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Senior Design Project Report

Lifeguard Drone

**In partial fulfillment of the requirements for the
Degree of Bachelor of Science in Electrical Engineering**

Team Members

Student Name	Student ID
Abdulrahman A. Alfridan	201301972
Abdullah A. Alansari	201303885
Abdulaziz K. Aljubair	201001245

Project Advisors:

Advisor Name: Prof. Nizar Tayem
Co-Advisor Name: Mr. Ahmed Abul Hussain

Abstract

Based on studies conducted in several countries around the world, death rate caused by drowning is getting high year after another. One of the main reason was the time limitation the rescuer has to reach the drown people. An average of up to 7 to 10 minutes needed to reach the victim from the bay which is considered long enough for a person to be died before he/she get rescued.

This project aims to design and build a hexa-copter with capability of carrying a payload of up to 1 kg. The payload will be mainly used for carrying a life ring. A wireless communication system is used to fully control the drone by an RC (Remote Controller) which can be used by the Baywatch to deliver the life ring with the minimal time. A comparison was conducted between the drone and the regular rescuer speed, and it was obvious that the drone won by ultimate minimal time consumed to reach the drown person. As of our online research, we couldn't find any similar project application in PMU and Saudi Arabia yet. Upon the successful completion of this project, it can be introduced to be consider for implementation and commercial.

Acknowledgement

The opportunity that we had to do our project was a great chance to learn and develop our skills and knowledge that we have been studied at Prince Mohammed Bin Fahd University. Also, it was our pleasure to meet with many filed professionals people to understand and link the theory studies that we gained to the real touchable project.

The success and final outcome of this project required a lot of guidance and assistance from many people and we are extremely privileged to have got this all along the completion of our senior project. All that we have done is only due to such supervision and assistance and I would not forget to thank them.

We respect and thank our advisor Prof. Nizar Tayem for providing us an opportunity to do our senior project in a shared room with two private cabinets where we can work freely at our convenient time and giving us all support and guidance which made us complete the major parts of our senior project in the first semester. We are extremely thankful to him for providing such a nice support and guidance, although he had busy schedule managing the corporate affairs.

We owe our deep gratitude to our co-advisor Mr. Ahmed Abul Hussain who took deep interest on our senior project and guided us all along, till the successfully completion of the project by providing all the necessary information for developing a perfect system.

We would not forget to remember Dr. Yahya Chedly for his encouragement and more over for his timely support and guidance till the completion of our senior project among two continues semesters.

We are thankful to and blessed enough to get continuous encouragement, support and guidance from all PMU faculty and students which helped us in successfully completing our senior project.

Lifeguard Drone Team.

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1. Introduction

1.1 Project Definition

To design a hexa-copter drone that is controlled by an RC (Remote Control) in which it can carry and deliver a life ring to a certain location. The hexa-copter have five sub-systems in addition to the main one, which they are frame structure, motors and propellers, communication systems, camera for live streaming, a life ring and life ring controller. These subsystems will highly enhance the performance of the drone in which it will increase the speed, stability and efficiency.

1.2 Project Objectives

1. Applying the advanced technology in saving lives.
2. Learn about the communication systems and control a drone
3. Having the minimal time to deliver a life ring.
4. Showing a live streaming of the delivery and while flying.

1.3 Project Specifications

- a. Flying time is up to 15 minutes free load.
- b. Capability of carrying a payload of 1kg.
- c. Li-Po 6-Cells, 22.2 V, 16,000 mAh.
- d. Sized from motor to motor is 960mm and ground clearance 350mm.
- e. Wireless communication.
- f. Radio system with a control range: 0.6km on land, 1.0 km on air.
- g. Monitor the flying operation through a live streaming and an RC.
- h. Portable, having a light-weight, and environmentally friendly.

1.4 Product Architecture and Components

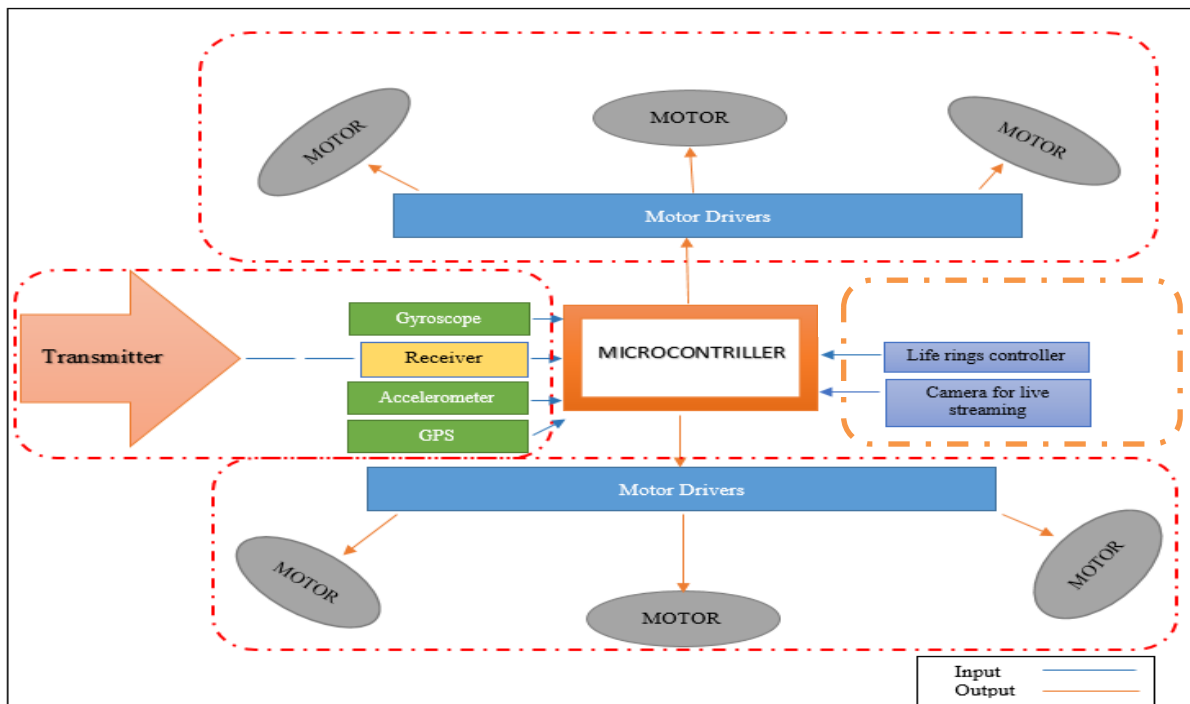


Figure #1.4-1: shows the three subsystems of our project

Figure #1.4-1 shows the block diagram of the project and the subsystems circled as four subsystems and the fifth one would be the drone structure. Three of which have been completed on the previous semester Spring 2018 which they are the frame structure, motors & propellers, and communication system. The other two which include, a life ring and a life ring controller, and camera for live streaming were completed in this semester Fall 2018 during the course of assessment III.



Figure#1.4-2: shows a photo of our real system

Figure #1.4-2 shows a photo of our real system after the completion of fixing the structure, motors, motor drivers, landing gear, battery, flight controller components, and wire connection/soldering.

1.5 Applications

The main application of our system is to deliver a life ring with a minimal time. Also, a live streaming by sending the information (video) from the camera which it displays on a smart phone through Wi-Fi. This application show a synchronise streaming of the drone movement.



Figure #1.5-1: shows a similar application as our project's [10]



Figure #1.5-2: shows another application as our project's[13]

2. Literature Review

2.1 Project background

The trend graph shows the drowning deaths and death rates over a period of time from 2002-2011 in Australia as it's decreasing in compared with the rate of the last decade.

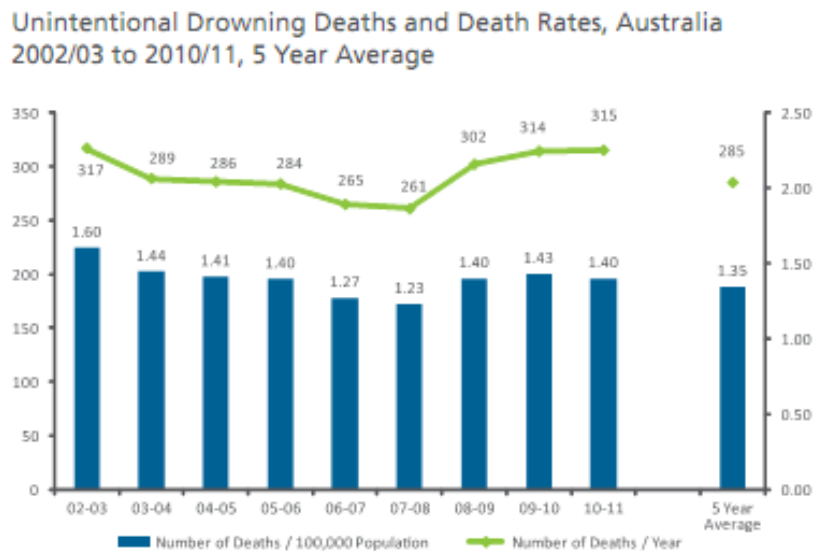


Figure 2.1-1: shows a trend over time of fatal drowning in Australia [15]

Over the past few years, drowning deaths and death rates were increasing significantly. Researchers and engineers were trying to find a solution for this problem and trying to innovate & create an idea which can minimize this huge number of drowning death.

Engineers and students have suggested some solutions for this problem which they have addressed them in the following:

1. A lifeguard boat used by the Baywatch
2. Very well-trained rescuers to be present and monitor the bay from a small tower.
3. A number of Jet-ski ready to be used in case of emergency.
4. Wearable alarm which can be used by the swimmers or wave riders to send a signal to the rescuers in case of drowning.

These solutions can make a deferent in saving the drowning people, but we were thinking in something can reduce the time of rescuer to the shortest time. Therefore, we come up with the drone idea and we start searching and reading a lot to build our first lifeguard drone in Saudi Arabia.

Drones have become central to the functions of various businesses and our drone is used to save people's lives. Our drone has some features such as:

1. The lifeguard drone has great vision range and it is easy to maneuver and control.
2. The lifeguard drone is equipped with a life ring, so that it can help to deliver the life ring in a shorter time to the victim.
3. The lifeguard drone is equipped with a camera for livestreaming.

A rescue team could take 7 to 10 minutes where a lifeguard drone can take only up to one minute. Basically, this increases the efficiency and decreases danger to lifeguards. Here it shows the comparison of the suggested solutions and ours in term of speed, efficiency, and minimizing the victim and lifeguard risk.

2.2 Previous Work

After research conducted, we came across three similar projects of ours took place in three different countries.

- Autonomous Hexa-copter software designed by University of Western Australia on October 2014. This system is currently in use with a variety of simultaneous projects, including field searching and multiple object tracking, all tied in together with a web-based user interface. [1]
- Usage of a hexa-copter platform for Chemical plume detection and photography by California State University Bakersfield on November 2014. To adapt a hexa-copter drone into a platform which can be used to locate the source of a chemical plume and to photograph the location. [2]
- Quadcopter technology by Amity University on January 2015. Quad-copter. 3D mapping is used for new areas which need to be studied geographically for projects or other reasons. The second application is used to monitor farming progress and monitoring the farming growth. Lastly used for search for lost person and give coordination for rescue team to locate the person. [3]

2.3 Comparative Study

A comparative study where conducted through different projects and funding are listed in the below table 2.3-1 as it shows three different projects in compare to our project which we have named it as a Lifeguard Drone using six motors as mentioned in the comparison.

Table #2.3-1: shows a comparison study of our project and the three previous ones.

