for military purposes. Then, when they start allowing the use of this type of drone, many doors have opened for new fields of applications. It allows the drone to have multiple functions; for instance, it allows it to remain in a fixed position with respect to location and latitude. Another function is return to home, which allows it to remember the spot at which it took off and automatically returns to it, and this is made by pressing on a button called “return”. Clearly, this type of technology does not require any human pilot as it uses the autopilot concept by following the trajectory given by a set of GPS points, which is a way the autonomous flight predetermines the path of the drone [3: Chris, 2021].

Drones are technically called unmanned aerial vehicle as they are not operated by a pilot. These airborne crafts serve useful purposes in spying, military services and other related operations. Drones are often operated by a controlling person from the ground using a remote control or a computer. Until recently, the idea of drones seemed futuristic, farfetched, and maybe unrealistic. The evolution of drones and its widespread adoption in various fields today is simply mouth gaping. There applications not only in photography to take fun photos from the sky, geographic surveillance, package delivery or military operations have made drones the hottest toy on the market for both the young and old. The prices of drones range anywhere from under a hundred dollars

to thousands upon thousands of dollars depending on specifications, and they come in different sizes everywhere from fitting into the palm of your hand to bigger than the average human being. Quadcopter unmanned aerial vehicles are used for surveillance and reconnaissance by military and law enforcement agencies, as well as search and rescue missions in urban environments. The military use of unmanned aerial vehicles (UAVs) has grown because of their ability to operate in dangerous locations while keeping their human operators at a safe distance. The larger UAVs also provide a reliable long duration, cost effective, platform for reconnaissance as well as weapons. They have grown to become an indispensable tool for the military with or without payload in advanced countries. One such example is the Aeryon Scout, created by Canadian company Aeryon Labs which is a small UAV that can quietly hover in place and use a camera to observe people and objects on the ground [4: Aeryon, 2021].



Figure 2: The Aeryon Scout Quadcopter

II. METHODOLOGY

The scope of this project shall cover an indebt study on Unmanned Aerial Vehicles (UAV) taking the design, modelling and development of a Quadcopter on center stage. This expands the scope of the electrical engineering education to include the control and the understanding of the mechanical components. The Quadcopter has many applications that we are interested to develop like mapping and video streaming especially in a disaster and dangerous area. It also opens up the possibilities to broaden the understanding and applications of control systems, stabilization, artificial intelligence and GPS navigation as it applies to the Quadcopter.

Application of Drones

In addition to the military uses of the small UAV, we are interested in evaluating applications in the commercial and industrial sector. Our premise was that if smaller and cheaper UAVs become readily available, new markets and uses will emerge. Potential new markets in commercial and industrial applications include inspecting pipelines or even inspecting dangerous areas like a meltdown site at a nuclear power plant. Disaster relief or crop assessment seems also to be likely areas where small UAVs could be useful. We were also motivated by on-campus uses such as monitoring parking or quick-look video of an incident, or monitoring hard to reach locations, or exploration of a collapsed building or other dangerous location. Below is a list of fields of applications of drones:

- (i) Military use
- (ii) Agriculture
- (iii) Engineering applications
- (iv) Search and rescue
- (v) Aerial photography
- (vi) Shipping and delivery
- (vii) Aerial surveillance
- (viii) Research and science
- (ix) Mineral's exploration.

System Requirement

Requirements are important because they establish a foundation for product scope, vision, schedule, and cost. They eventually should target the quality and performance of a finished product. Requirements supply stakeholders like electrical engineering, software engineering, and mechanical engineering with one uniform set of goals and vision. Each stakeholder holds realistic expectations after understanding the requirements of the final product. No surprises should occur from the final product in terms of functionality and design, which will yield a profitable and a successful product launch [5: Mann, 2017]. In order to determine the project requirements, a hierarchical decomposition of a quadcopter is shown below:

