Information and Communication Technologies Engineering

Quad-copter

Bachelor Thesis

Uninettuno University - Helwan University

By

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THIS IS TO CERTIFY THAT:

[I]The thesis comprises our original work towards the bachelor degree.

[II]Due acknowledgement has been made to all

other material used.

Adam Esam shabon

Ahmed abdul Moneem Soliman

Adham Mohammed Tarek

PREFACE :

- We present to the reader our bachelor thesis, containing the results of our graduation project at Uninettuno university and Helwan university.
- We would like to express our thanks and gratitude to all of our professors for their help and support.
- Special thanks to our supervisors Dr.Alaa Hamdy(Helwan university, Cairo, Egypt) and Dr.Dario Assante (uninettuno university, Roma, Italy).

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Abstract

In this paper we discuss a quad-copter system as an extremely maneuverable and versatile platform for many applications especially surveillance and aerial photography which can be used to monitor and survey important areas as well as areas which are normally very difficult to access or dangerous locations.

We present our design of a quad-copter system employing an ardupilot mega 2.6 chip with an RF transmitter with several live control forms available as well as mission planner for autopilot control.

At the end of our paper we should end up with good understanding of multi-rotor crafts, why they are better for smaller sized drones and how to build a quad and operate it as well as RF communication.

Table of content:

Chapter 1

Preview:

In this chapter we present the project idea, project objectives, proposed solution and discuss documentation outlines.

Introduction

1.1 Objectives:

As a group of senior Engineering students, we thought of our graduation project to be a massive opportunity for us to do our part contributing to satisfying a social need or to solving a national, local or social problem yet in a way that could be considered promisingly innovative.

Building a quad-copter with live control as well as autopilot capabilities that is versatile enough to be used to tackle several problems.

Fitting the quad with a camera that can be controlled from the ground station, the problems we are trying to tackle are:

1.1.1 Security:

Recent bomb attacks in Egypt have clearly shown that we need a better form of security and surveillance to secure human lives as well as vital locations like ministries, banks or high traffic urban areas that could be targeted by terrorism.

Figure 1.1: Devastation caused by a bomb attack in Mansoura, Egypt

1.1.2 Rescue:

Quads can be used to deliver aid to people in distress in areas that could be difficult to reach or too dangerous for human operators.

According to WHO there's an estimated 359,000 people that die by drowning every year, making it responsible for approximately 10% of total global mortality.

Quads can be placed on boats or beaches and used to drop inflated life buoys to someone that could potentially drown as shown in figure

Fig1.2: Quad-copter delivering life buoy

Quad-copters also can do more in safety field by attachment of the required component for the task, for example: earthquake, firefighting, flooding etc…

The main advantage of Quad-copter is being flexible and upgradable for many applications with the same components and interface.

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1.2 Goals:

- Achieving quad mobility.
- Setting up a user friendly interface between quad and pc.
- Accurate photo shooting and location tracking.
- Building an easily maintainable system.
- Building an upgradable versatile system that can be interfaced with many other components, sensors, cameras, etc.
- Accurate autopilot way point planning.
- Get high performance and accuracy for required task in real time.

1.3 Block diagram of the project:

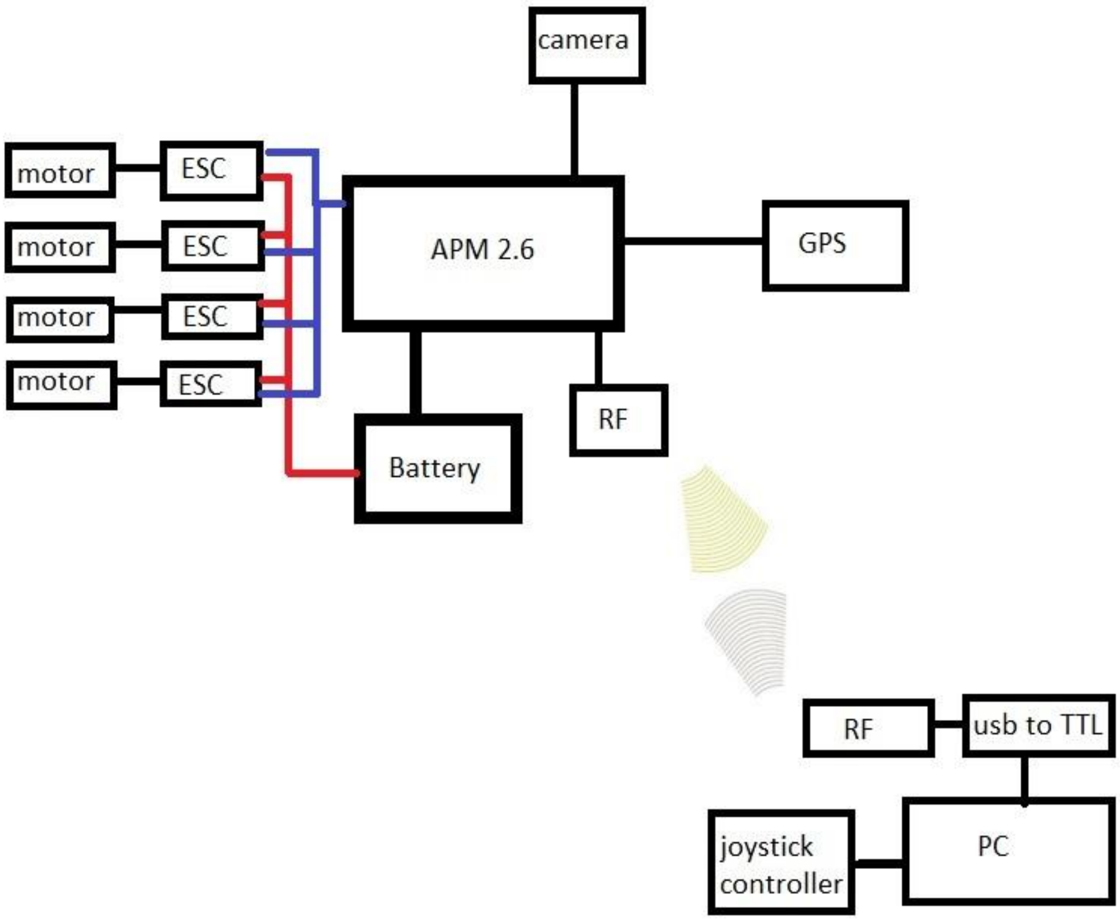

Figure 1.3 block diagram of full system

Chapter 2

Preview:

In this chapter we introduce quad-copters, compare them to helicopters and other multi-rotor crafts and we discuss their potential applications.

Quad-copter

2.1 Introduction to quad

Multi-copters are multi-rotor aerial vehicles; they come in plenty of variations including tri-copters, quad-copters, hexa-copters and octo-copters, having 3, 4, 6 and 8 rotors respectively.

A quad-copter by definition is an aerial vehicle that uses four rotors, it has four arms arranged in a "+" configuration with a motor and propeller on each end, situated in the same plane at a fixed distance from the center of mass of the quad and a center piece where the control system, battery and various sensors are mounted as shown in fig2.1.

Figure 2.1: typical quad-copter

Quad-copters can vary from as big as a CD to a few meters in width.

A Typical quad-copter consists of:

- Frame
- Four motors
- Four ESCs
- Controller (APM)
- Battery
- RF transceivers
- Ground station and dynamic controller

2.2 Quad-copter configurations:

Multi-rotors are so inherently unstable that no human can fly them, so they need to be controlled through electronic stabilization that controls the speed of their rotors in order to control the motion of the quad or multi-rotor craft.