Project	Autonomous Hexa-copter	hexa-copter platform	Quadcopter technology	Lifeguard Drone (Our Project)
University	Western Australia	California State Bakersfield	Amity UAE	PMU, SA
Motors #	Six	Six	Four	Six
Rescue ring	No	No	No	Yes
Live streaming	Yes	Yes	Yes	Yes
Night LED	No	No	No	Yes
Material	Plastic	Plastic	Plastic	Carbon fiber
Landing Gear	No	Yes	Yes	Yes
Naza Microcontroller	Yes	No	No	Yes
GPS	Yes	Yes	Yes	Yes

All these project are very good and we got benefit by studying their projects to overcome future mistakes. From the above table, there are many parameters in the comparison and our project has the preferences. However, we are focusing to have a lightweight drone so it can serve our purpose in lifting the live ring and deliver it with a minimal time.

3. System Design

3.1 Design Constraints

3.1.1 Design Constraints: Engineering Standards

Flying a multi-copter through a corridor requires a minimal available working width as a safety margin is needed to allow small drift from the multi-copter due to external disturbances. For the harvest yield estimation UAV, a 2m wide corridor is assumed with on either side 0.5m margin for drift, leaving 1m for the width of the multi-copter. To be commercially viable, the multi-copter is required to have a high endurance to be able to inspect large areas. High endurance means large battery capacity and thus high battery weight. In addition, the payload and computer hardware also add significantly to the total weight. Due to the width restriction, a standard multi-copter would have small propellers (short radius R) compared to the weight W they carry, in other words a high disk loading DL (1) [4].

$$DL = \frac{W}{\pi R^2} = \left[\frac{N}{m^2} \right] \quad (1)$$

Yet, during hover and slow forward flight, where thrust T (approximately) equals weight W (2), a low disk loading and thus low induced propeller wash velocity v_i is preferred (3) in order to efficiently generate thrust T, keep the required power P_{hov} low (4) and have a long endurance.

$$T_{hov} = 2\dot{m}v_{i_{hov}} = 2\rho\pi R^2 v_{i_{hov}}^2 = W \quad (2)$$

$$\Rightarrow v_{i_{hov}} = \sqrt{\frac{W}{2\rho\pi R^2}} = \sqrt{\frac{DL}{2\rho}} \quad (3)$$

$$\Rightarrow P_{hov} = T_{hov}v_{i_{hov}} = Wv_{i_{hov}} = W\sqrt{\frac{DL}{2\rho}} \quad (4)$$

The downside of using a large propeller is that its high inertia requires not only large power inputs to change its rotational velocity, but foremost reaction time. When the helicopter is flying in choppy winds, this delay in response can be devastating for the platform's

performance, especially when flying through narrow corridors where the drift has to be kept minimal. Therefore, high agility requires small propellers.

The compound hexa-copter has a hexa shape have one size control propellers to achieve high endurance (Fig. 3.1.1-1). The hexa shape expands the limited space needed for generating lift. Six control propellers (C1, C2, C3, C4, C5, and C6) around a central payload box. In addition to the configuration, the method of control is also an innovative feature: the propellers are counter-rotating (C1, C3, and C5) and clockwise-rotating (C2, C4, and C6) at a constant speed to deliver most of the lift required in hover, but not all. The control propellers are commanded by the autopilot, which is actually configured to behave as a hexa-copter with an adapted flight model. The lift propellers rotating at high rotational velocity act as gyroscopes when the multi-copter performs maneuvers resulting in unwanted roll/pitch moments that need to be accounted for in the flight model. In addition, when the multi-copter is tilted, the thrust vector of the lift propellers tilts as well, lowering the vertical thrust component. By accounting for these effects in the flight model of the hexa-copter used for attitude control, the unwanted lift propeller effects can be minimized when combined with a suitable controller.



Figure #3.1.1-1: shows the hexa-copter configuration

3.1.2 Design Constraints: Economic

We have an economic constraint of a total of SR9000. Each of us contributed SR3000 of our own money to be pooled together in attempts to create this project. Already, about SR 8000 has been used for buying the frame, motors, propellers, flight controller and landing gear. This gives us a remaining SR1000 to work with. Besides this, we have a working Quadcopter that is a great deal for us to practice maneuver. Though researched, the hexa-copter has been used before and as such, could be damaged beyond what we see.

Table #3.1.2-1: A Summary of Economic Constraints.

Economic Constraints Summary
1. Keep total costs under SR9000
2. The frame structure and the communication system (RC) are the most expensive piece.
3. Motors and LiPo battery are the second largest expenses.
4. Landing gear and propellers are the most minor expenses.
5. End-goal is to have cheap, straightforward replacement parts.

Optimally, we did not need nearly this amount of money. The three large purchases are the frame structure, radio control, and the LiPo battery. The microcontroller, life ring holder, and servo motors are the minor expenses. Then the motors and propellers are more than the Landing gear, but less than that of the hexa frame kit.

The hope of the project, given an ample amount of time, is for us to create a new application of the hexa-copter in PMU and Saudi Arabia. So, it would be optimal that our project would become a product to establish, that have arcade components. This would be the perfect controlled environment while bringing in profits for our establishment customers. In such a setting, we want our product to be as cheap as possible.

The cheaper we can make the product, the easier it is to replace. This would appeal to both us, the ones making and testing the product, and the company, the ones buying and paying for maintenance of the product. Instead of trying to convince a company to buy an extremely large and expensive piece of equipment, we would be selling an extremely portable, relatively inexpensive, product that needs just a small, windowed room. [11]

3.2 Design Methodology

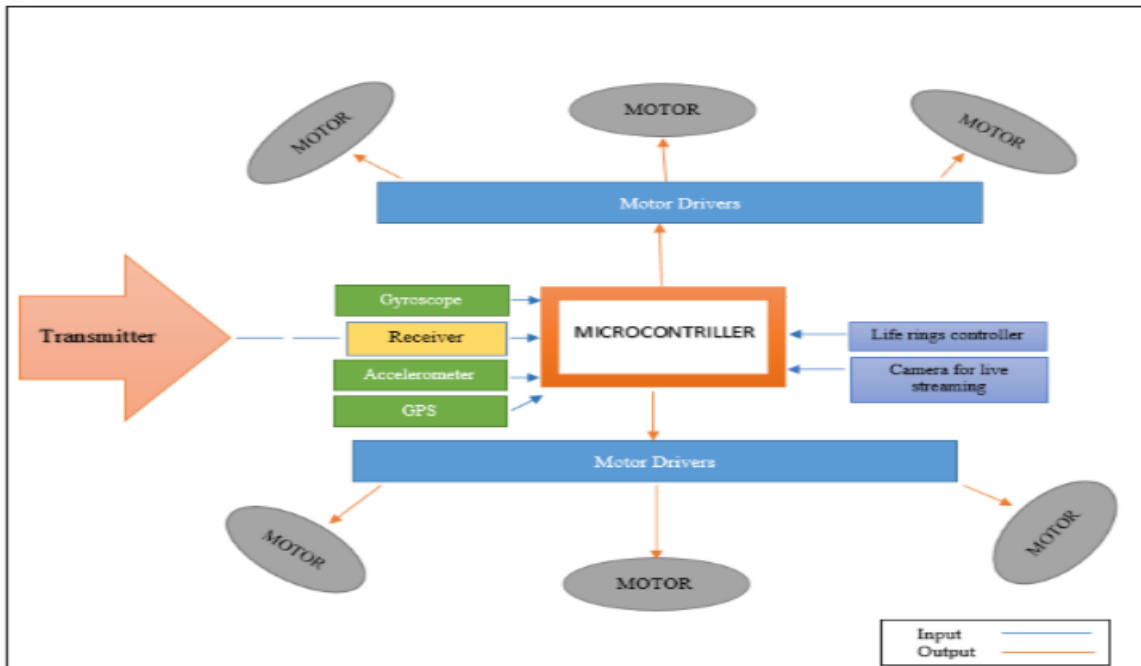


Figure #3.2-1: shows the architecture diagram of our project.

Figure #3.2-1 shows the block diagram of our project. The methodology we followed in arranging our subsystems is to have a nearly real arrangement of the physical order of our project. As an example, the diagram shows the six motors are separated equally and all connected to the motor drivers. Also, we have considered the base of our project which is the hardware starting from the frame structure, landing gear, motors & motor drivers, and finally the flight controller kit & configuration of the software.

3.3 Product Subsystems and Components

3.3.1 Product Subsystem 1: Frame structure

There are several types of frame structures for a hexa-copter drone. These are the alternative options we considered for our subsystem:

1. A plastic frame



Figure #3.3.1-1: shows a plastic frame for a hexa-copter [5]

2. Carbon fiber



Figure #3.3.1-2: shows a carbon fiber frame for a hexa-copter [6]

For our project, we were looking for strength combined with light weight. Therefore, we have chosen that our frame should be a carbon fiber. Also, the carbon fiber has a shock observance unlike the plastic which is in compare with carbon fiber heavy and it can break easily.

3.3.2 Product Subsystem 2: Motors and Propellers

For the motors and propellers, we have searched for the most appropriate components for our project which satisfied our requirements. We were required to have strong motors with high revelation and thrust. As a minimum of our need is 350 kV for each motor. **kV** refers to R.P.M./Volt. It is how **motors** are rated and does not **mean Kilo-Volts**. If we have a 12V electronic speed controller (ESC), the speed will be 12 times that number. The higher the **kV** rating the faster the R.P.M of the **motor**. The lower the turns, the higher the R.P.M. of the **motor**. We have encounter different types of motors. [16]

For the Motors, there are two types:

a. Brushless motors. (Selected one)

We have chosen brushless motors with 390 kV since it matches our requirement of payload lifting capability and because their durability, versatility, and ability to generate a lot of power. Also, have no brushes to wear out nor brushes to replace and it has a high efficiency performance. [7]

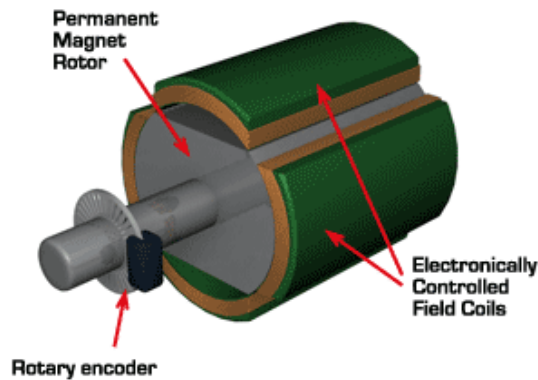


Figure #3.3.2-1: shows a block diagram of a brushless motor

b. Brush motors

Have less efficiency and electrically noisy. The switching action of the commutators constantly creating and breaking inductive circuits creates a great deal of electrical and electromagnetic noise. Lifespan as they are in perpetual physical contact with the shaft, brushes and commutators wear out. [7]

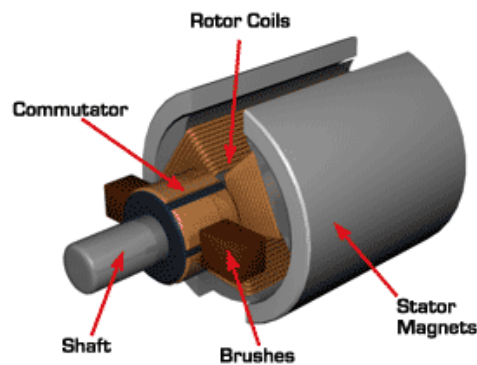


Figure #3.3.2-2: shows a block diagram of a brush motor

For the propellers, there are three types of materials for propellers:

a. Plastic

One of the advantages of plastic propellers is that they are cheap. However, the price should be considered but not over the quality and requirement. Some disadvantages of plastic propellers that they are way heavy and easy to break.



Figure #3.3.2-3: shows plastic propellers

b. Carbon fiber. (Selected one)

We have chosen carbon fiber propellers 15” in our project since they proportionally fit with our motors’ kV and are very light in weight. Also they are very strong and hard to break. In addition to that, they have less vibration, and perform well under high RPM (work well with high kV motors).



Figure #3.3.2-4: shows carbon fiber propellers [8]

c. Wooden propellers

This kind of propellers are very heavy and mostly used in big air-plane and air-craft. Where the strength is more valued over the weight.