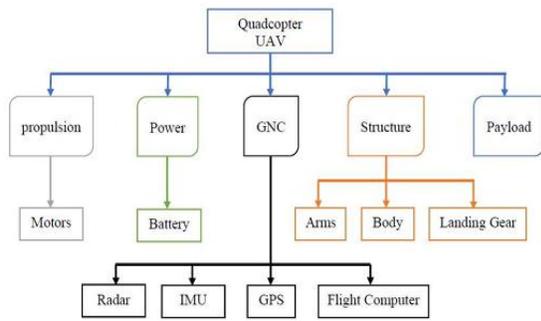


Figure 3: Hierarchical Decomposition of a Quadcopter

The figure above describes a hierarchical decomposition of a simplified model of a quadcopter drone by dividing it into two tiers. The first one has five primary subsystems, which consist of power, propulsion, structures, GNC, and payload. As for the second one, it further breaks down to smaller units comprising the battery, IMU, flight computer, radar, motors, GPS, body, arms, and landing gear.

Technical Specification

The drone's technical specification is the technical data that makes a clarified description for the drone's specific use, functionality, or performance levels. We should hence abridge the previous concept by claiming that the quadcopter's technical specification is a set of Key Performance Indicators (KPIs), which is able to describe the performance competence of a quadcopter. The set of the significant technical data or the technical specification plays a crucial role when it comes to make a formal decision about choosing the ideal drone; especially, when making a comparison between different quadcopter models. Nonetheless, when acquiring the right indicators of the technical specifications is not always easy for two reasons. The first one is because some fundamental parameters are hidden by some manufacturers as they are not optimal when compared to the rivalry (6: Affortunato, 2020). The second one because the specifications are not the same reported by all manufacturers. For instance, producer A can report his drone's maximum tangency quota; on the other hand, producer B can only omit this data in the technical specs.

MATLAB Simulation

After completing the motion's equations which describe the flight system's dynamics, now a simulation environment to view and test the results of several controllers and inputs can be created. Even

though some methods, which are more advanced are available, a simulator which uses the method of Euler can quickly be written to solve differential equations that evolve the state of the system. This simulator along with the functions needed to compute all the physical torques and forces are shown in APPENDIX A using MATLAB. Besides, values needed for all my physical constants, which were not shown are: Functions to convert from the derivatives of yaw, pitch, and roll to an angular velocity vector ω and vice-versa, and a function that computes the rotation matrix R . Then, the 3D visualization quadcopter is drawn along with angular velocity and displacement as the simulation is running like shown below (7: Gibiansky, 2012).

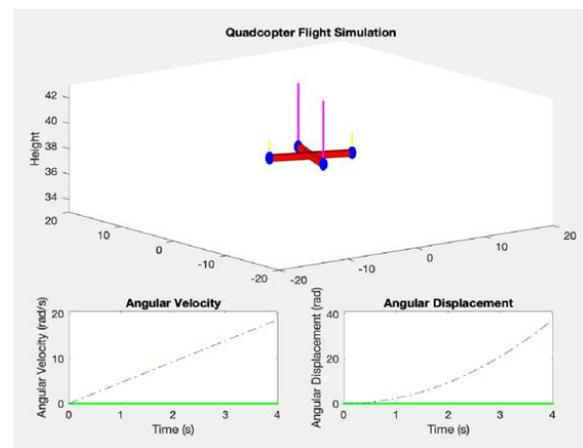


Figure 4: Quadcopter Flight Simulation

CAD Design and Analysis

SolidWorks is used as the CAD design, which is a 3-D modelling CAD and CAE software that runs primarily on Windows operating systems. It is used for mechatronics systems development from the start to the end. Initially, SolidWorks is used to plan, visualize ideation, model, assess feasibility, prototype, and manage projects. Then, it is used to design and build software, mechanical, and electrical elements. This software can also perform different analyses on the product in order to check its behaviour in the real world. Hence, it can be tested differently before the product is manufactured. To make it clearer, the product can go through three stages using this software. First, the product is conceptualized and drawn. Second, it is modelled and analysed virtually depending on the user's needs. Finally, it is modelled and analysed in real life by 3-D printing it or laser cutting it but this is beyond the scope of this project. One of the SolidWorks major advantages over other CAE and CAD Software is that the desired part design can be rendered in many

different materials, and the quality is so good in such a way that makes it very realistic.