Stability of quad-copters is achieved with the arrangement of the rotors, as two of them will be rotating CW and the other two CCW to stabilize the quad-copter.

Quad-copter rotors are arranged in either "X" or "+" configuration, each requiring a slightly different way of control, as illustrated in the figure 2.3, the significant difference between those two configurations is where the front side of the quad is.

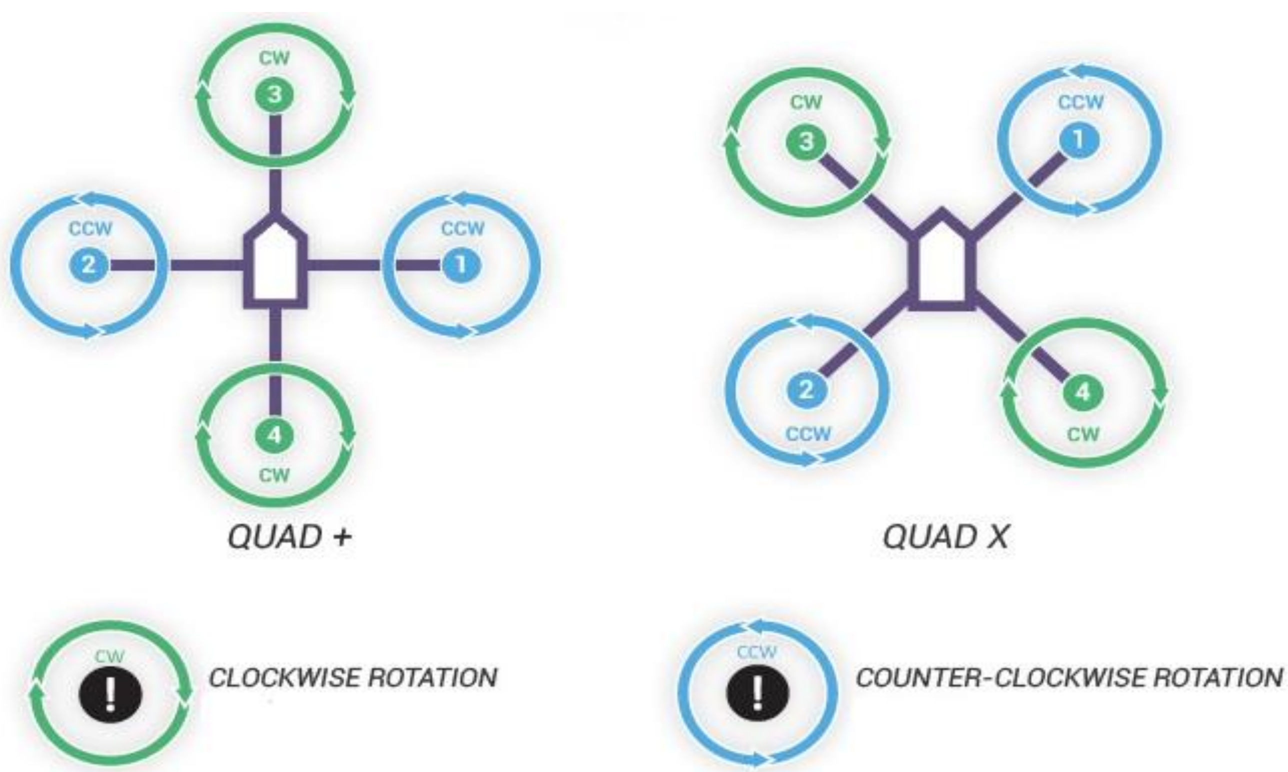

Figure 2.2: different quad configurations

2.3 Multi-copter stability VS helicopter stability:

Quad-copters are similar to helicopters in being vertical take-off and landing vehicles (VTOL) but their lift and thrust comes from four propellers rather than just one, also helicopters have a “pitch” or tail rotor shown in figure 2.2 that helps stabilize the craft whereas quad-copters do not.

Figure2.3 Traditional helicopter with an arrow showing the rudder

2.4 Quad-copter VS other multi-copters:

2.4.1 Tri-copters:

Quads have one more motor than tri-copters therefore they produce more thrust, they produce about a third more thrust than tri-copters, which is a great advantage

considering similar sized quads and tris weigh approximately the same.

More thrust means quads can carry more weight, this though comes at the cost of using more power meaning if the same battery is used for a tri and a quad, the quad would have less flight time.

More thrust means quads can carry more weight, this though comes at the cost of using more power meaning if the same battery is used for a tri and a quad, the quad would have less flight time.

2.4.2 Multi-rotors with more than 4 motors:

As stated more motors means more thrust and the capability of carrying more weight which would help to apply even more applications but for our project we chose the quad because it produces enough thrust to carry the camera and any sensor modules we can add.

Multi-rotors larger than quads have the disadvantage of using even more power which means they require more batteries at higher costs to increase their flight duration.

Multi-rotors though have the ability to fly even if they lose one motor, whereas quads and tris cannot fly if they lose a motor.

2.5 Quad-copter motion:

Quad-copters became very popular because they are mechanically simple. Through controlling the angular velocity of the four rotors, these quads can perform four different types of movement, that includes roll, yaw, pitch and accelerate.

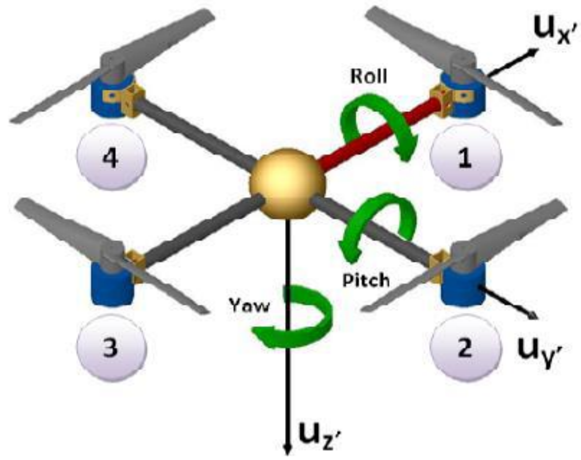

Figure 2.4 Quad motions

Each rotor in the quad-copter is responsible for a certain amount of thrust and torque about its center of rotation in addition to a drag force (force generated by the air resistance) opposite to the rotor crafts direction.

When all of the rotors have the same speed then the overall moment produced is zero and quad-copter will hold its altitude. Increasing and decreasing the speed of all rotors at an equal rate will change the altitude of the quad.

Change in pitch angle is generated by variations in the speed of rotors 1 and 3 in figure 2.4 resulting in a forward and backward translation, change in roll angle is generated by varying the speed of rotors 2 and 4 in figure 2.4 resulting in a lateral translation.

These variations in speed cause the lift force to be displaced in the x and y axis direction resulting in a horizontal force component causing the previous movements.