Figure #3.3.2-4: shows wooden propellers [9]

3.3.3 Product Subsystem 3: Communication System

Radio Controller:

For the communication system, an RC (Radio Control) is used for drone in general. RC comes with different types and features. The most important feature is how many channels it contains. Some RCs contain 4, 6, 8, 10 and 12, based on your requirement you select the most appropriate one. RC comes with a receiver. The receiver then connected to the flight controller and set it up with the RC. Here is one of the most advanced RC shown in Figure #3.3.3-1. This RC is very advanced and has more feature than needed for our project. Also, its price is way beyond our budget.



Figure #3.3.3-1: shows the advanced radio control

We have chosen the 10 channels RC and the brand is Futaba. With this number of channels, it gives us the flexibility to add more features and upgrade our project without having the limitation of a certain channel to use.



Figure #3.3.3-2: shows the selected radio control for our project

Flight Controller:

a. Arduino board

Arduino board is a very powerful controller and gives more options for the programmer to add more features and program it according what's desired. The board itself is very cheap in compare with other controllers. However, the time spent on programming the board only may takes very long and its complexity are to be avoided for the time being at least.

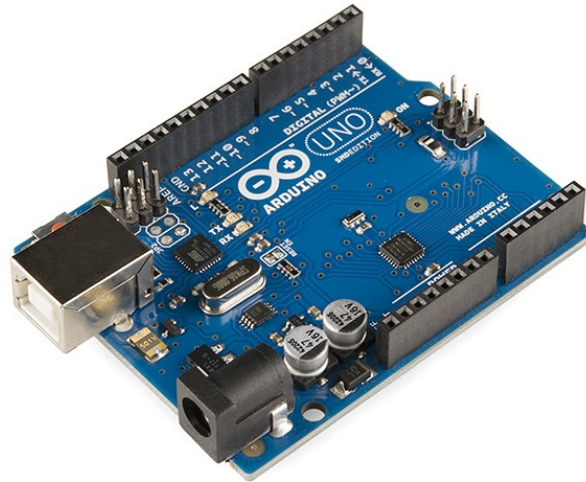


Figure #3.3.3-3: shows Uno type of Arduino controller

b. Naza controller. (Selected one)

Naza is very well-known controller for drone in general. The price of Naza kit is quite expensive. However, it's very easy to be used and installed. Also, no need to program the controller, only to configure it with its software. It is not an easy mission however, it consumes less time in comparison with programming Arduino board.



Figure #3.3.3-4: shows V2 type of Naza flight controller

3.3.4 Product Subsystem4: Camera for Live Streaming

GoPro Hero 4 camera. (Selected one)

For the live streaming, we have searched for the most appropriate components for our project which satisfied our requirement. In addition, we were required to have high quality camera resolution. We have chosen GoPro hero 4 since it is a small and very light camera with high resolution and can stream a live streaming video to any device such as (phones, laptops, and smart TVs).



Figure #3.3.4-1: shows GoPro Hero 4 camera

3.3.5 Product Subsystem 5: A life ring and a life ring controller

a. Life Ring.

Life ring is designed to be thrown to a person in the water, to provide buoyancy and prevent drowning. We have searched for a lightweight life ring to combine it with our hexa-copter.



Figure #3.3.5-1: shows a life ring shape.

b. Life Ring Controller

For the holding and dropping mechanism of the life ring. We come up with an idea after deeply thinking, discussing, and brainstorming. Our idea was to do some modification on the landing gear and to get benefit from them. The landing gear is connected with servo motors and when we send the signal to the servo, they open or close the landing gear. However, the life ring was attached to the landing gear while it is open. The mechanism for dropping was by sending a signal to close the landing gear, and then the life ring will slide then drop to our target.



Figure #3.3.5-2: shows the landing gear shape.

3.4 Implementation

From an online research conducted about the drone and its application, we found similar project with similar application. After, subsystems were identified and studies each as an individual, list the proper specifications based on the conducted research and our studies, we have concluded our target and set our product specifications.

As a target of the duration of flying, we have set it to be up to 15 minutes free load with usual expectation of having this number reduced once attached payload to it. This duration might be more than what is required for our application, however, we have chosen to be in a safe side and ready for any upgrade in future project or for any additional function added to the existing ones.

Upon this, we have chosen a battery in which it withstand the amount of power required for the set time. With powerful battery as the chosen one, it gives more power where strong motors having high kVs can easily fit in the circuit without causing too much drop and maintain the circuit stability.

These motors have high RPM and thrust where a combination of six motors with the proper size of propellers which it can be from 15 to 18in will give the ability to lift up to 1 kg or more of payload in addition to the weight of the drone itself. The battery was chosen to be Li-Po 6-Cells, with delivering voltage of 22.2V and 16,000 mAh. With these battery specifications, it will not require any type of step down or up voltages or current to connect other parts or components of the drone in the circuit.

The height and width of the drone is very convenient of such an application and can be easily used anywhere. Out of its hexa-drone kind, the Tarot T960 considered to be the biggest in size and highly recommended drone professional for high use. The diameter of our drone in term of height from the ground is 350mm and as a hexa shape width from motor to motor is 960mm.

In addition, the communication system was chosen upon the set range we set in our specification which having a coverage of signal range of 0.6km on land, and 1.0 km on air. With this range, it is more than the required range of coverage for our application.

A camera of 270 degree more or less degressed angle had been added for the live streaming sub-system. Furthermore, a life ring holder controller with its servo motors had been added as an independent sub-system. In each sub-system, we have considered at least two options of components as we measure its availability, cost, quality, and suitability.

As showed in part 3.3, for all sub-systems there were some options and from which we have chosen. Overall, our system as all is portable, and having a light weight as well as environmental friendly since it uses a rechargeable Li-Po battery as the power source of the drone.

We were given a shared room with two storage cabinets to put all our components in and have the space to work freely at any time of our convenient. This help us with our team meetings. We brought our own hand tools, and borrow the soldering machine from the lab.

Every day we meet after our classes and assemble a certain part of the project, with following the agreed and discussed methodology of implementation. Part of the system were verified through the software program. For example, the rotation of the motors, we used NAZA program to configure the appropriate rotation. And for other sub-systems, we follow the designed circuit and some of the component user manual.

4. System Testing and Analysis

4.1 Subsystem 1: Frame Structure

Objectives: To fix and install the frame and make sure that each arm is connected well.

Setup: We used robotics lab to fix our hexa-copter, this room is well equipped with the needed tools (Screwdriver, Allen key ... etc.) for setup our frame structure.

Results: We have completed install the frame of hexa-copter and fixing the arms with the landing gear. In addition, we make sure that all arms are straight and not bended. Also, we have confirmed that the size and dimension of our drone from motor to motor is 960mm and ground clearance 350mm.



Figure #4.1-1: shows the frame structure

4.2 Subsystem 2: Motors and Propellers

Objectives: To confirm the position and connection of the motors and motor drivers in the frame as well as the propellers.

Setup: For the setup we have used the robotics room, because it has the soldering machine for soldering the wires between motors and motor drivers.

Results: We have completed soldering wires for motors and motor drivers. We have tested the motors rotation and we fixed any wrong rotation to the right directions. Moreover, we have verified that the motors are straight, a line, and the space between the motor & base should be 0.2 cm for smooth rotation.

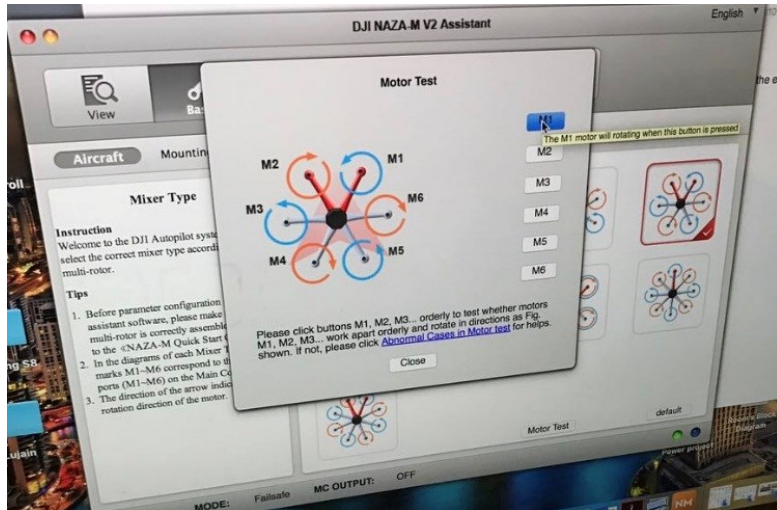


Figure #4.2-1: shows testing the rotation of the motors using NAZA software

4.3 Subsystem 3: Communication System

Objectives: To verify that the control system is capable to communicate with our hexacopter and follows the command.

Setup: For testing the communication module, we used to work at robotics room to configure the remote control with RC-receiver. Moreover, the transmitter and receiver need to be tuned to the same frequency to be communicated well. [12]

Results: We finished testing the communication system and now we are able to control the landing gear after we have configured it through the NAZA software. We have configured more features to be remotely control the drone as an example the GPS mode in this semester under Assessment III course. The below figure# 4.3-1 shows the connection of the NAZA microcontroller and the RC receiver. From M1 to M6 where used in our project for motor drivers since the drone is hexa.

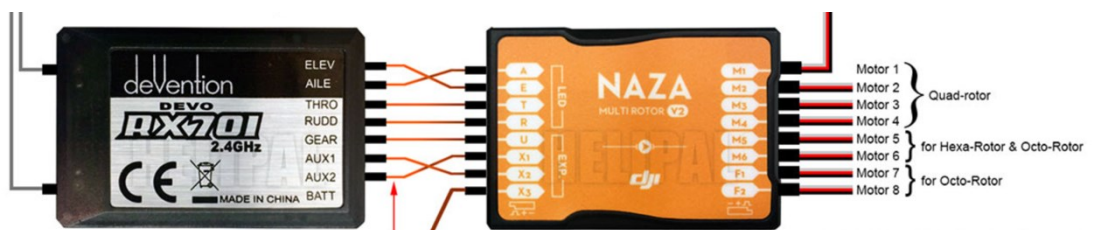


Figure #4.3-1: shows the connection of the microcontroller and RC receiver [14]

4.4 Subsystem 4: Camera for live streaming

Objectives: To make sure the connection between the camera which is the transmitting device and the smart phone which is the receiving part is linked and synchronized with no time delay of sending and receiving data.

Setup: We have used a camera case holder and mounted it on the drone positioned to face the bottom of the drone where the most important part to show the life ring dropping operation and have it dropped at a certain spot.

Results: This subsystem was successfully completed and tested on the drone and before fixing it. Also, we were able to save the data received by the camera in the same linked smart phone with a quality filming of 4K.



Figure #4.4-1: shows the camera used in this project linked to a smart phone

4.5 Subsystem 5: A life ring and a life ring controller

Objectives: To have a strong holding mechanism ably to hold the life ring and release it when a signal given from the RC with proper functionality and smooth operation with no obstacle and delay.

Setup: In this subsystem, we have used the landing gear to be the life ring holder after some modification on it. The life ring was put in a certain way where if the landing gears open, the life ring will be hold as close to the structure. And if we close the landing gear, the life ring will be dropped.

Results: The subsystem was successfully completed and tested on the robotic room where we used to work on our project in. Below Figure #4.5-1 shows the life ring and the life ring holder subsystem while testing.



Figure #4.5-1: shows the life ring and life ring holder subsystem while testing

4.6 Overall Results, Analysis and Discussion

Overall, we have tested all our subsystems and they were as what expected. Starting with the frame structure, we have connected each bolt and made sure that all are tight and align so the weight of our drone is distributed equally. Moving to the motors, we have chosen the motor based on our requirement. Therefore, we got brushless motor with a 390 kV to be able to lift the payload on our drone. We made the connection to the motor drivers (ECS) after we made some soldering and we attach each motor to its arm with the correct rotation. We faced some problems such as the motors mounting, where it was touching the frame base and prevent the motor to rotate smoothly. However, we overcome this issue by an idea to use some washer so the spacing increased around 0.2 cm and this issue was resolved. Lastly, the communication was wireless through frequency waves between the transmitter and the receiver unit. We configure our RC to the receiver, and we were able to control the landing gear opening and closing.