Components of a Quadcopter

1. Frame: One of the most critical parts is the frame in every design. It needs to be formable, rigid (the material is selected carefully), and able to withstand the pressure and the seasonal weather like rain, wind, and so on so that the vehicle does not fail. Furthermore, it can be used as a mounting platform for all crucial components (mechanical, electrical, and propulsion). In order to prepare a design for my drone project, many designs were observed from different websites. However, the one chosen by me is a wooden drone frame from a website called Grab Cad, and many modifications can be made according to the material, dimensions, and thickness. Once I am done with the project the new developed design will be uploaded to the same website in order to make it available for interested members. The two figures below show the frame chosen in both the collapsed and exploded view (8: Dragatis, 2018).

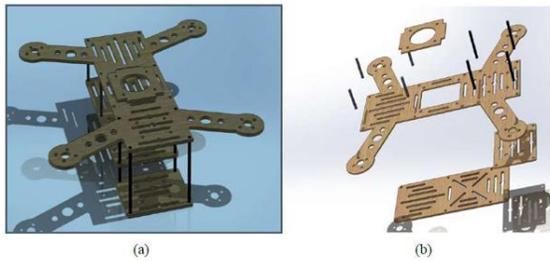


Figure 5: (a) The collapsed view of the drone. (b) The exploded view of the drone

Before launching a product in the market, a prototype should be made. Nonetheless, in addition to the time and money to make a prototype, analyses and tests should be performed to assure its design effectiveness and physical capabilities. Nowadays, many manufacturers use CAE or CAD to either 3D print or laser cut a desired product. Consideration is taken into the latter information and different analysis made to compare materials used in laser cutter and 3D printing. There are two materials available to choose for the laser cutter, which are: Fiberboard (Plywood) and acrylic (plexiglass). The aforementioned materials are compared with the ABS (Acrylonitrile Butadiene Styrene), which is used as a material in 3D printing.

2. Propellers: One of the most crucial parts the quadcopter are the propellers. The craft's wings are these spinning blades which lift the system

into the air by creating an airflow. There are many different sizes and shapes but the same overall purpose that the drone propellers come with; however, each flight characteristics can be different dramatically. In order to choose the right drone propeller, we must take into consideration miscellaneous factors. Power and the drone flight smoothness can be significantly affected by the propellers; hence, the flight efficiency is one of the most fundamental considerations to be taken. Size and number of blades are important factors when selecting new propellers of a drone. Depending on the platform, payload, and usage requirements, the number of blades per propeller required will vary. Smaller blades (under 8 inches) are most usually used for acrobatics and racing drones. Generally, smaller motors with high kV ratings are paired with smaller blades. Larger blades (over 8 inches) can be used to carry heavier payloads like spraying containers for agriculture and video equipment. They are generally paired with low kV motors. When selecting a propeller, we need to choose wisely taking into account its diameter and pitch. Pitch: is known as the propeller's traveling distance per each revolution. Frequently, it depends on what the specific application is for a quadcopter platform to determine the correct pitch. Lower pitch generally leads to less turbulence and more torque for lifting; as a consequence, it relieves how hard the motors have to work to lift heavy payloads resulting in a flight time increase because less current is drawn by the motors from the battery. Higher pitch propellers can move more air, but they create less torque and more turbulence. Diameter: typically, a propeller blade with a larger diameter permits more contact with the air. This latter has a relation with the flight efficiency, when there is a small decrease or increase in diameter, it can change the efficiency of the drone performance. There is a tendency that when hovering, larger propellers are more stable than smaller ones. Nevertheless, less effort is required for the smaller propeller blades to slow down or speed up than larger ones, which make them more responsive. As said previously, larger propellers with low pitch are better suited for aerial video cameras and lifting heavy payloads while smaller propellers with high pitch are more appropriate for quick and fast manoeuvres. As a summary, depending on the planned utilization and many other factors as aforementioned that need to be taken into account in order to select well the propeller blades of the quadcopter. For instance, larger propeller blades with low pitch are more suited in applications that require heavy