Figure number	Movement
2.5.a	Negative X-axis
2.5.b	Positive X-axis
2.5.c	Negative Y-axis
2.5.d	Positive Y-axis
2.5.e	Upwards along Z-axis
2.5.f	Downwards along Z-axis
2.5.g	Yaw left
2.5.h	Yaw right

Table 2.1: Movements resulting from figure 2.5 according to the axis in figure 2.4

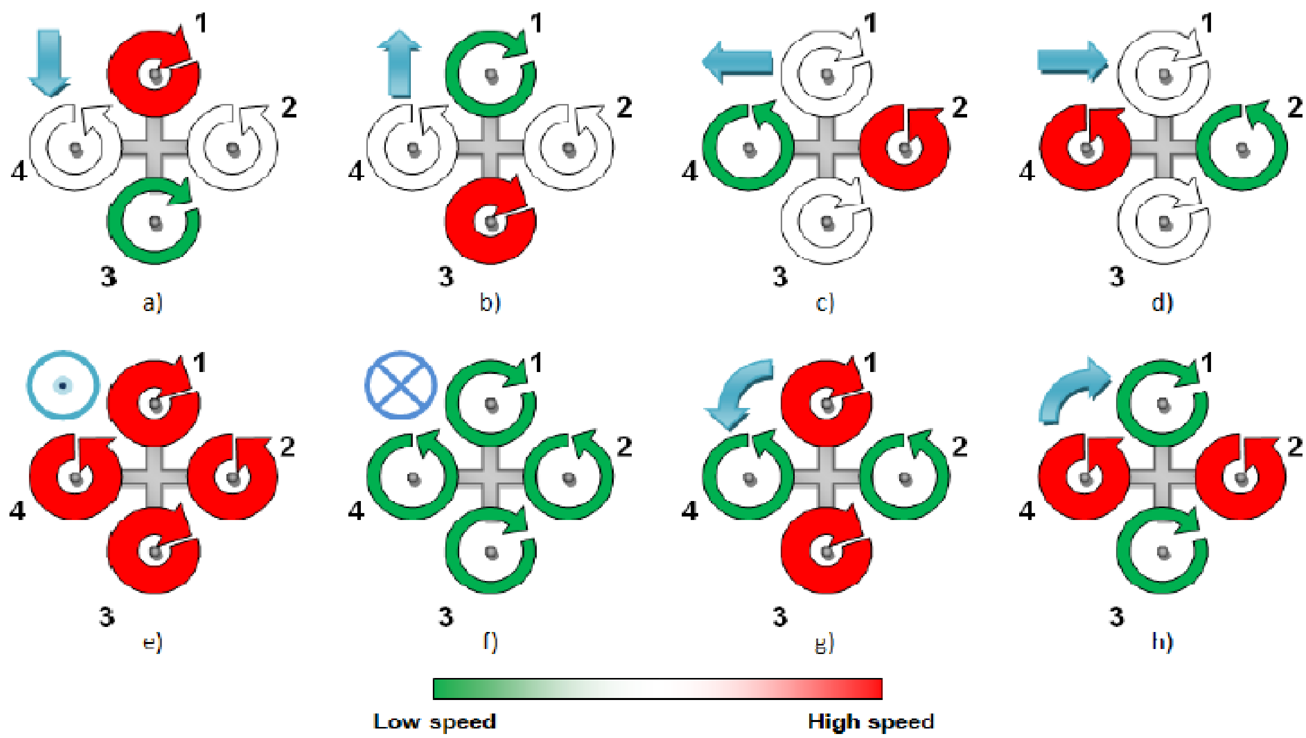

Figure 2.5: Different motions

2.6 Quad-copter applications:

Quads are relatively cheap and their mechanical simplicity makes them attractive to amateurs as well as researchers.

Because they are highly maneuverable, quad copters could be useful in all kinds of situations and environments. Quad copters capable of autonomous flight could help remove the need for people to put themselves in lots of dangerous positions. This is a prime reason that research interest has been increasing over the years.

It's due to these reasons that quad-copters have grown widely popular amongst amateurs and professionals alike for a wide array of applications ranging from research to military and policing applications alongside commercial applications

2.6.1 Military and policing applications:

The military use of UAVs has grown because of their ability to keep human operators at a safe distance. The military applications include surveillance, search, rescue, remote inspection or any application that would be dangerous if done with operators within close range.

Figure 2.6 shows a police quad-copter equipped with a camera that is used for surveillance.

Figure 2.6: Police surveillance drone

2.6.2 Commercial and industrial applications:

In commercial and industrial fields quads have many applications such as:

- Pipeline and dangerous area inspection such as nuclear reactor site meltdowns as shown in figure 2.7

Figure 2.7: Quad used for inspection

- Crop assessment as shown in figure 2.8

Figure 2.8: Quad used for crop assessment

- Monitoring hard to reach or dangerous locations
- UAE has a project employing quad-copters as delivery drones to deliver government issued IDs and other vital documents to your door step after you order it online.

Figure 2.9: UAE quad used for delivery

- Monitoring hard to reach locations and exploration of a collapsed building or a dangerous location.

2.6.3 Research:

Quads are inherently unstable they rely on the equal thrust from their four rotors to remain stable, this is very difficult to do manually, in order for the quads to change speed, direction and height, the power of each of the four rotors needs to be

varied in a controlled way with the quad returning to its stable position after a movement is finished, this requires complex sensors and in flight control.

This is their biggest drawback and surprisingly it's what makes quads interesting for university students and researchers.

This means that flying them properly represents a test. In academic speak 'they are a challenging example of a safety critical embedded real time system".

Quads are a great tool for university students and researchers to test and evaluate new ideas in a number of different fields.

Chapter 3

Preview:

In this chapter we discuss each component of a quad-copter system and how we made our choices.

Hardware

3.1 Frame:

The body of the quad on which everything is mounted, it's most important features are:

- Weight
- Durability

We chose the hobby king X650F glass fiber quad-copter frame, it's shown in figure 3.1

3.1.1 Specifications:

Weight	598 grams (frame only)
Width	550mm
Height	265mm
Ground clearance	155mm (bottom of the frame), 185mm (camera mount rails)
Motor bolt holes	16~30mm

Table 3.1: Frame specifications

Figure 3.1: X650F frame

3.1.2 Why we chose this frame:

- Made from light weight yet durable glass fiber as well as aluminum.
- The extended landing mounts provide enough ground clearance to mount the camera easily and safely.
- The aluminum arms serve as a platform to mount the ESCs, providing cooling for the ESCs.
- The aluminum arms can be folded for ease of transportation and storage of the quad.

3.2 Motors:

A quad-copter uses 4 motors to generate the thrust needed to make it fly.

Most motors operate according to Faraday's law of induction.

Motor operation is based on attraction and repulsion between magnetic poles, current flows through stator windings creating a magnetic pole that attracts the nearest permanent magnet pole on the rotor which causes the rotor to spin if the current shifts to an adjacent winding.

Pushing current through each winding in sequence will cause the rotor to start rotating.

3.2.1 Brushless motors VS brush motors:

The biggest difference between brush and brushless motors is that in brush motors the magnets are placed on stator and windings on rotor, while in brushless motors, magnets are placed on rotor and windings on stator

Figure 3.2: Brushed motor with windings on rotor and magnets on stator

Disadvantages of brushed motors:

- Brushes wear out eventually.
- Sparks and electrical noise caused by brushes making and breaking connection.
- Brushes decrease the maximum speed of the motor.
- Harder to cool because the electromagnet is in the center.
- Using brushes limits the number of poles the armature can have.

Advantages of brushless motors:

- More precise, more efficient.
- No sparks and less electrical noise due to lack of brush.
- Easier to cool because electromagnets are on the stator.
- You can increase the number of electromagnets on the stator for more precise control.

The disadvantage of brushless motor is the higher cost but it's compensated by longer motor life and higher efficiency.