5. Project Management

5.1 Project Plan

- a. We breakdown the tasks in a list and identify the tasks and the requirements.
- b. We map tasks and responsibilities to all team members and clarify and understand all the tasks and responsibilities.
- c. Every week one of the team members is assigned to make sure that the progress of the assign week is met on time.
- d. Every two weeks, one of the team members is assigned to write the progress report and send it to our instructor (Prof. Yahya).
- e. Every two weeks, we meet with the advisor (Prof. Nizar Tayem) and co-advisor (Mr. Ahmed Abul Hussain) for discussing the progress of the project and create solution for any problem with the project.
- f. We set a deadline for every task assigned, and the one who is working in particular task should meet our plan.
- g. Make a channel of communication between us, to discuss any challenges and future upgrading.

5.2 Contribution of Team Members

Table #5.2-1: Effort contribution of the team members

Task	Abdulrahman	Abdullah	Abdulaziz	Task Total
Search & choosing the components	30%	40%	30%	100%
Acquiring the components	40%	40%	20%	100%
Design Subsystems	35%	35%	30%	100%
Testing Motors and connections	30%	20%	50%	100%
Write Reports & Preparing the Presentations	40%	40%	20%	100%
Configuring the Software	25%	25%	50%	100%

5.3 Project Execution Monitoring

- a. Every two weeks we make a meeting with our advisor (Prof. Nizar Tayem) and co-advisor (Mr. Ahmed Abul Hussain). In order to discuss our last update and what's can be done better if possible.
- b. We meet in weekly bases three times a week (Mon, Tue, and Wed) usually takes from two to three hours working on the project making the connections and discussing the project. In addition, we discuss the materials which we needed, and if there is any part missing & need to be ordered. Moreover, we discuss the future work, what we need and what we have to order online for the missing parts which are not available locally.
- c. Every week we test the parts on Tuesday evening and make sure it's working fine and smoothly such as motors, sending and receiving signal from the RC, and battery operation.
- d. We make flying sessions to ensure that our drone can fly accordingly.
- e. We test the remaining subsystems such as the live streaming and the live ring release mechanism controller.

5.4 Challenges and Decision Making

- a. Some of the components were not allowed to be available due to some restrictions. We planned to go to UAE to bring these components.
- b. Some parts of the motors was touching the base of the arm and prevent it from rotating smoothly. We have added some washers to make a small gap, so the rotor run smoothly.
- c. Landing gear was not suitable for our drone. We figured out a way to connect it to our frame and having a great mechanical movement.
- d. One of the sellers was not replying fast and delaying the delivery of the items. We have contacted the website to cancel that item from that seller, so we have contacted another seller in order to buy the same item from another person.
- e. Due to the high price of the project, we were not having any spare parts. As a result, on the last flying session (We were testing the live streaming on air) we have broken one propeller and we ordered another set of propellers but it will take time to be delivered.

5.5 Project Bill of Materials and Budget

Our estimated budget for the project is 9000 SR, and everyone in the group contribute 3000 SR. Our final cost for the all the materials is 8997 SR so it was as of our estimation budget. The cost of some parts is expensive, because some of the parts has restrictions in Saudi Arabia. As a result, we have traveled to UAE and buy them with higher price.

Table # 5.5-1: Materials cost

No.	Description	Quantity	Unit Cost (SR)	Total Cost (SR)
1	Frame	1	1500	1500
2	ESC	6	130	780
3	Motors	6	203	1218
4	Propellers	3	120	360
5	Li-Po Battery	1	1400	1400
6	Remote Control	1	1630	1630
7	Battery Charger	1	300	300
8	Terminals	2	30	60
9	Landing Gear	1	515	515
10	Flight Controller	1	634	634
11	Camera	1	400	400
12	Camera Case	1	50	50
13	Life Ring	1	50	50
14	Hand Tolls	1	100	100
Total				8,997

6. Project Analysis

6.1 Life-long Learning

We have learnt and gain new knowledges and skills while we were working on our project.

We improve our understanding in this project as following:

- a. Introduce to the NAZA flight controller.
- b. Functionality of major component (Gyroscope, accelerometer, ESC, motors).
- c. The RC operation.
- d. Type of motors and the KV meaning.
- e. New software tools of NAZA controller.
- f. project management skills,
- g. time management skills,
- h. Teamwork skills.

We read and did our research on this project by looking to the similar projects and using internet to get some useful information.

6.2 Impact of Engineering Solutions

Our project will have a great impact on the society while it will save lives. Also, it is an environmentally friendly, so there is no any gases that will affect the atmosphere. Our project will help the lifeguards to rescue people in a short time and it will view a live streaming on what happening in the location of the drowning people.

6.3 Contemporary Issues Addressed

In the present situation, the drowning deaths rate is increasing. The issue is because the lifeguard takes too much time to rescue people from drowning. Therefore, our project will give a better improvement to rescue the drowning people with the minimal time. It is a safety related and it should be into consideration.

7. Conclusions and Future Recommendations

7.1 Conclusions

In conclusion, this project was quite different from any other project. We have applied most if not all the skills we learnt and gained during our time in PMU. Research skills, time management, technical skills, technical writing skills, planning and teamwork. As a result, we have successfully completed, tested, and presented the project.

Starting from the research time, and selecting the components, buying the components, assembling them together. In addition to writing every two weeks progress reports and at the same time looking for more innovated ideas and upcoming some technical difficulties, we are proud to take such a challenging project. All team members are fully aware of all components of the project and their functionality.

Furthermore, each member where involve by somehow in every single step of the project progress with variation of participation. Regarding the component, none of the component were bought in Saudi. The major parts were bought from Dubai. Abdulrahman and Abdullah made a car trip to UAE during the weekend to buy the major components. The components were bought from two different stores within the city of Dubai. Landing gear and flight controller, AbdulAziz made an online order from Amazon.com. Same goes with the camera and the life ring. We were told that these communication components like the RC (Radio Controller) and the hexa frame might not be allowed to enter the country. That's why we brought them by ourselves.

Several meeting with the advisors made a positive impact in accomplishing these results. We got so much help from our advisor and co-advisor regarding the project components and choosing alternatives since we were facing time limitation. They were always helpful with sharing their knowledge and experience in this kind of projects. Also, Prof. Nizar has assigned us a shared room with two private cabinets where we can work freely at our convenient time.

Class lectures in the first semester of this project are another factor in our success. So many information about the right needed skills to successfully do the project with the proper planning, teamwork, codes & standards, managing the project, and looking for the best and alternatives. Enough time were given by Prof. Yahya for the students to meet their advisors and work on the project which helped us a great deal on achieving the set goal and meeting the deadlines.

We learned so many skills during this semester and the previous one. One of the most thing we learned is that noting impossible as long as it's doable. Design, research, selections, time management and alternative choosing were the most enhanced skills we developed during the year.

7.2 Future Recommendations

For the future recommendations and based on our experience with designing, assembling and testing the project, we have some recommendation that we would have done during the time we worked on the project.

The first one is to have a well-designed mechanical arm to hold the life ring. In addition, this arm should be connected to the microcontroller of the flight in which it'll be part of the communication subsystem of the drone. A wireless communication configuration shall be established and tested to ensure the mechanism of the arms are working as required and operating well without causing any disturbance while flying.

The second thing would be using a thicker soldering wires for all wiring part on the drone. This will limit the cable cut during the testing sessions as we have faced some due to the weak wire soldering.

The third one will be a switch which control the power outage of the battery. By this method, the risk of the spark coming out of the battery leads will be minimized and will be more convenient for the user to switch on/off without having to connect or disconnect the battery wires every time manually.

The fourth one is having extra spare parts like an extra motor, motor driver, propeller CW and CCW just in case any break during the testing session a replacement will be ready. We have broken one of the motor's propellers during the last testing session and unfortunately, we do not have a spare part nor the time to order a replacement from an online website. So, it is always recommended to have extra pieces of the parts which might get damaged during testing and assembling.

The fifth one is to have the testing sessions in a proper area. A wide and grassed area would be the most proper one as the grass is softer than a solid floor. It will observe some of the shock when the drone fell and minimize the breaking chances. Also, when testing at night, the place should be lighted well and you should always have your testing sessions on a good weather, never do in a windy one. The control of the drone is so difficult on a windy weather.

The sixth one will be adding LED lights. This will enhance the night missions and make the drone very visible when used at night. Two colours of LED would be recommended to be used. This will also can show the front and back side of the drone while flying which will give easy control for the person who's flying it.

The eighth one will add more feature to the night mission. The camera can be replaced with a night vision camera. This will give more ability to see and video the flying during night use.

The ninth one is to add extra life rings. So, instead of delivering one only, it will deliver three at the same trip. The dropping mechanism of the rings should be one by one. This can be accomplished by the design of a mechanical arm when it can hold the three life rings.

8. References

- [1] University of Western Australia (October 2014). "[Autonomous Hexacopter software design](http://robotics.ee.uwa.edu.au/theses/2014-Hexacopter-GPS-Baxter.pdf)" (PDF). <http://robotics.ee.uwa.edu.au/theses/2014-Hexacopter-GPS-Baxter.pdf> (Accessed date: 02/10/2018).
- [2] CLIFORNIA STATE UNIVERSITY BAKERSFIELD . (2014, November 20). Retrieved from <http://www.cs.csuabak.edu/~mheaton/490B%20report.pdf> (Access date: 02/10/2018)
- [3] Amity University. (2015, Jan 9). Quadcopter technology. Retrieved from https://www.slideshare.net/michaelbeliss/quadcopter-technology?next_slideshow=1 (Access date: 02/11/2018)
- [4] R.W. Prouty, "Helicopter Performance, Stability and Control", 2003, Krieger publishing Company, p. 1-10

<https://pdfs.semanticscholar.org/e6a8/7e22c0c42cebfa04b5476613d4064c4d34be.pdf> (Access date: 05/02/2018)
- [5] <https://www.amazon.com/Hobbypower-Upgrade-Hexacopter-Fuselage-Landing/dp/B01CQX0BG> (Access date: 05/02/2018)
- [6] <http://www.helipal.com/tarot-t960-hexacopter-frame-set.html> (Access date: 05/02/2018)
- [7] <http://www.quantumdev.com/brushless-motors-vs-brush-motors-whats-the-difference/> (Access date: 05/02/2018)
- [8] https://www.quadrocopter.com/Tiger-14x48-Carbon-Fiber-Propeller-Pair_p_895.html (Access date: 05/02/2018)
- [9] <https://www.dolphinco.com.au/wooden-propeller-for-nitro-petrol-engine/> (Access date: 05/02/2018)
- [10] <https://www.popsci.com/article/technology/lifeguard-drone-ready-mass-production-video> (Access date: 05/02/2018)
- [11] http://www.eecs.ucf.edu/seniordesign/su2015fa2015/g06/senior_design_dump/senior_design_2_final_paper/sd2finalpaper.pdf (Access date: 05/02/2018)
- [12] <http://www.dummies.com/consumer-electronics/drones/understanding-how-your-drone-is-controlled/> (Access date: 05/03/2018)
- [13] <https://www.dhgate.com/product/wholesale-skyhawkrc-f750-hexacopter-rc-multicopter/386584948.html> (Access date: 28/11/2018)
- [14] <http://image.helipal.com/pack-tarot-hardware-diagram-01-big.jpg> (Access date: 15/12/2018)
- [15] <http://budgetpoolsafetyinspections.com.au/drowningstatistics.php> (12/15/2018)
- [16] <http://www.flyelectric.com/ans.kv.html> (12/18/2018)
- [17] https://dl.djicdn.com/downloads/nazam-v2/en/NAZA-M_Quick_Start_Guide_v1.26_en.pdf (12/19/2018)
- [18] http://www.dualsky.com/AjaxFile/DownLoadFile.aspx?FilePath=/UploadFile/20150211/XM5015MR_SPEC.pdf%20&fileExt=file (12/19/2018)
- [19] <http://www.helipal.com/tarot-1555-carbon-propellers-two-holes-cw-and-ccw.html> (12/19/2018)