lift (9: Rees, 2017). Since I already know the components, to be used to create a quadcopter, we take advantage of the report discussed whereby the 30A ESC, A2212 1000 KV brushless motors, and the size (10" x 4.5") of my propellers are used to see how much thrust and ampere can be obtained from them using excel. The motor propeller combination will be using for my quadcopter, and this test gives some important data for the dimensioning. When the set of propellers chosen is used with the 3 cells battery and 1000KV motors, the ability of 0.97 kg of static thrust can be given by each motor in which 172 Watts that will be consumed. In other words, around 4kg that the system will be able to lift. From my background studies, it is known that it is recommended for the quadcopter to lift twice its weight, which means that at least 500 grams should be lifted by each arm. A simulation of the propeller can be made in SolidWorks using Computational Fluid Dynamics (CFD), but before that, a propeller has to be imported to the Software. The propeller used is shown in the figure below:



Figure 6: Propeller Model Used in the Simulation
(11: Wankhade, 2020)

Myriad of analysis methods are used by engineers to better understand the world's impact around us on their designs. One of the best and a key analysis method that is used to analyze and solve problems, which involve the fluid flow impact like gases or liquids is Computational Fluid Dynamics. Many industries use CFD to solve a wide range of engineering problems, including aerodynamics and aerospace analysis, high-tech electronics cooling, combustion and engine analysis, industrial systems design, and many others (10: Staples, 2014).

3. Electronic Design: In order to have a safe and smooth flight, all drone components and parts are vital. When knowing the drone components, the user can have more confidence while flying it. After knowing each drone component, it will help

the user to get to the bottom of any flight issue. The figure 16 shows the schematics of the electrical components and in APPENDIX B it shows it in detail. Each component is shown and explained in detail in the following sections.

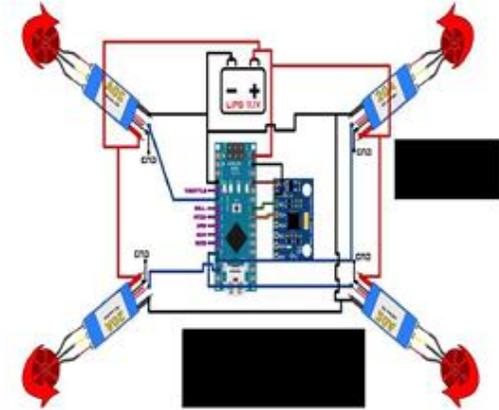


Figure 7: Quadcopter Electrical Connections Schematics

4. BLDC Motors: Brushless motors are brushless outrunner motors or DC electric motors, which are also known as ECMs (Electronically Commutated Motors). Those motors are synchronous, powered by an electric DC source through an integrated inverter switching power supply that produces an electric alternating current (AC) signal in order to drive the motors. This latter implies a bi directional current with no restriction on waveform rather than a sinusoidal one. The BLDC motors I chose to work with are 1000 kV ones made specifically for multirotor and quadcopters. They provide power, high performance, quality, dependability at an affordable price, and brilliant efficiency. They are perfectly suited for medium size drones with propellers of 8 to 10 inch. When ordered, they come with power leads, prop adapters, and mounting bolts as shown in the figure below. Each 30A ESC should be used to drive each motor.



Figure 7: A 1000KV BLDC Motor

These kinds of motors were made with wire wound stator poles and a permanent magnet rotor. The attractive magnetic forces between a rotating magnetic field, which is induced in the wound stator poles, and the permanent magnetic motor convert the electrical energy into a mechanical one. There are 3 electromagnetic circuits that are commonly connected to a point, and each one of them is divided in the center; hereby, allowing the permanent magnetic rotor to move amidst the induced magnetic field. Brushless motors can be used in so many applications, such as: electric bicycles, fans to raise the system's overall efficiency, spindle drives, pumps, and so many others.