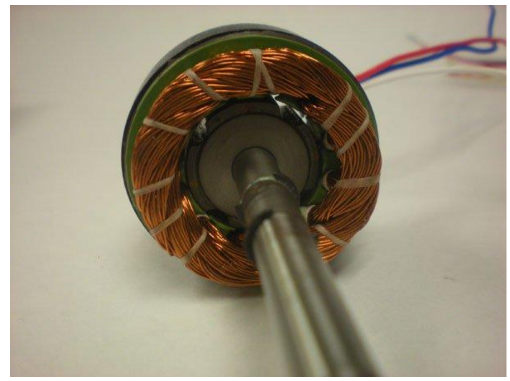

Figure 3.3: Brushless motor with windings on stator and magnets on rotor

We chose the EMAX BL2220/07 1200 kv brushless out runner motor

Figure 3.4: EMAX BL2220/07 brushless out runner motor

3.2.2 Why we chose this motor:

- Efficient motor.
- Relatively cheap motor with enough thrust to carry the craft.
- 4 x 1300 gm = a total of 5200 gm thrust.
- Since the weight of the quad with everything installed is approximately 650 gm.
- That leaves us with approximately 4550 gm, enough to carry a camera and any other sensors we might add.

3.2.3 BL2220/07 Specifications:

No. of cells	3
Stator dimensions	22 x 20 mm
Shaft diameter	4 mm
Weight	85 gm
Recommended propeller size	10 x 47
Recommended model weight	400 – 1200 gm
Max RPM	8560
Max current	28 A
Thrust	1300 gm

Table 3.2: BL2220 specifications.

3.3 ESC:

ESC's or Electronic speed controls are often used on electrically powered radio control. It converts the DC power comes from the battery to AC current, and converts the voltage to the voltage required for the brushless motors , not all speed controllers have this capability, only those with BEC or UBEC written on them which stand for universal battery elimination circuit.

ESC can control the speed and power of brushless motors; it also acts as a dynamic break. By generating a three phase electric power low voltage source.

3.3.1 Types of ESCs:

1- Brushed ESC : this is the first ESC that have been created, and it is used for brushed motor (e.g.: electric RC vehicles)
2- Brushless ESC: is an advanced ESC that work with brushless motors by sending a sequence of signals.

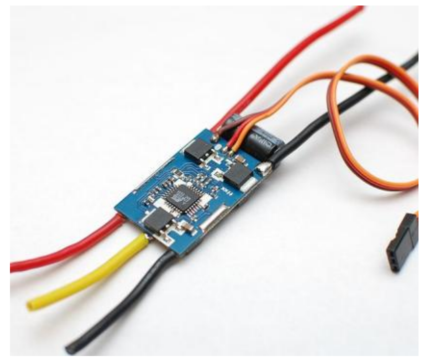

Figure 3.5: ESC

3.3.2 How to choose the right ESC?

Each ESC is designed specifically for specific type of motor.

- The ESC has to match the type of motor, meaning you have to use a brushless ESC for a brushless motor and a brushed ESC with a brushed motor.
- The ESC also has to match the motor in the amperage rating, because every motor requires different amount of amps.

We chose in our project the EMAX Brushless ESC 25A

Figure 3.6: ESC 25A

3.3.3 ESC-25A specifications:

Continuous current	25 A
Burst current	30 A
Lithium battery	2-4 cell
Dimensions	50 x 28 x 12 mm
Weight	31 gm
BEC (linear)	2 A/5 V
Programmable	yes

Table 3.3: ESC-25A specifications.

3.4 Microcontroller:

Quads are inherently unstable they constantly need an on board computer to calculate the changes in rotor speeds necessary to stabilize the quad and adjust their speeds accordingly.

A microcontroller acts as the brain of the quad-copter, it's responsible for all actions a quad can perform from take off and landing to autonomous flight as well as camera and sensors control.

For our project we chose APM 2.6 which is an open source UAV platform capable of controlling multi-copters, fixed wing crafts as well as ground vehicles and boats and by employing a GPS module

Figure 3.7: APM inside it's protective casing

it can turn any of those vehicles into autonomous vehicles capable of carrying out GPS missions programmed with way points.

Figure 3.7 shows the APM inside it's protective casing.

3.4.1 APM 2.6 features:

- Arduino compatible
- Side and top entry pins
- Includes 3-axis gyros, accelerometer and a high performance barometer.
- Onboard 4 mega byte data flash chip for automatic data logging.
- It's composed of atmel's ATMEGA2560 and ATMEGA32U chips which are used for processing and usb functions respectively.

3.4.2 APM 2.6 over view:

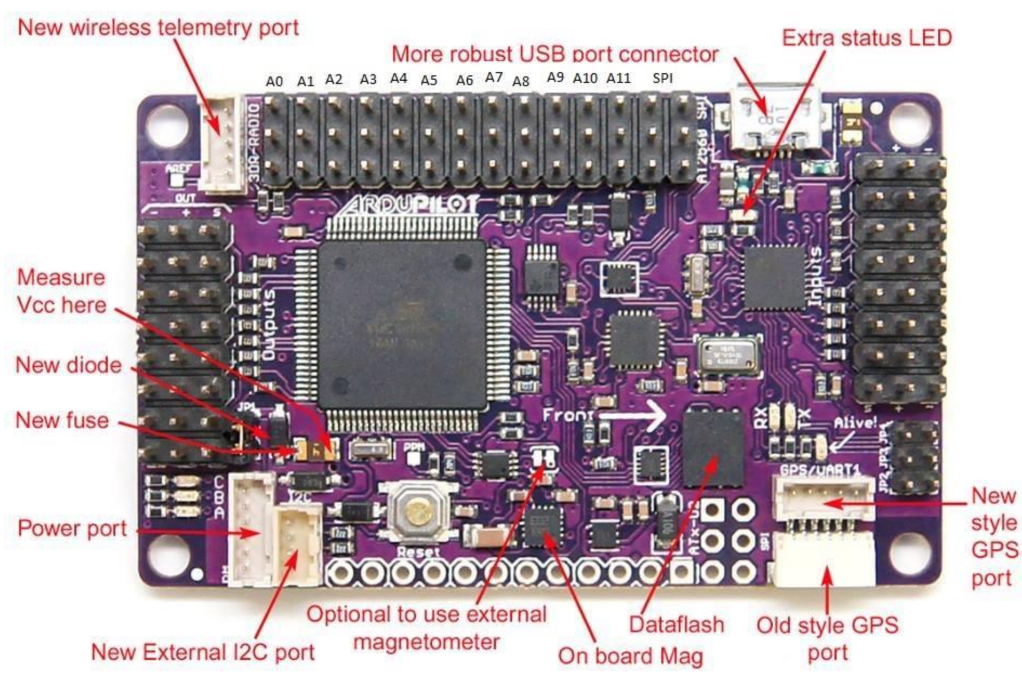

Figure 3.8: APM 2.6 overview

3.4.3 <u>GPS:</u>

APM 2.6 will be connected to Ublox-NEO 6M GPS module with built in HMC5883L compass.

Figure 3.9 shows the Ublox NEO-6m GPS module

Figure 3.9: Ublox NEO-6m GPS

3.4.4 <u>APM 2.6 specifications:</u>

- **3 axis gyro**
- **3 axis accelerometer**
- **High resolution altimeter**
- **Dimensions = 70.5 x 45 x 13.5 mm**
- **Weight = 31 gm**

3.5 <u>Battery:</u>

- **Battery is our voltage source in this system, we need a 3 cell lithium polymer battery for our system,**
- **We chose the BAT-LIPO-0051 battery (11.1 V, 4500 mAH -30C)**
- **Lithium polymer battery with high discharge rate/capacity and economic price. Its low weight /size and high power make it suitable for many applications**

Figure 3.10: 3 cell Li-Po battery

3.5.1 Battery specifications:

Capacity	4500 mAh
Configuration	3S1P/11.1v/3cell
Peak discharge	30 C
Charge	10 C
Pack weight	368 gm
Pack size	27 x 44 x 136 mm
Connector type	T-connector

Table 3.4: BAT-LIPO-0051 specifications

3.6 Wireless communication (RF):

We used a serial UART module, 200 m range, 433 mhz frequency.