Appendix A: Progress Reports

For the First semester: Design Method & Proj Mgmt

Project Title	Lifeguard Drone	
TEAM	Abdullah Alansari (AA)	<u>Abdulaziz Alijubair (AJ)</u>
	Abdulrahman Alfridan (AF)	

Tasks	Description (brief but clear)	% Completion	
Completed Weeks 1 to 6	1	Background research and reading about Hexa-copter drone	100%
	2	Search for components and resources within PMU and local market Frame, Motors, Propellers	
	3	Prepared project proposal and project plan	
	4	Started design for subsystem 1 Flying and Carrying up to 3 life rings (5kg)	
	5	Search for circuits and components to implement subsystem Arduino microcontroller, gyroscope sensor for balancing	
	6	Order the main components form eBay website	
In Progress Weeks 7 & 8	7	Search for more resources and planned to make a trip to UAE.	100%
	8	Made a trip to Dubai, UAE to buy the components	
	9	Fixed the carbon fiber frame	
	10	List the missing components and in process or ordering online	
	11	Making motor wires connection	
In Progress Weeks 9 & 10	7	Searching for missing components and ordering online	100%
	8	Soldering the motor wires and motor drivers wires	
	9	Fixing and installing the motors into fiber frame	
	10	Fixing motor drivers to into fiber frame	
In Progress Weeks 11 & 12	11	Ordering some of the missing components.	85%
	12	Completed the wire connection between motor drivers and motors including the soldering.	
	13	Added some washers to the holding base of the motors	
	14	Extended the battery and the flight controller wires from the motor drive.	
	15	Assemble the landing gear	
	16	Research on how to control the motor rotation	

Comments	<ul style="list-style-type: none"> We have faced some difficulties with ordering the components online. We tried with more than 4 sellers in different websites. However, we have taken the decision to make a trip to UAE and buy the major components from there. Most of our components have some restriction of being entered to the country. However, we managed to bring them in. (Week 7&8) We have faced some difficulties with the motors they were not smooth while rotating, we have tried to file the part which makes the motor rough to rotate. (Week 9&10) We have encountered some difficulties with fitting the motors into its holding fiber base. A rotating part of the motor was stuck and gives some difficulties with having the motor rotating smoothly. We have tried to file that part which makes the motor rough to rotate. However, it didn't work. Then we have decided to add double washers from the bottom and it worked. Also, we have extended the battery wires as well as the others which will be connected to the flight controller. (Week 11&12)
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	Project Management: Plan	
	Electrical Engineering Department	
	EEEN4311: Design Methodology & Project Management	
	Instructor: Dr. Chedly B. Yahya	Spring 2018

Project Title:		
Team:	Abdullah Alansari (AA) Abdulaziz Aljubair (AJ)	Abdulrahman Alfridan (AF)


SN	Tasks & Responsibilities		Begin**	End**	% Completion
1	Finish design subsystem SS2 (Motor drivers and motors)	AA,AJ, AF	Sep. 10	Sep. 27	100%
2	Implement Design for SS2	AA,AJ, AF	Sep. 27	Oct. 30	100%
3	Test and refine design for SS2	AA,AJ, AF	Sep. 10	Nov. 6	100%
4	Design subsystem SS3 (Communication)	AA,AJ, AF	Oct. 31	Nov. 18	80%
6	Implement Design for SS3	AA,AJ, AF	Nov. 18	Nov. 29	80%
7	Test and refine design for SS3	AA,AJ, AF	Nov. 21	Nov. 29	40%
8	Integrate subsystems SS2 & SS3	AA,AJ, AF	Nov. 5	Nov. 9	100%
9	Design subsystem SS4 (Camera)	AA,AJ, AF	Nov. 18	Nov. 29	50%
10	Implement Design for SS4	AA,AJ, AF	Nov. 21	Nov. 29	0%
11	Test and refine design for SS4	AA,AJ, AF	Nov. 21	Nov. 29	0%
12	Integrate all subsystems	AA,AJ, AF	Oct. 7	Nov. 21	0%
13	Test and make final changes	AA,AJ, AF	Nov. 28	Dec. 6	0%
14	write progress reports (weekly)	AA,AJ, AF	Sep 27	Dec 6	30%
15	Prepare midterm presentations	AA,AJ, AF	Oct. 25	Nov. 12	100%
16	Prepare Demo. (prototype)	AA,AJ, AF			
17	Prepare Final presentation	AA,AJ, AF			
18	Prepare final report	AA,AJ, AF			
** Dates: From week 1 Sep2 until week 14 Dec6			% Completion by set end date		

For the Second Semester: Learning Outcome Asse. III EEN

Project Title	Lifeguard Drone	
TEAM	<u>Abdullah Alansari (AA)</u>	<u>Abdulrahman Alfridan (AF)</u>
	<u>Abdulaziz Aljubair (AJ)</u>	

Tasks		Description (brief but clear)	Date	% Completion
Completed Weeks 1 to 6	1	Installing the structure.		100%
	2	Tested the motors drivers and motors.		
	3	Calibrating communication between remote and landing gear.		
	4	Testing the communication between remote and landing gear.		
	5	Ordering the Camera for livestream		
Completed Weeks 7 to 8	1	Ordering the missing parts (Some connectors and switches)	Oct.25	100%
	2	Implement Design for SS2 (Motor drivers and motors)	Oct. 15	
	3	Calibrating the communication between the motors with the remote control.	Oct.18	
	4	Testing the motors. (Start and Run, Rotation)	Oct. 20	
	5	First flying session.	Oct. 23	
Completed Weeks 9 to 10	1	Adjust and fixe the damages from first session	Oct. 29	100%
	2	Recalibrate SS3 (Commination, GPS system)	Nov. 1	
	3	Test the current of all motors.	Nov. 4	
	4	Adjust the place of the battery.	Nov.4	
	5	Second flying session	Nov. 6	
In Progress Weeks 11 & 12	6	Design subsystem SS4 (Camera)	Nov. 14	100%
	7	Test the camera and fixed it in the Hex-copter drone.	Nov. 17	
	8	Measure the distance of sending the information	Nov. 18	
	9	Design SS5 (Life ring controller)	Nov.21	

Comments	<p>a. We have completed all planned tasks, the first attempt flying session was not as expected where we failed to make it fly due to some motors that rotate faster than the others, and the battery was in the wrong place.</p> <p>b. The second attempt flying session was as expected where we succeeded to make it fly and land safely.</p>
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	Project Management: Plan	
	Electrical Engineering Department	
	EEEN4311: Design Methodology & Project Management	
	Instructor: Dr. Chedly B. Yahya	Spring 2018

Project Title:		
Team:	Abdullah Alansari (AA) Abdulaziz Aljubair (AJ)	Abdulrahman Alfridan (AF)

SN	Tasks & Responsibilities		Begin**	End**	% Completion
1	Finish design subsystem SS2 (Motor drivers and motors)	AAAJ AF	Sep. 10	Sep. 27	100%
2	Implement Design for SS2	AAAJ AF	Sep. 27	Oct. 30	100%
3	Test and refine design for SS2	AAAJ AF	Sep. 10	Nov. 6	100%
4	Design subsystem SS3 (Communication)	AAAJ AF	Oct. 31	Nov. 18	100%
6	Implement Design for SS3	AAAJ AF	Nov. 18	Nov. 29	100%
7	Test and refine design for SS3	AAAJ AF	Nov. 21	Nov. 29	100%
8	Integrate subsystems SS2 & SS3	AAAJ AF	Nov. 5	Nov. 9	100%
9	Design subsystem SS4 (Camera)	AAAJ AF	Nov. 18	Nov. 29	100%
10	Implement Design for SS4	AAAJ AF	Nov. 21	Nov. 29	100%
11	Test and refine design for SS4	AAAJ AF	Nov. 21	Nov. 29	100%
12	Integrate all subsystems	AAAJ AF	Oct. 7	Nov. 21	100%
13	Test and make final changes	AAAJ AF	Nov. 28	Dec. 6	100%
14	write progress reports (weekly)	AAAJ AF	Sep 27	Dec 6	100%
15	Prepare midterm presentations	AAAJ AF	Oct. 25	Nov. 12	100%
16	Prepare Demo. (prototype)	AAAJ AF	Nov. 12	Nov. 22	100%
17	Prepare Final presentation	AAAJ AF	Nov. 23	Dec. 8	100%
18	Prepare final report	AAAJ AF	Nov. 2	Dec. 10	100%
** Dates: From week 1 Sep2 until week 14 Dec6			% Completion <u>by set end date</u>		

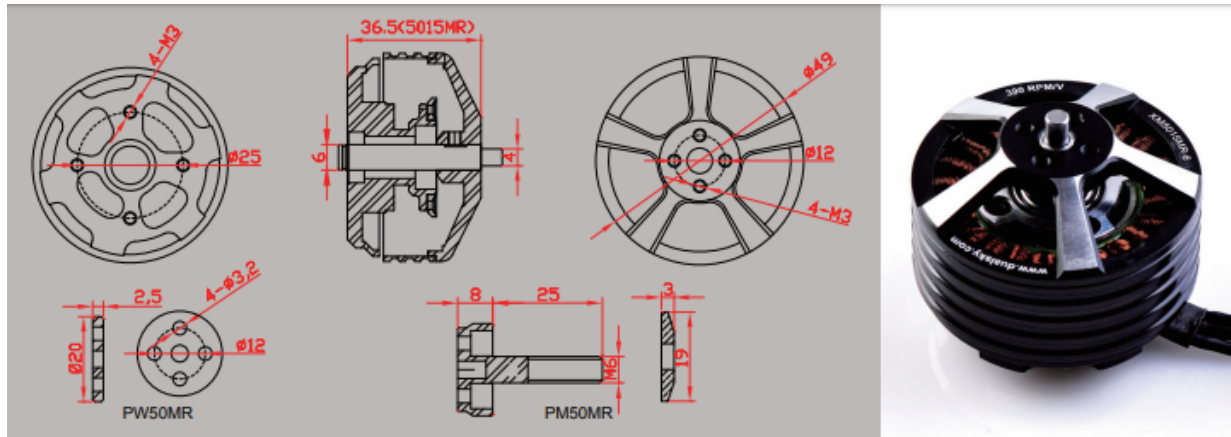
Appendix B: Bill of Materials

Table # Appendix B-1: Materials cost

No.	Description	Quantity	Unit Cost (SR)	Total Cost (SR)
1	Frame	1	1500	1500
2	ESC	6	130	780
3	Motors	6	203	1218
4	Propellers	3	120	360
5	Li-Po Battery	1	1400	1400
6	Remote Control	1	1630	1630
7	Battery Charger	1	300	300
8	Terminals	2	30	60
9	Landing Gear	1	515	515
10	Flight Controller	1	634	634
11	Camera	1	400	400
12	Camera Case	1	50	50
13	Life Ring	1	50	50
14	Hand Tolls	1	100	100
Total				8,997

Appendix C: Datasheets

Motor dimention and spacification [18]