5. Electric Speed Controllers (ESCs): ESC or an electronic speed controller is a device installed in a remote-controlled model to control the speed and direction of a brushless motor. Each one of them has an output for a motor and an input for a battery. Four of them are required so as to control each motor.



Figure 8: Electronic Speed Controller (ESC)

6. Battery: Li-Po batteries currently dominate the market due to their high current discharge and high energy density when it comes to lightweight drones. They are composed of many cells

connected in series but rarely in parallel, which are denoted respectively by S or P. Depending on the charge's state how the cell voltage changes; nonetheless, there is going to be permanent damage when discharging a Li-Po cell below 3V. Hence, discharging about 20% the battery is recommended, which gives an 80% depth of discharge. Besides, these batteries are characterized by a C rating, which identifies the maximum drawn current continuously, and their capacity in mAh. Obviously, this shows that maximum discharge current cannot be dependent on the battery capacity. In this experiment, a high amount of current is needed for the brushless motors to be used. Therefore, a 3 cell 3300 mAh 11.1 V Li-Po battery that can supply roughly 3A current constantly is used. This latter is not heavy and provides sufficient current, which is ideal for this application. Unlike Li-Po, NiMH is cheaper but much heavier. These kinds of batteries (Li-Po) vary from single 3.7 cells up to 37V 10 celled. The most well-known one is the 3SP1 that is three celled and is 11.1V.



Figure 9: 3300mAh 3 Cell Li-Po Battery

The power that each motor outputs at 7500 RPM rotation is 52 Watts, which after summing four of them up, we get 208 Watts. As previously mentioned, the motors have a maximum of 80% efficiency, which leads to an input power of the motors of roughly $208 \times 0.8 = 166.4$ watts... (01)

No more than 20 Watts will be used by the rest of the system. This permits a total input power of 280 Watts as a safe estimation that the battery should deliver. Taking into consideration that a 3 cell 11.1V battery will be used, a 22A will be drawn by the current, and as previously mentioned, the battery capacity is 3300 mAh with a 35C max current discharge, this clearly means that the battery can safely draw $3.3Ah \times 35 = 115.5 A$... (02)

This latter puts my system on the safe side. If we consider a constant current draw of 20A (the drone will not run at 7500 RPM the whole time), then the maximum flight time will be $3.3 Ah \times 60 \text{ min} / 20 \text{ A} \approx 10 \text{ minutes}$ (03)

This shows that my system will be able to fly for roughly 10 minutes at full throttle. Since from the start of the project, I specified that I want my drone to be able to fly for at least 15 minutes, we should consider a constant current draw of 13 A to fulfil that. In this case, the total flight time will be $3.3 Ah \times 60 \text{ min} / 13 \text{ A} \approx 15.23 \text{ minutes}$ (04)

7. Arduino Nano Microcontroller Board: When it comes to pinouts and features, the Arduino Nano Microcontroller board is quite similar to Arduino UNO. The only difference is its size, which made it better since it has the same functionalities but lighter. In my project, I made sure that each component I choose should be as light as possible so that my system's flight remains smooth, and as it is known, it is preferred that the embedded devices to be smaller in size. The Arduino Nano is a complete, small, and breadboard-friendly based on the ATmega328. This general-purpose microcontroller allows to make own flight controller by assembling the controller and coding it personally. It is a robust and reliable platform that can be connected to a computer by using a USB cable, an AC/DC adapter to power it up, and a battery. The best thing about this controller is it allows me not to worry about destroying it in case I mess with it. Finally, in order to program the Arduino Nano, the Arduino IDE Software is used.