Our choice was 11WRL-00.

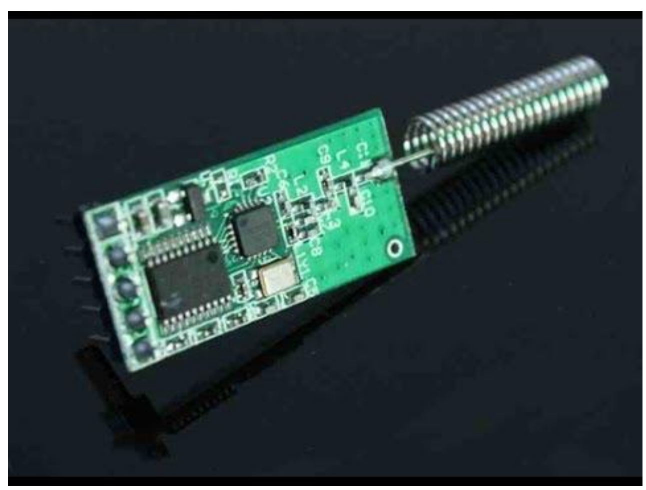

Figure 3.11: 11WRL-00 RF transceiver module

This module is very similar to zigbee but much cheaper, it's easy to use with microcontrollers through Tx/Rx pins, also like zigbee, you can adjust baud rate, channel and power by connecting to pc usb port using USB to TTL module to be discussed later.

You can write the AT commands using hyper terminal.

3.6.1 11WRL-003 Features:

- Serial UART can work directly with microcontroller
- Just as easy to use as ZigBee
- 3.3v – 5v operation, can operate directly with usb power.
- Default baud rate is 9600, can operate at higher speeds but at the expense of more errors and shorter range.
- Baud rate/channel can be modified using specific AT commands.

3.6.2 Pin definition:

1. Power, 3.3 – 5v (this pin is marked by a white square)
2. Gnd
3. Rx
4. Tx
5. Pin (high level enter AT control mode)

3.7 USB to TTL:

Our choice was PL2303 which is a small usb to TTL serial tool, we will use to connect our RF module to PC to establish communication with quad shown in figure 3.12

Figure 3.12: USB to TTL module

3.8 Live controller:

Mission planner allows the usage of a game pad (joy stick) as the live control input method instead of the very expensive and also currently illegal in Egypt RC controllers.

We will be using a generic twin usb joystick controller pair connected to pc as our radio controller.

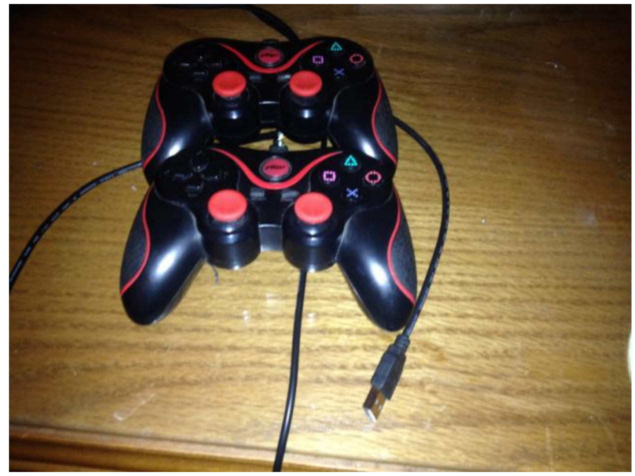

Figure 3.13: Dual joysticks to be interfaced with system

Mission planner has an interface for calibration of a joystick as the dynamic controller for your drone.

3.9 Laptop:

A pc is needed as the ground control station and for initial mission planner setup and first time flight setups.

We will be using an HP pavilion dv6 as the ground station.

3.9.1 laptop specifications:

Processor	Inter core i7 Q720 @ 1.60 Hz
Ram	4 GB
OS	Windows 7 professional 64-bit

Table 3.5: laptop specifications

3.10 Camera:

A camera is required for our system.

Our choice of camera was a canon power shot A560 fitted with a 2 GB SD card to save captured images on.

3.10.1 Camera specifications:

Sensor resolution	7.1 Megapixel
Optical sensor type	CCD
Total pixels	7,400,000 pixels pixels
Effective sensor resolution	7,100,000 pixels pixels
Optical sensor size	1/2.5”
Optical zoom	4 x
Digital zoom	4 x
Image processor	DIGIC III
Auto focus	TTL contrast detection
Auto focus points Qty	9
Digital video format	AVI
Image recording format	JPEG
AV interfaces	Composite video/audio
Manufacturer	Canon
Light sensitivity	ISO 800
Exposure metering	Evaluate
Exposure modes	Automatic
Shooting programs	Aquarium
Special effects	Vivid
White balance	Automatic
White balance presets	Cloudy
Max shutter speed	1/2000 sec
Min shutter speed	15 sec
Exposure compensation	±2 EV range, in 1/3 EV steps
Lens type	4 x zoom lens – 5.8 – 23.2mm – f/2.6-5.5
Focal length equivalent to 35mm camera	35-140 mm m
Focus adjustment	Automatic
Min Focus Range	17.7 in
Mcro focus range	2 in – 17.7 in

Zoom adjustment	Motorized drive
Features	Aspherical lens
Camera flash	Built in
Flash mode	Slow synchro
Features	AF illuminator
Effective flash range	1 ft – 11.5 ft
Memory storage	SD card
Battery	2x AA battery

Table 3.6: camera specifications

3.10.2 CHDK:

CHDK stands for canon hackers development kit, it's a firmware for the camera that adds tons of new features, particularly those that are usually available on more expensive, professional cameras.

CHDK is installed on our canon camera by placing it on the SD card after preparing it to be bootable in our camera.

That will allow us to put the camera in <ALT> mode which will enable the Ardupilot to control the camera shutter for capturing pics during flight.

3.10.3 Connecting camera to APM:

The canon power shot A560 is connected to PC using a usb to usb mini-B connector. The usb end is cut and the red and black wires which are positive and negative wires respectively are fitted with pin headers and connected to pin A9 on the +5 and GND pins as shown in figure

Figure 3.14: Camera connected to APM with modified cable

This serves as the APM's method of control on the camera.

Remote must be enabled through CHDK menu as shown in figure 3.15

Figure 3.15: Enabling remote through CHDK

3.10.4 Setup APM to be used with CHDK:

Connect your camera to APM with modified cable, open up full parameters list in config/tuning tab in mission planner.

Parameters are set as follows:

- CAM_DURATION: 1
- CAM_TRIGG_DIST: 49
- CAM_TRIGG_TYPE:1
- RELAY_PIN: 13

Chapter 4

Preview:

In this chapter we discuss mission planner and other software required to run our system.

Software

Mission planner is ground control station software for APM copter, plane and rover, it's compatible with windows.

Mission planner can be used as a configuration utility or as a dynamic control supplement for our autonomous vehicle.