Specification

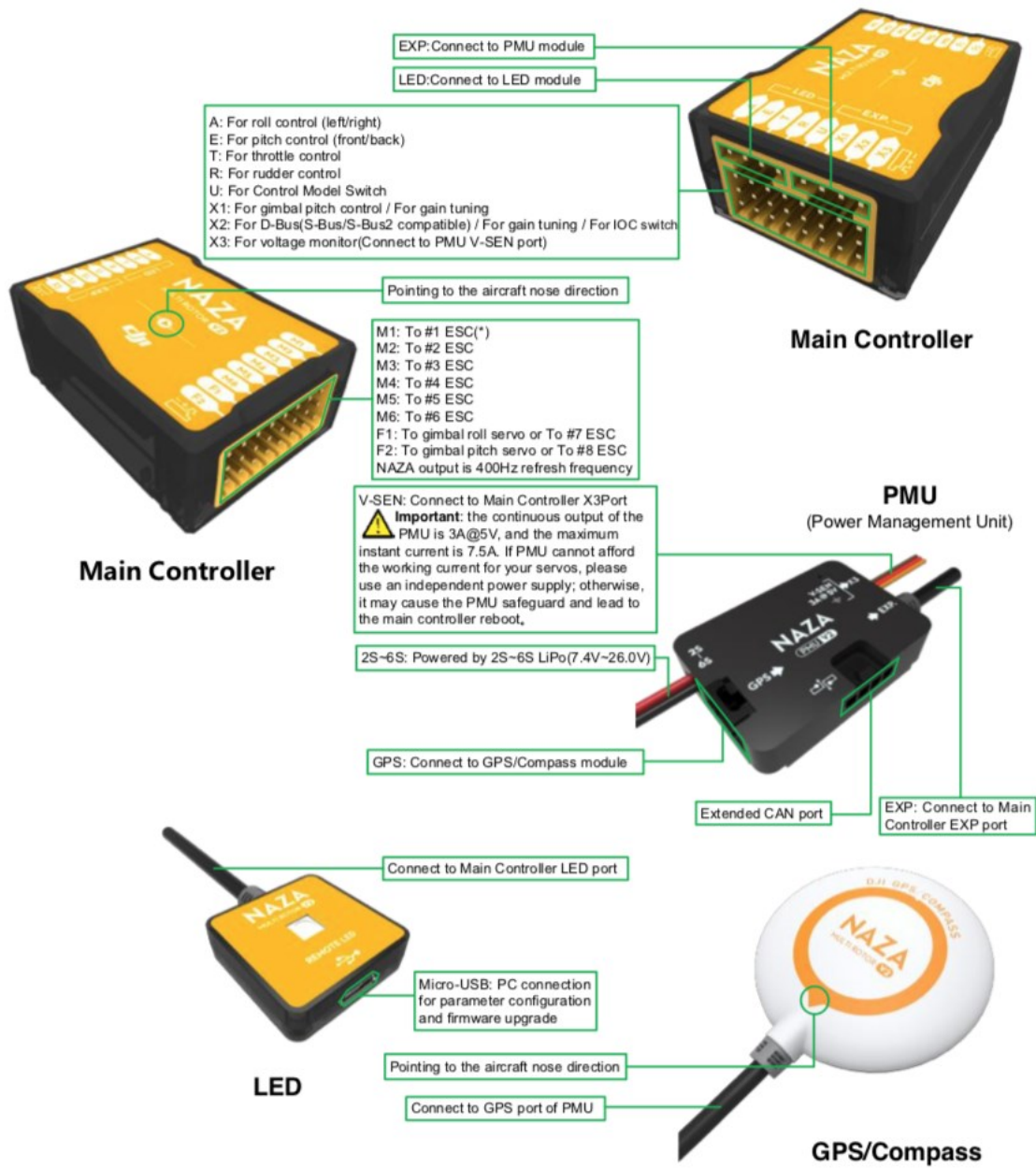
Xmotor Multi-Rotor		XM5015MR 6 TURN	XM5015MR 7 TURN
RPM/V(KV值)	(KV)	390	340
Weight w/o wires(重量)	(g)	150	150
Diameter(直径)	(mm)	50	50
Length(长度)	(mm)	36	36
Diameter of Shaft(轴径)	(mm)	4.0, 6.0	4.0, 6.0
Mounting holes pitch(安装孔距)	(mm)	25/25	25/25
Slots,Poles(极数)		24, 28	24, 28
Idle Current(空载电流)	(Io) @10V(A)	0.8	0.7
Resistance(内阻)	(Ri)(mOhm)	58	75
Cruising power(巡航功率)	(W)[8 mins]	416	375
Bursts current(最大电流)	(A)[15s]	34	30
Peak power(峰值功率)	(W)[15s]	756	680
Input wire(输入线)		18AWG, 600mm	18AWG, 600mm
Recommended ESC(推荐调速器)		XC-401-MR	XC-401-MR
Setup 1(配置1)	(No. of Cell, Prop.)	6S, 15x5 - 16x5	6S, 15x5 - 17x5
Weight of quad-copter(4轴重量)	(kg)	4.6	4.2
Weight of hex-copter(六轴重量)	(kg)	7.0	6.3

Naza microcontroller specification [17]

Specifications

General	
Built-In Functions	(1) Three Modes of Autopilot
	(2) Enhanced Fail Safe
	(3) Low Voltage Protection
	(4) S-Bus/S-Bus2 Receiver Support
	(5) PPM Receiver Support
	(6) 2-axle Gimbal Support
Peripheral	
Supported Multi-rotor	<ul style="list-style-type: none"> ● Quad-rotor I4, X4; ● Hexa-rotor I 6, X6, IY6, Y6. ● Octo-rotor I8, V8, X8
Supported ESC output	400Hz refresh frequency.
Recommended Transmitter	PCM or 2.4GHz with a minimum 4 channels.
Assistant Software System Requirement	Windows XP SP3; Windows 7; Windows 8
Electrical & Mechanical	
Working Voltage Range	<ul style="list-style-type: none"> ● MC: 4.8V - 5.5 V ● PMU Input: 7.4V - 26.0 V (recommend 2S - 6S LiPo) Output(V-SEN port red wire): 3A@5V Output(V-SEN port red wire)burst current:7.5A
Power Consumption	<ul style="list-style-type: none"> ● MAX: 1.5W(0.3A@5V) ● Normal: 0.6W(0.12A@5V)
Operating Temperature	-10°C - 50°C (14F -122F)
Weight	<ul style="list-style-type: none"> ● MC: 27g ● GPS/Compass: 27g ● PMU: 28g ● LED: 13g
Dimensions	<ul style="list-style-type: none"> ● MC: 45.5mm × 32.5mm × 18.5mm ● GPS/Compass: 46mm (diameter) x 10mm ● PMU : 39.5mm × 27.5mm × 10.0mm ● LED : 25mm × 25mm × 7.0mm
Flight Performance (can be effected by mechanical performance and payloads)	
Hovering Accuracy (GPS Mode)	<ul style="list-style-type: none"> ● Vertical: ± 0.8m ● Horizontal: ±2.5m
Max Yaw Angular Velocity	200°/s
Max Tilt Angle	35°
Max Ascent / Descent Speed	Ascent : 6m/s, Descent : 4.5 m/s

Naza Assembly & Connection [17]



Propellers data sheet [19]



Made of imported Japanese TORAY 3K carbon fiber, this is the reliable and efficient choice for your multi-rotors, each pair are balanced by hand and made fine adjustment.

Features

- Made with imported Japanese TORAY 3K carbon fiber
- Each pair are balanced by hand and made fine adjustment
- Blended winglet increase efficiency by 13%

Specifications :

- Diameter : 15 inch
- Pitch : 5.5 inch
- Weight: 20.2g / each blade
- Center hole : 4mm (for motor shaft)
- Two holes mounting : M3 screw, 12mm eye-to-eye
- Suitable : 41XX to 50XX or above motors