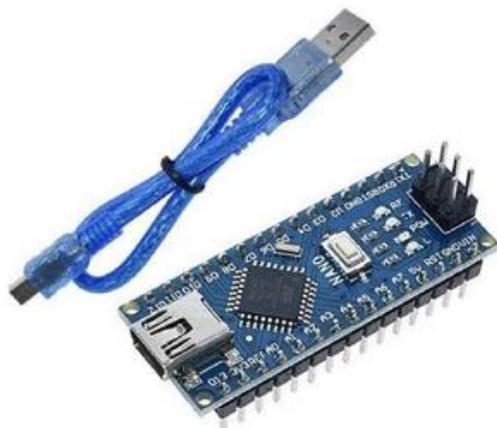


Figure 10: Arduino Nano Microcontroller Board

The Arduino Nano Pinout is represented as shown in the figure below.

ARDUINO NANO PINOUT

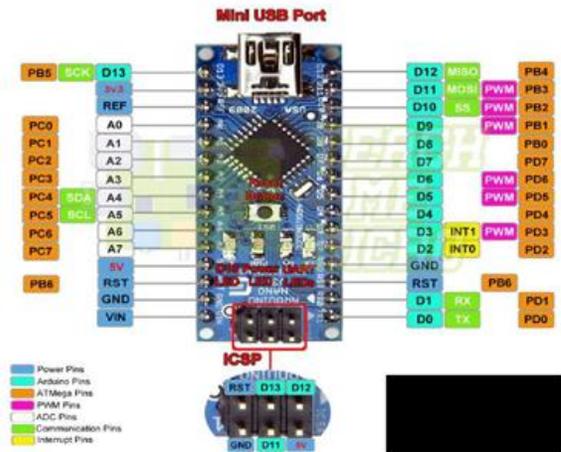


Figure 11: Arduino Nano Pinout

8. Inertial Measurement Unit (IMU): The IMU or Inertial Measurement Unit is used to level my quadcopter and measure its velocity, orientation, and force of gravity. This data is very significant for manoeuvring the quadcopter. This board uses the I2C-bus to interface with the Arduino Nano Microcontroller board. The IMU uses a collection of sensors which is comprised of a gyroscope that reads the angular velocity values around the X, Y, and Z axis of the IMU and an accelerometer that measures the force (downwards gravity) and acceleration on the X, Y, and Z axis. These when combined are called the six degrees of freedom (6-DOF), which were previously explained in detail in this report. This is how it senses the orientation of the quadcopter. Sometimes the IMU can be comprised of other sensors such as barometers, magnetometers, and other sensors to supplement these. As I reported previously, mine is a 6-DOF IMU that only contains a gyroscope and an accelerometer.

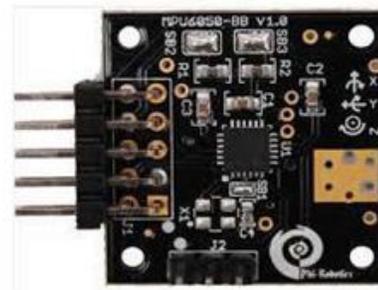


Figure 12: Inertial Measurement Unit (IMU)

9. RC Controller: An RC controller is the use of a radio that transmits control signals to control a device remotely. There are many expensive high

range receivers and transmitters in the market. Nevertheless, as what I am working on is a prototype and in order to minimize the cost, I have used an HC 05 Bluetooth receiver Module that can be used with any device with Bluetooth functionality like a laptop or Phone, which acts like a transmitter. In this case, an app called MultiWii is used. By the help of this app, one can control the flight system of the quadcopter.

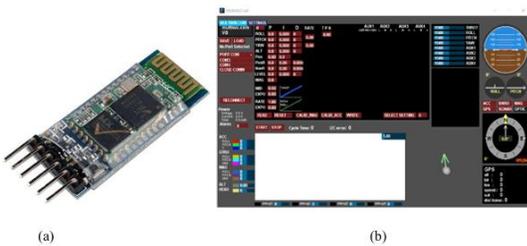


Figure 13: (a) HC-05 Bluetooth Module and (b) MultiWii App

For this project, the HC-05 can add a full-duplex (two-way) wireless functionality. As previously mentioned, it can communicate with a phone using already available android applications, which makes this process easier. This module can interface with an Arduino or any microcontroller that supports USART since it communicates with the help of this latter at 9600 baud. In other words, this wireless module is a right choice for transferring data from a phone or computer to a microcontroller or vice versa. The HC-05 Bluetooth module can easily be paired with microcontrollers because it operates using the SPP (Serial Port Protocol). As shown in the figure below, the module is simply powered with +5V, the Rx pin of the module is connected to the Tx of MCU, and the Tx pin of the module is connected to Rx of MCU.