4.1 Features of mission planner:

- **Autopilot control by point and click way point entry using google maps**
- **Full ground station for monitoring missions and sending in flight commands.**
- **See sensor output and test autopilot performance**
- **Download mission log files and analyze them**
- **Configure APM setting depends on the kind of frame configuration you're using**
- **User friendly interface with loads of useful functions**
- **Loads firmware onto APM, configures how you want to use your APM chip from different aerial and ground vehicles**

Figure 4.1: mission planner GUI

4.2 Initial setup with MP:

- Install mission planner on your pc.
- Load firmware onto your APM 2.6 chip using the usb to micro-usb cable provided with the APM

Figure 4.2: APM 2.6 micro USB port

- Find out which com port the APM is using and connect to it via mission planner.

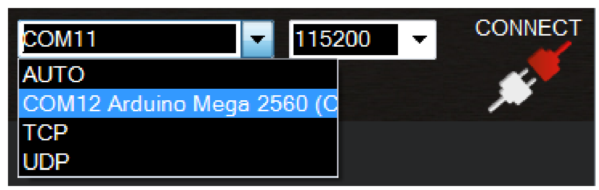

Figure 4.3: connecting via mission planner

- Select the firmware corresponding to your desired drone type.

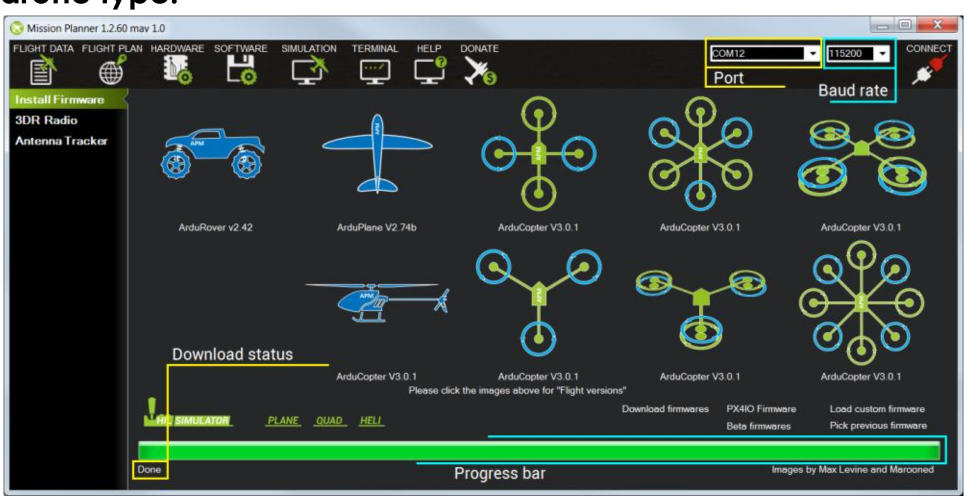

Figure 4.4: Selecting appropriate firmware

- **Click connect at top right corner to load MAVlink parameters to APM**
- **Select frame type**

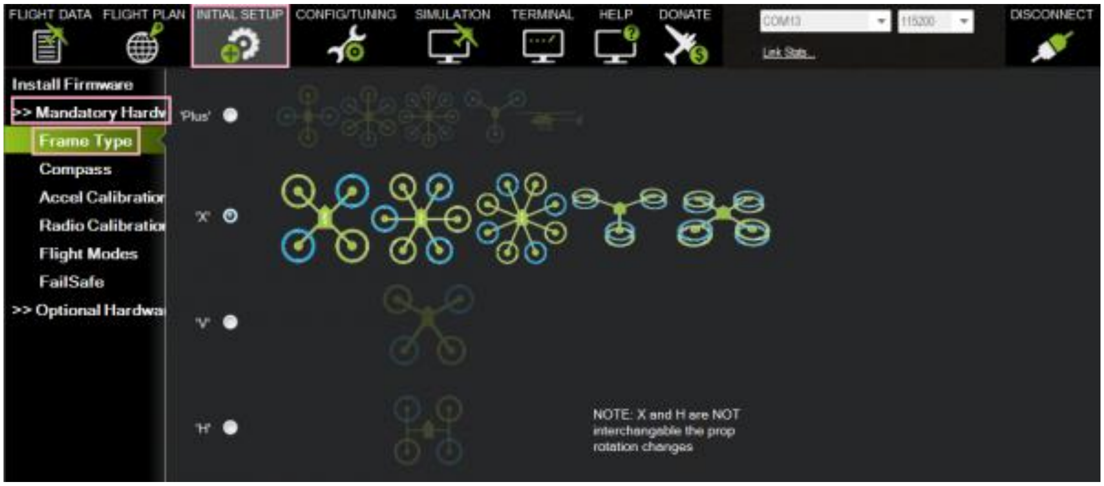

Figure 4.5: Select desired frame type

- **Mission planner then guides you through compass calibration**
- **Then it asks you to calibrate accelerometer by placing the quad on one of it's 6 faces at a time, as shown in figure 4.6**

Figure 4.6: Accelerometer calibration positions

- **Calibrate radio control**
- **Set up joystick as input for dynamic control**

4.3 Mobile software:

Mobile alternatives to mission planner are available and will be included in our future work:

- **Droid planner shown in figure 4.7**

Figure 4.7: Droid planner GUI

- **Andropilot shown in figure 4.8**

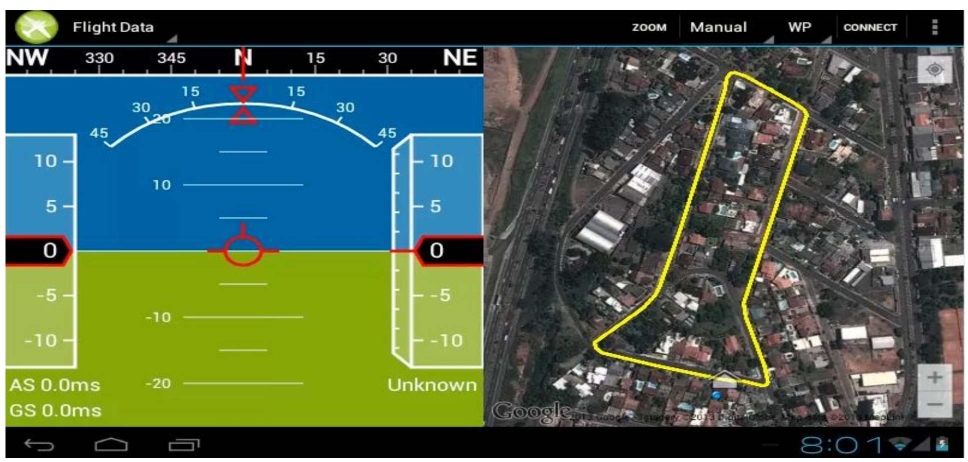

Figure 4.8: Andropilot GUI

Chapter 5

<u>Preview:</u>

In this chapter we will discuss the main components of the system's block diagram and their implementation an integration

Overall System

Here we will discuss the main components of the system's block diagram, the function of each component and how all the components can be successfully integrated together to produce an autopilot system as well as dynamic control system capable of flight as well as photography.

Our APM based system is much less complex than attempting to achieve the same result with an arduino based system.

Because of it's already made mission planner software used for configuration, tuning and serving as a ground station and a receptacle for mission data logs and sensor data acquired during flight.