Appendix D: Program Codes

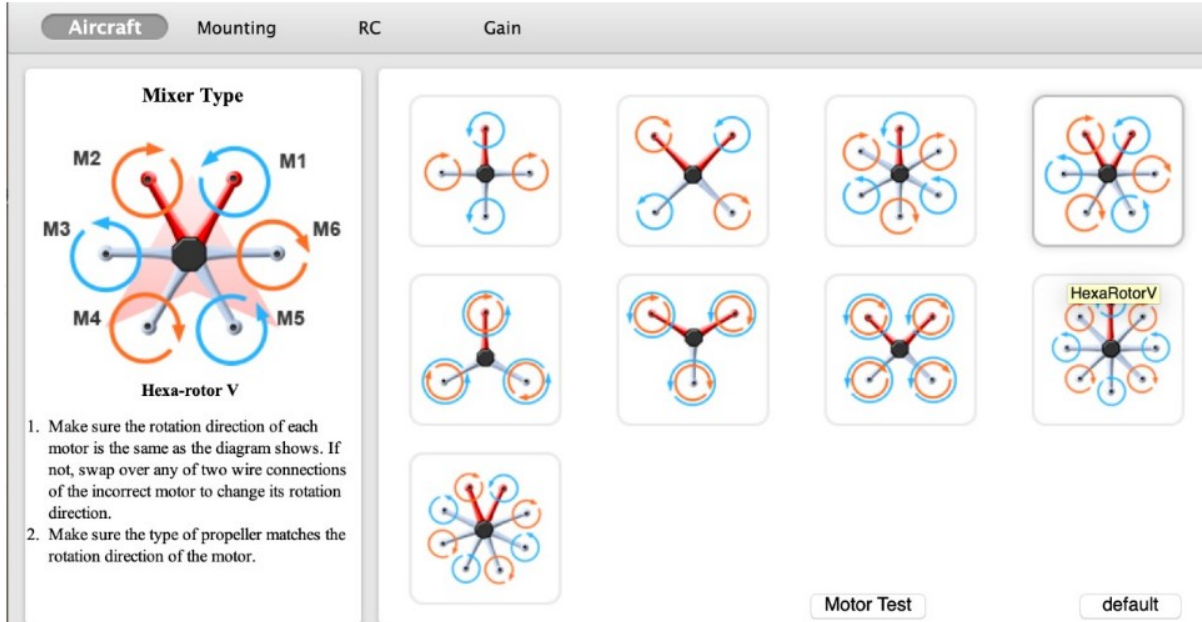


Figure D-1: Configure the microcontroller for Hexa rotor

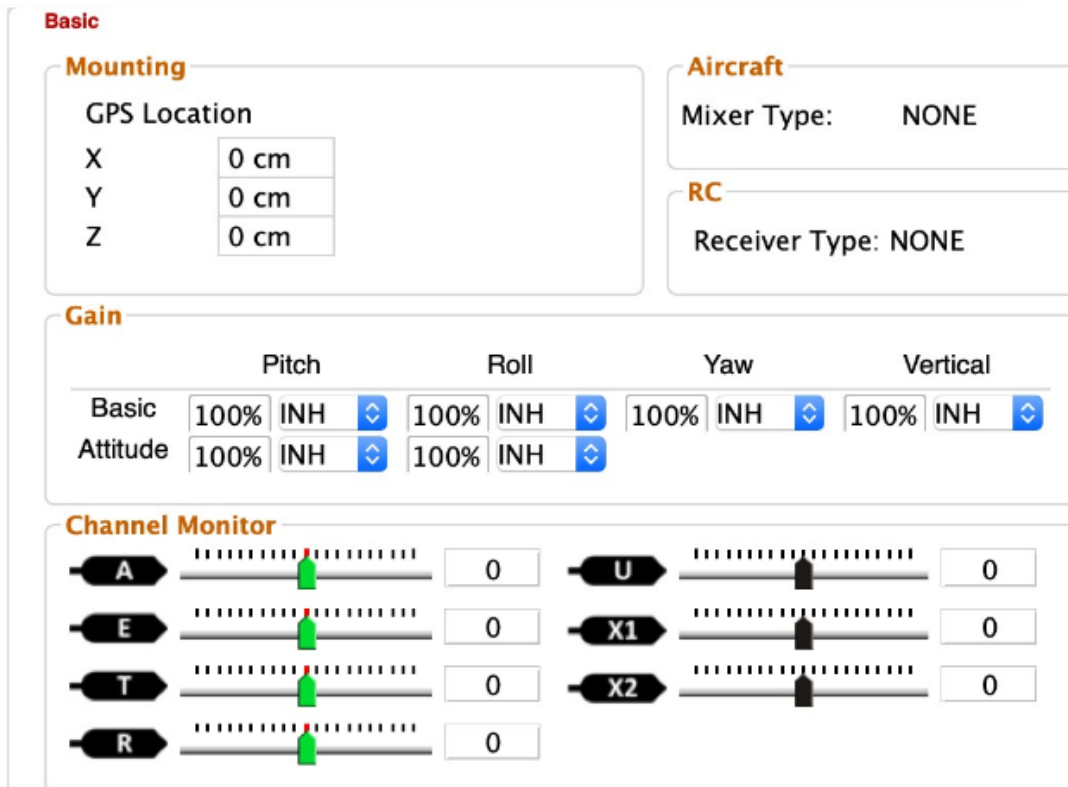


Figure D-2: Set the GPS by using Naza application

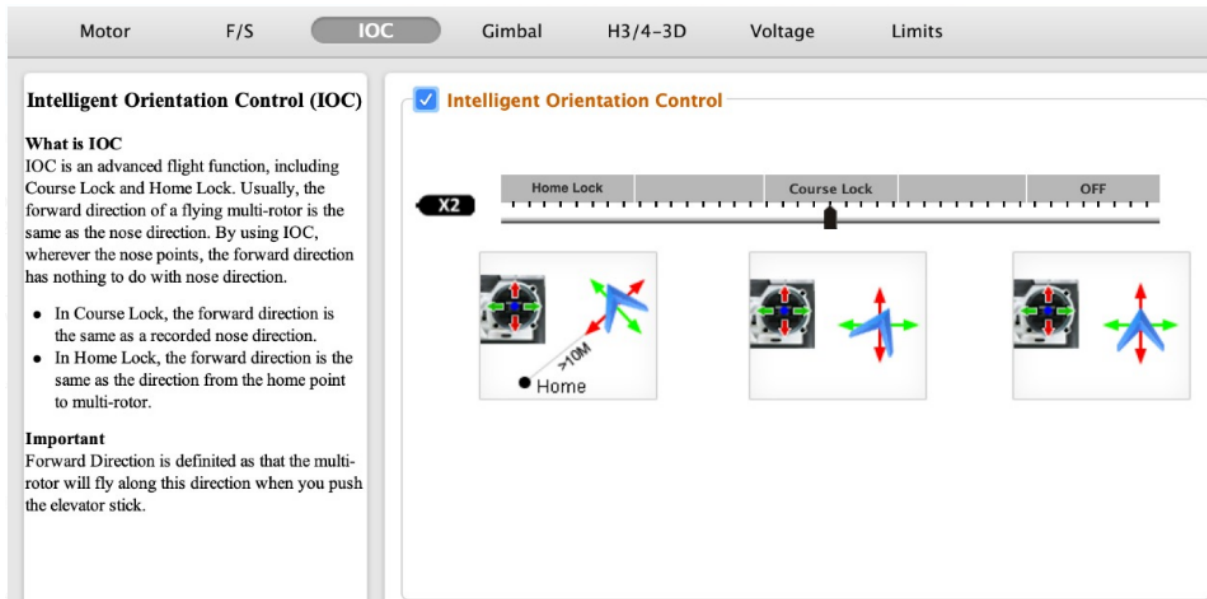


Figure D-3: Configure the RC (Radio controller) for controlling the Direction of the drone

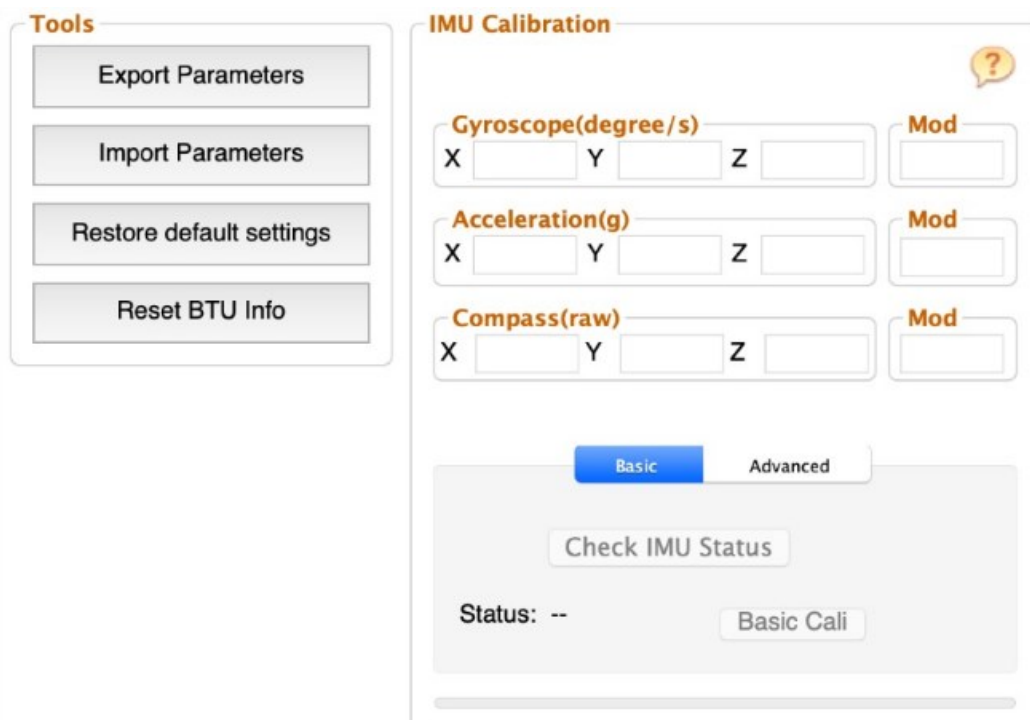


Figure D-4: Calibrate the drone angles by using the application where we set the XYZ of the Gyroscope and Accelerometer.

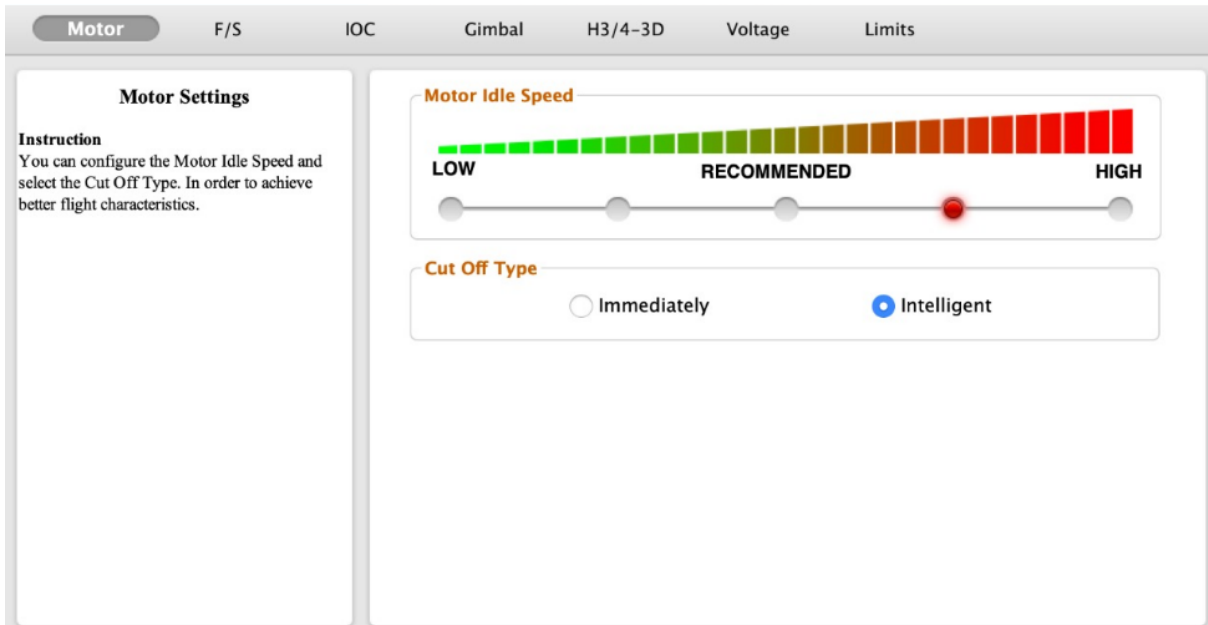


Figure D-5: Shows the Speed controller of the motor in the Application

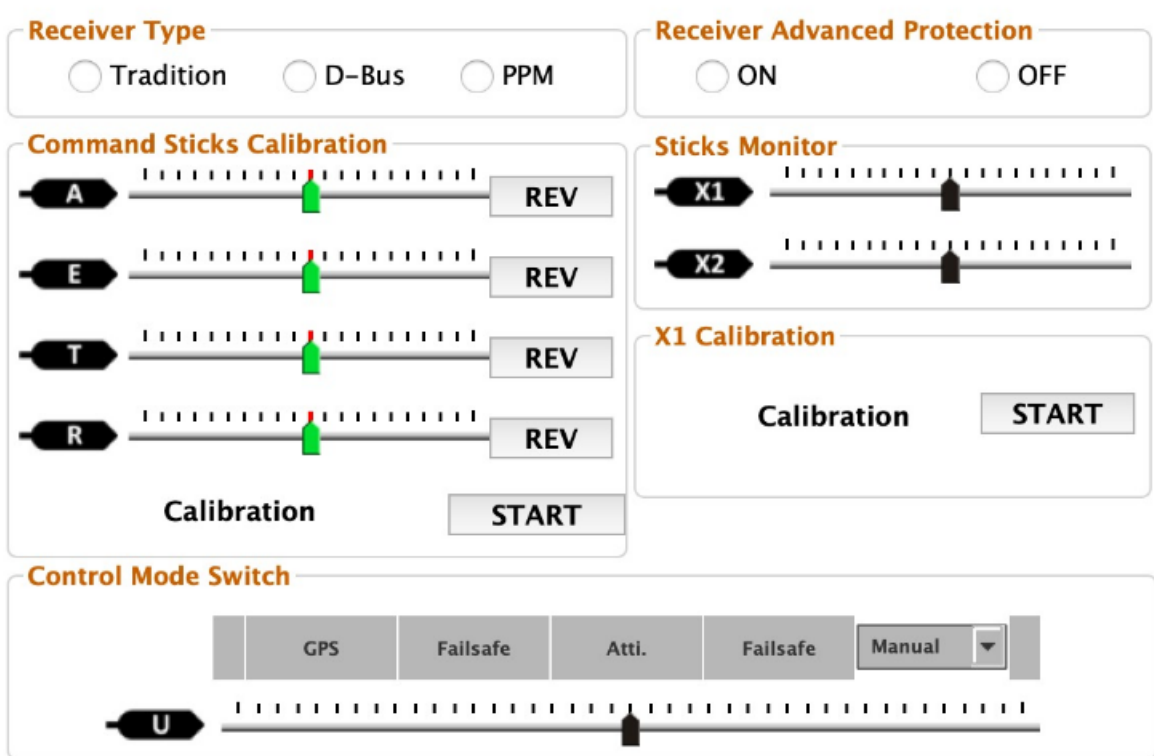


Figure D-6: Shows the RC gears calibration.

Appendix E: Operation Manual

For deeply steps of operation manual please refer to reference [17]

Basic Flying

Control Mode Knowledge

Please read the Control Mode Knowledge clearly before usage, to know how to control the aircraft.

Different control modes will give you different flight performances. Please make sure you understand the features and differences of the three control modes.

	GPS ATTI. Mode (With GPS Module)	ATTI. Mode	Manual Mode
Rudder Angular Velocity	Maximum rudder angular velocity is 150° /s		
Command Linearity	YES		
Command Stick Meaning	Multi attitude control; Stick center position for 0° attitude, its endpoint is 35°.		Max-angular velocity is 150° /s. No attitude angle limitation and vertical velocity locking.
Altitude Lock	Maintain the altitude best above 1 meter from ground.		NO
Stick Released	Lock position if GPS signal is adequate.	Only attitude stabilizing.	NOT Recommend
GPS Lost	When GPS signal has been lost for 3s, system enters ATTI. Mode automatically.	Only performing attitude stabilizing without position lock.	---
Safety	Attitude & speed mixture control ensures stability		Depends on experience.
	Enhanced Fail-Safe(Position lock when hovering)	Auto Level Fail-Safe (Attitude stabilizing)	
	With GPS/Compass module and the failsafe requirements are satisfied, in each Control Mode (including GPS Mode, ATTI. Mode, Manual Mode and IOC Mode), the aircraft will enter the failsafe Mode.		
Applications	AP work	Sports flying.	---

Start & Stop Motor Knowledge



- (1) Both Immediately Mode and Intelligent Mode are available in the Assistant Software: Advanced->Motor->Stop Type.
- (2) Stop Motor method is defaulted to Immediately Mode.