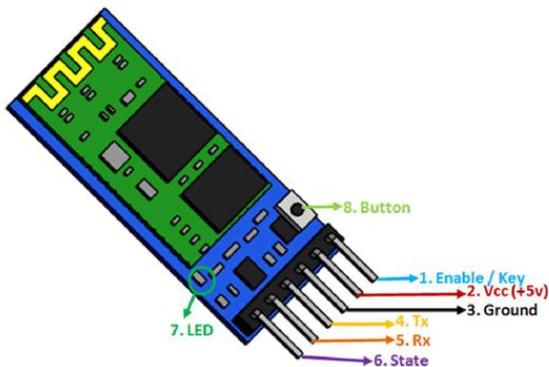


Figure 13: HC-05 Bluetooth Module Pinout

III IMPLEMENTATION

MultiWii

The figure below shows the process flow chart of the drone code, namely, MultiWii. And the code configuration is shown in APPENDIX C (12: Kotelnikov, 2015). It is an open-source code, and it was written by several people in more than a year.

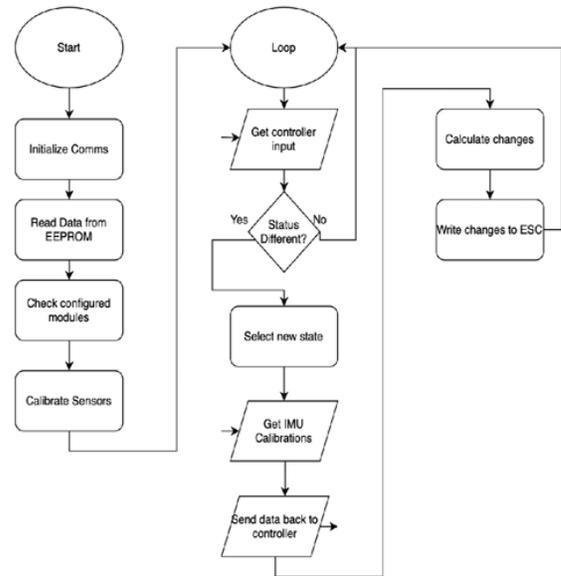


Figure 14: The Drone Code Flowchart

To explain how MultiWii works, I made a simple flowchart that highlights the process in which the drone goes through. As we can see, the drone starts by initializing the communication through the desired channel, which is Bluetooth for the drone. Next, a pre-loaded drone profile, which contains the settings for the drone, are loaded from the EEPROM. After that, the drone checks the modules chosen by the user in the parameters of the program and calibrates the sensors used in the drone. Then, the loop of the program starts as previously mentioned the parts were only performed once. The drone takes user input from the controller through the desired channel and checks if there is any modification that the drone needs to have; otherwise, the program loops back and asks for input again until changes happen. If there is any, the drone checks if it is a noticeable one, as some changes generated from vibration or small signal noise should not cause the drone to go out of its course. The drone then selects the new state it needs to change into. After that, it acquires sensor data from the IMU and sends it back to the controller. This makes the debugging process much easier and provides useful data that can be used to simulate the movement of the drone in a virtual environment.

Finally, the drone calculates the changes it needs to make to the motors and writes those values to the micro-controller's ports, sending those values to the ESCs and eventually to the brushless motors. In the end, the program goes back to the loop state.