5.1 Typical quad layout:

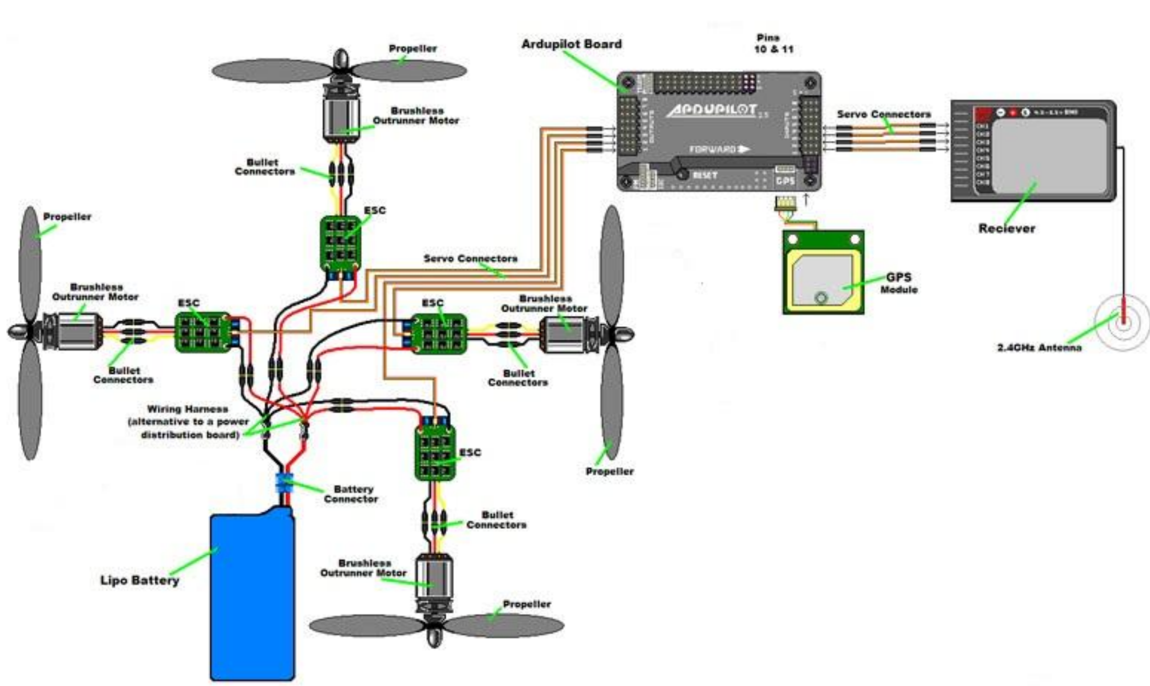

Figure 5.1: typical quad system

5.2 Block diagram of the proposed system:

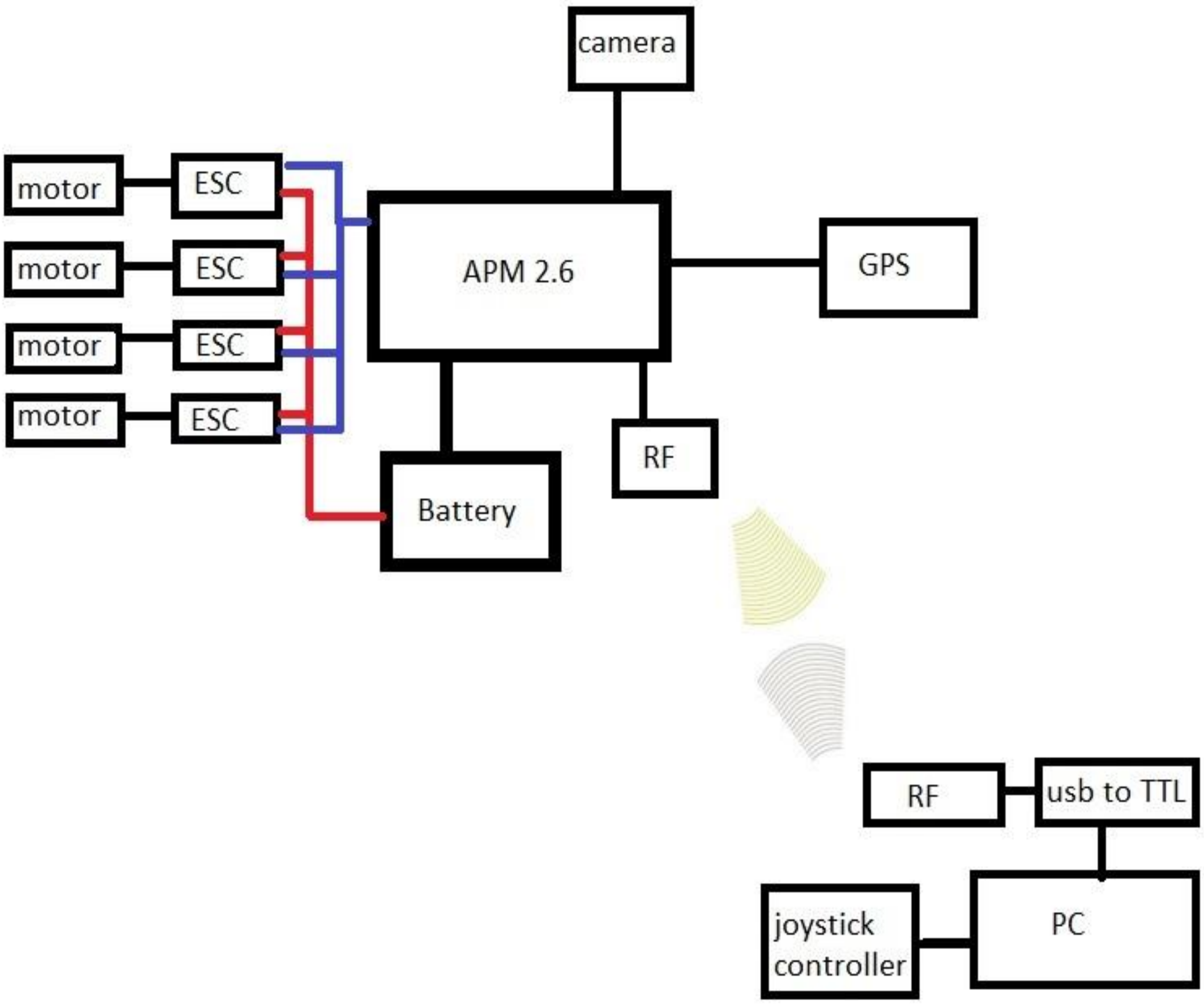

Figure 5.2: our system's block diagram

5.3 Description of the proposed system:

Our system is composed of an APM 2.6 board that is used as the controller for the quad, it senses data from the on board gyros, altimeter, accelerometer, etc and makes the calculations necessary to change the outputs going into the ESCs, effectively controlling the speed of the motors to keep the quad stabilized.

The system is powered by a 3-cell Li-Po battery which is connected to a power distribution cable that is used to feed power to the ESCs and also route 5V of power to the APM's power module with a 6 position cable.

The 5V routed to APM are sufficient to run it along with all the on board sensors as well as the external GPS/compass module.

Each ESC is connected to one of the motors through 3 bullet connectors, they act as a 3 phase power source for the motors and control the speed, direction of rotation and also can act as a dynamic brake for the motors.

The inputs of those ESCs are connected to the output pins on the APM 2.6 board, to pins 1, 2, 3 and 4, the purpose is to control the speed of each motor, so we can effectively perform all 4 possible quad movements which are roll, yaw, pitch and accelerate along the common orientation.

The external Ublox NEO-6 GPS module is connected to the APM board using old style GPS connection as well as a connection to feed it power from the APM.

Our intended form of communication is RF transmission, with the ground station and controller being a laptop with joysticks connected to it and also connected through USB to a USB to TTL module connected to our RF transceiver.

Mission planner software serves as the ground station for our system, it is also used for first time setup of the APM board, to load firmware and also used for our system's configuration.

Mission planner is the ground station software in charge of autopilot, where we can set way points for our quad to carry out it's mission.