Please get to know well about this section before flying.

- 1 Start Motor:** Pushing throttle stick before takeoff will not start the motors. You have to execute any one of following four Combination Stick Commands (CSC) to start the motors:



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- 2 Stop Motor:** We provide two options to stop motors in the assistant software: Immediately and Intelligent.
 - (1) **Immediately Mode:** If you select this mode, in any control mode, once motors start and throttle stick is over 10%, motors will not stop immediately only when throttle stick is back under 10% the motors will stop. In this case, if you push the throttle stick over 10% within 5 seconds after motors stop, motors will re-start, CSC is not needed. If you don't push throttle stick after motors start in three seconds, motors will stop automatically.
 - (2) **Intelligent Mode:** By using this mode, different control mode has different way of stopping motors. In Manual Mode, only executing CSC can stop motors. In ATTI. Mode or GPS ATTI. Mode, any one of following four cases will stop motors:
 - a) You don't push throttle stick after motors start within three seconds;
 - b) Executing CSC;
 - c) Throttle stick under 10%, and after landing for more than 3 seconds.
 - d) If the angle of multi-rotor is over 70°, and throttle stick under 10%.

Step 1 Compass Calibration

Without GPS module, please skip this step. If you use with GPS module, follow step-by-step for calibration.

- (1) DO NOT calibrate your compass where there is magnetic interference, such as magnetite, car park, and steel reinforcement under the ground.
- ⊘ (2) DO NOT carry ferromagnetic materials with you during calibration, such as keys or cell phones.
- (3) Compass module CANNOT work in the polar circle.
- (4) Compass Calibration is very important, otherwise the system will work abnormal.

Calibration Procedures

1. Switch on the transmitter, and then power on autopilot system!
2. Quickly switch the control mode switch from *GPS Mode* to *Manual Mode* and back to *GPS Mode* (or from *GPS Mode* to *ATTI Mode* and back to *GPS Mode*) for more than 5 times, The LED indicator will turn on constantly yellow so that the aircraft is ready for the calibration.
3. (Fig.1) Hold your Multi-rotor horizontal and rotate it around the gravitational force line (about 360°) until the LED changes to constant green, and then go to the next step.
4. (Fig.2) Hold your Multi-rotor vertically and rotate it (*its nose is downward*) around the gravitational force line (about 360°) until the LED turns off, meaning the calibration is finished.

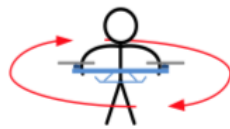


Fig.1

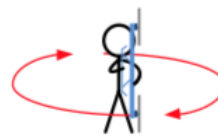



Fig.2

5. If the calibration was successful, calibration mode will exit automatically. If the LED keeps flashing quickly Red, the calibration has failed. Switch the control mode switch one time to cancel the calibration, and then re-start from step 2.



1. When the GPS is abnormal, the Main controller will tell you by the LED blinking Red and Yellow alternately (), disable the GPS Module, and automatically enter the aircraft into the ATTI Mode.
2. You don't need to rotate your multi-rotor on a precise horizontal or vertical surface, but keep at least 45° difference between horizontal and vertical calibration.
3. If you keep having calibration failure, it might suggest that there is very strong magnetic interference around the GPS /Compass module, please avoid flying in this area.
4. When to do re-calibration
 - (1) The flight field is changed.
 - (2) When the multi-rotor mechanical setup has changed:
 - a) If the GPS/Compass module is re-positioned.
 - b) If electronic devices are added/removed/ re-positioned (Main Controller, servos, batteries, etc.).
 - c) When the mechanical structure of the multi-rotor is changed.
 - (3) If the flight direction appears to be shifting (meaning the multi-rotor doesn't "fly straight").
 - (4) The LED indicator often indicates abnormality blinking when the multi-rotor spins. (It is normal for this to happen only occasionally)

Notes of Intelligent Mode



- (1) In ATTI. / GPS ATTI. Mode, it has landing judgment, which will stop motors.
- (2) Start motors in ATTI. / GPS ATTI. Mode, you have to execute CSC and then push throttle stick over 10% in 3 seconds, otherwise motors will stop after 3 seconds.
- (3) During normal flight, only pull throttle stick under 10% will not stop motors in any control mode.
- (4) For safety reason, when the slope angle of multi-rotor is over 70° during the flight in ATTI. / GPS ATTI. Mode (may be caused by collision, motor and ESC error or propeller broken down), and throttle stick is under 10%, motors will stop automatically.

Notes of Intelligent Mode & Immediately Mode



- (1) If you choose the Immediately Mode, you should not pull throttle stick under 10% during flight, because it will stop motors. If you do it accidentally, you should push the throttle stick over 10% in 5s to re-start motors.
- (2) DO NOT execute the CSC during normal flight without any reason, or it will stop motors at once.





- (1) If you choose the Intelligent mode, and the throttle stick is under 10%, this will trigger the landing Procedure, in any control mode. In this judgment, pitch, roll and yaw controls are denied except the throttle, but multi-rotor will still auto level.
- (2) In any control mode, DO NOT pull throttle stick under 10% during normal flight without any reason.



- (1) Any of these two cut off types will only work properly if TX calibration is correct done.
- (2) In failed-safe, CSC is denied by the main controller, motors will hold their state.

Step 2 Assembly Checking List

Please check each item, to make sure for safety.

Any of the following mistakes will lead to a dangerous accident, double check all these items:	
	(1) Rotation direction of motor is opposite
	(2) Infirm connection between the motor and the ESC
	(3) Wrong or infirm installation of Main controller
	(4) Wrong or infirm connection between the main controller and ESC.
	(5) Propeller installation mistake
	(6) Magnetization of the compass
Make sure the following items are correct.	
	(1) Make sure you have assembled your multi-rotor correctly.
	(2) Make sure you have done the configuration procedure correctly.
	(3) Make sure all connections are in good condition.
	(4) Make sure batteries are fully charged for your transmitter, autopilot system and all devices.

Step 3 Before Flight

Carry out the following procedures (is based on Intelligent Mode of Motor Stop) to make sure all configurations are correct. Refer to the Appendix->LED Description for more LED details.

- Always switch on the transmitter first, then power on multi-rotor!
- Keep the aircraft stationary until the system start and self-check has finished (●●●●●●●●●●). After that, the LED may blink Yellow 4 times quickly (●●●●). Start motor is disable during LED blinking Yellow 4 times quickly (●●●●), as the system is warming up.
- After the 4 times Yellow LED disappears, toggle the control mode switch on your transmitter to make sure it is working properly. For example, LED blinks (●●●●), which means the system is in ATTI. Mode and the GPS signal is worst Check it with LED indicator to specify the current working mode for MC. See following table for details about LED indicator;
 - There are Manual Mode and ATTI. Mode without a GPS/Compass module, no GPS signal status LED indicator.
 - After connecting to the GPS/Compass module, GPS ATTI. Mode is available, and GPS signal status LED indicator is available.

Control Mode LED Indicator	GPS Signal Status LED Indicator
Manual Mode: NO LED	Signal is best (GPS satellites > 6) : NO LED
ATTI. Mode: ●●●● indicates that is stick(s) not at center	Signal is well (GPS satellites = 6) : ●
GPS Mode: ●●●● indicates that is stick(s) not at center	Signal is bad(GPS satellites = 5) : ●●
	Signal is worst (GPS satellites < 5) : ●●●

4. Keep the aircraft stationary, and then push both sticks to the left bottom or right bottom (shown as the following chart, defined as Combination Stick Commands (CSC)), to start the motors.




5. Release the yaw, roll and pitch sticks and keep them at the mid point, and the throttle stick under the mid point. Then check whether all propellers are rotating correctly.
6. Stop motors, power off the Multi-rotor.
7. Make sure all settings and configurations are correct and then you can take off you aircraft.


After power on, if abnormal LED Indicator occurs, please refer to the Abnormal LED instruction in the FAQ and aids troubleshooting.

Step 4 Flying Test

1. Choose an open space without obstruction, tall buildings and crowds as flying filed. Place the aircraft 3 meters away from you and others, to avoid accidental injury.
2. If in GPS ATTI. Mode, place the aircraft in an open space without buildings or trees. Take off the aircraft after 6 or more GPS satellites are found (Red LED blinks once or no blinking). If in Manual Mode or ATTI. Mode, you can skip this step.
3. Start-up
 - (1) Switch on the transmitter first, then power on multi-rotor! Keep the aircraft stationary until the system start and self-check has finished.
 - (2) Please wait for the system to warm up gradually with the LED blinks Yellow 4 times quickly (●●●●). You should not start the motors until the blinking disappears.
 - (3) Keep the aircraft stationary, and execute the CSC to start the motors.
 - (4) Release the yaw, roll and pitch sticks and keep them at the mid point, at the same time raise the throttle stick from the bottom. The motors will stop if you do not push the throttle stick from the bottom within 3 sec and you will need to re-start the motors.
 - (5) Keep raising the throttle stick until all the rotors are working, push the throttle stick to the mid point and then take-off your multi-rotor gently, pay attention not to push the stick excessively.
 - (6) Pay attention to the aircraft movement at any time when flying, and use the sticks to adjust the aircraft 's position. Keep the yaw, roll, pitch and throttle sticks at the mid point to hover the aircraft at the desired height.
4. Lower the aircraft slowly. Pull the throttle stick to the bottom and then execute the CSC to stop the motors after landing.
5. Please always power off the Multi-rotor first, and then switch off the transmitter after landing.

FLYING NOTES(VERY IMPORTANT) !!!

- (1) If the warm up waiting is longer than 2 minutes (the 4 times Yellow blink continues), please power off for 10 minutes, cold start, and then connect the assistant software, enter the "Tools" -> IMU calibration, carry out the Advanced calibration.
- (2) If you enable the Immediately Mode of Motor Stop; you should not pull throttle stick under 10% during flight, because it will stop motors. If you do it accidentally, you should push the throttle stick over 10% in 5s to re-start motors.
- (3) DO NOT execute the CSC during normal flight without any reason, or it will stop motors at once.
- (4) Pay attention to the GPS satellite status LED indicator. Bad GPS signal may lead the aircraft to drift when hovering.
-  (5) DO NOT fly near to ferromagnetic substances, to avoid strong magnetic interference with the GPS.
- (6) Please avoid using GPS ATTI. Mode in the areas, where GPS signal is most likely bad.
- (7) If the LED flashes quickly Red then this indicates battery voltage is low, land ASAP.
- (8) If the transmitter indicates low-battery alarm, please land ASAP. In this condition the transmitter may cause the aircraft to go out of control or even crash.
- (9) In GPS ATTI. Mode, make sure that the home point is recorded when the GPS signal is well; otherwise the home point recording may be not so precise.

- (1) In ATTI Mode, throttle stick center position is for 0m/s along the vertical direction. You should keep the position of throttle stick higher than 10% from cut-throttle during the flight! In any control mode, DO NOT pull throttle stick under 10% during normal flight without any reason.
-  (2) It is recommended to land the aircraft slowly, to prevent the aircraft from damage when landing.
- (3) If Low-Voltage Alarm is set, the aircraft will act according to the configuration of the Assistant Software once Low-Voltage Alarm is triggered. Make sure you remember what you have set before.
- (4) If Fail-Safe function is set, the aircraft will act according to the configuration of the Assistant Software once Fail-Safe is triggered. Make sure you remember what you have set before.