Proteus

Proteus is a virtual system modelling (VSM) program that enables the simulation of micro controller systems and electronic circuits. It is designed to provide a virtual environment for rapid development of electronic systems without the need for any hardware. It is used by embedded engineers to design their own PCB circuits and integrate it with other required peripherals to create the desired systems. Because of its massive library of models such as motors, drivers, micro-controllers, and so on, I decided to use it in order to model my system. First of all, I imported all of the drone components that I talked about in the report from the Proteus library except for the Bluetooth model HC-5. It was not available, thus, I had to look for it online and found a model developed by TheEngineeringProjects.com and imported it to my part library (13: Nasir, 2016). Next, a hex file was generated from an Arduino code I used to stimulate the rotation of all 4 motors with equal speed, which simulates the take-off procedure. The Figure below shows an electronic system that uses the Arduino model discussed in my report in addition to the same Bluetooth module, namely, HC-05. Four Brushless motors are used and are connected to L293D Drivers and all the drivers are connected to a battery that supplies 12V.

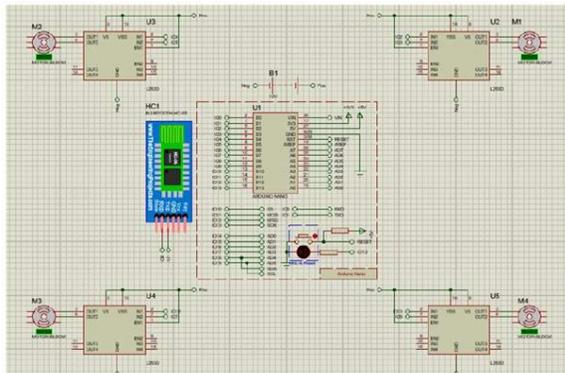


Figure 15: Electronic Connections in Proteus

To demonstrate the take-off procedure for my system, the simulation is started and the speed for all motors set to 0. The reason for this is to make the behaviour of the system more controlled as the default value in the microcontroller pins are unpredictable and the speed keeps changing.

III. SUMMARY AND CONCLUSION

Summary

This project was one of the golden opportunities that prompted me not only to gain knowledge on different topics and learn a fair number of new technologies but also put them into practice. It was a great way for me to apply part of the skills and knowledge I have acquired during my undergraduate degree in Computer Science and lots of research work put in to make this possible. I was able to apply the engineering development process on a real-life project. I managed conducting a feasibility study, understanding and prioritizing the component requirements, designing and simulating the project, and eventually testing it. During this project, I became much more familiar with the quadcopter flight dynamics and many software, such as SolidWorks, MATLAB, Proteus, and MultiWii. I used SolidWorks to work on the mechanical part of my project to determine the best available material to use (in developing a prototype) and to see the air's velocity and pressure impact on the propeller. These were done by making different simulations and analyses, such as the linear static analysis (to generate the Von Mises stress, displacement, strain and factor of safety), the drop test analysis (to see which material would withstand falling from a height of 100 meters), fatigue analysis (to determine the damage percentage and life cycles), and the flow simulation (to simulate the air flows through and around the propeller in order to calculate its capabilities and performance). MATLAB was used to generate the quadcopter thrust while flying along with its angular velocity and displacement. In addition, I made a sketch connecting the electrical components using Proteus so that I can upload the code from MultiWii to the software and simulate it.

CONCLUSION

I can never say I have learnt much or enough as I will always strive for learning more. Learning never ends and that being said, I do not see this project as complete. I aim to develop it further and once fully completed; a final version will be published online for free. The principal work to be done next is to

ensure the drone's smoothness and stability. Besides, the feasibility

of using the image processing has been investigated. The idea is to enable the drone to avoid obstacles and recognize people's faces in order to identify missing people, civilians, and criminals. Thus, working on this will enable me to eliminate criminal activities; especially, that there is a massive increase in crime rate in Morocco and other countries. In addition, this can be used in favour of many institutes to record attendance by detecting faces without wasting time or effort. This is only one of many other applications that this general-purpose drone could be used to accomplish, which could have a huge impact on societies.

A conclusion section is not required. Although a conclusion may review the main points of the paper, do not replicate the abstract as the conclusion. A conclusion might elaborate on the importance of the work or suggest applications and extensions.

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