MP allows the usage of regular pc gaming joysticks as input which is what we plan to use for our system dynamic control.

The RF transceiver connected to the APM itself should be connected to the 3dr telemetry port on the APM but since the cable is not available in Egypt, we have chosen to connect our RF transceiver directly to the UART 0 pins on our board as a solution to the connector problem.

5.4 Snap shots of quad building progress:

- Figure 5.3 shows the frame parts before assembly, it contains 4 center plates for mounting, 4 aluminum arms where ESCs will be mounted for added cooling, arm motor housing, upper and lower piece for each motor, 4 glass fiber pipes for landing gear assembly.

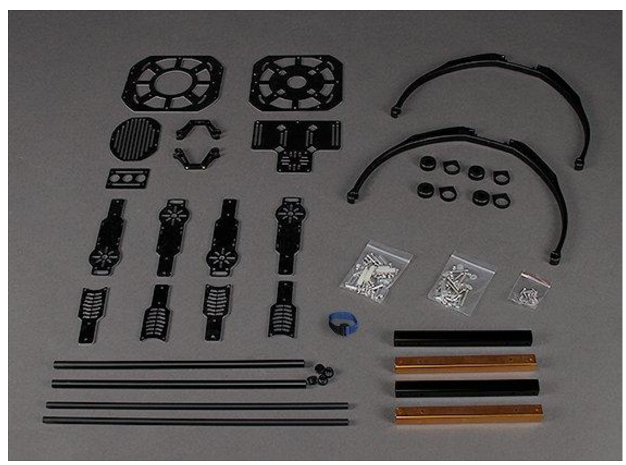

Figure 5.3: quad X650F parts

- Figure 5.4 shows the landing gear after assembly, it provides enough ground clearance for our camera to be comfortably mounted and provide a durable stable landing gear for our quad to keep our components safe.

Figure 5.4: assembled landing mounts

- Figure 5.5 shows 2 center plates assembled, they will be used to mount APM and GPS exactly at the center of the quad away from interference sources.

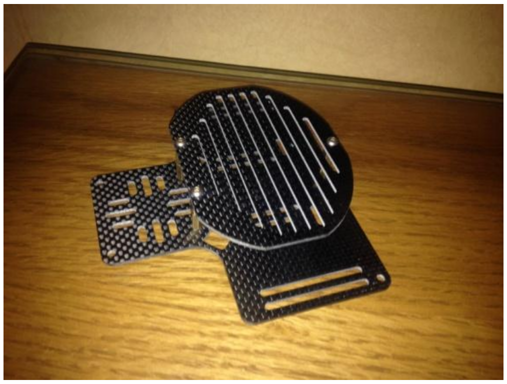

Figure 5.5: Center piece where APM and GPS will be mounted

- Figure 5.6 shows motors connected to the arms of the quad before they're assembled with center piece.

Figure 5.6: motors connected to motor housing and aluminum arms

- Figure 5.7 and 5.8 show the center plate connected to all 4 arms from top and bottom view.

Figure 5.7: center piece connected to 4 arms bottom view

Figure 5.8: Center piece connected to 4 arms top view

- **Figure 5.9 shows the battery connection in charge of regulating 5V to the APM and connecting battery to all 4 ESCs.**

Figure 5.9: battery and required connection for ESCs and APM

- **Figure 5.10 shows the connection between the canon power shot A560 camera and the APM, the red and black wires are fitted with female pin headers and connected to APM 2.6 to pins A9.**

Figure 5.10: connection between APM and camera

- **Figure 5.11 shows the fully assembled quad after camera, battery and all other components mounted.**

Figure 5.11: shows full quad-copter system

Chapter 6

Preview:

Conclusion and future work

Conclusion and future work

6.1 Conclusion:

An autopilot is a mechanical, electrical, or hydraulic system used to guide a vehicle With no assistance from a human being. Many projects are based on different type of vehicles. One of the powerful rotor-crafts is a quad-rotor.

The main focus of this project was implementing a quad-copter autopilot system. The main purpose of this quad-copter is to fly in a pre-defined trajectory with no assistance from humans and have photography capabilities.

Finally after connecting the APM to ESC's , motors , GPS, Battery, RF Transceivers and Camera, we should be able to live control the Quad-copter on the Laptop by joystick through the RF transceiver , and take live photos while flying .

The complete quad-copter system is shown in figure 6.1

Figure 6.1: complete quad-copter system

6.2 Future work:

6.2.1 Using smart phone as ground station:

Instead of having a full sized computer operating mission planner, you can use an android smart phone or tablet to act as ground station with the help of several open source android based applications such as:

- Droid planner
- Andropilot

So the required tools to set up a mobile ground station are:

- Smart phone or tablet among the list of compatible phones; Google Nexux 10", Samsung galaxy nexus and many more, the only requirement is that the phone firmware is android 4.0 or higher.
- Micro USB OTG cable used to connect the phone to the transceiver; 3DR radios direct USB connect to tablet, RFD900 long range radios direct connect to tablet,XBee direct to tablet, bluetooth adapter direct connect to XBee modem, bluetooth adapter direct connect to tablet.

This can also be upgraded by developing more ground station apps for android or iOS based systems.

6.2.2 Field strength meter:

In general, the field strength meter is a relation between distance from the transmitter and receiver and calculates it by equation fig5.1

$$E = \frac{\sqrt{30 \cdot P}}{d}$$

Fig5.1: the main equation for field strength meter

Where:

E: is the electric field strength in volts per meter

P: is the transmitter power output in watts

d: is the distance from the radiator in meters

It is a simple receiver with a tuner and micrometer which is scaled in dBɥ, the tuner is usually within the terrestrial broadcasting bands.

To get accurate measurement of field strength, the antenna must be in standard height, which is 10 meters (33 feet).

Connect the field strength meter with the Ardupilot as shown in figure 5.2.then fly the Quad around the area that would be tested. The Ardupilot will hold the measurement number in seven segment digital screen.

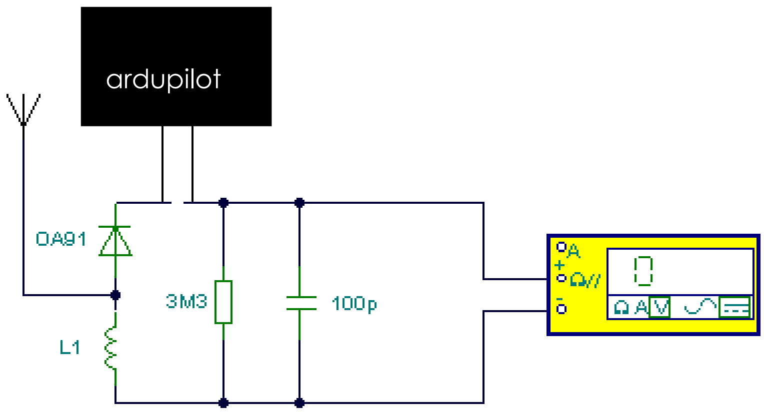

Fig 5.2: connect the field strength meter with Ardupilot

In this case the measurement process will be easy and accurate that you can keep the quad in known height and distance, without putting human lives in danger and risk with their lives in order to achieve signal measurement.

References:

1.Herman, Stephen. Electric motor control 8TH edition.

2. http://www.fut-electronics.com/

3. http://abcnews.go.com

4. http://www.roboticsbusinessreview.com

5. http://www.stefanv.com

6. http://www.rcmodelswiz.co.uk

7. http://emaxmodel.com/

8. http://www.instructables.com

9. http://ardupilot.com/