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Autopilot Quad-copter Drone

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ABSTRACT- This article demonstrates how to build an autopilot quad-copter drone and its applications. The drone's construction was first discussed, as well as key components such as the frame, propellers, engine, power system, electronic control, and communication system. Batteries are used to power drones, and lithium-polymer batteries are commonly employed. The military and commercial droneswere then compared on selected examples. In terms of size and propulsion, military drones
differ from civilian drones. They are larger anduse internal combustion engines to power them. Electric motors power civilian drones.
The potential for using drones were then demonstrated. They can be employed by the government, the army, industry, for photography and videography, and for delivering products. The primary risk of utilising drones is a drone falling from a large height, which could be caused by a discharged battery, weather-related damage (low air temperature, precipitation), or colliding with an obstacle (tree, building, high-voltage line). Many projects are currently underway to generate electricity for drones, including grapheme batteries, pure lithium anodes, and fuel cells. The main objective of this project is to design and develop a stable flying drone as amodel for general purposes that can be used for deliveries. The drone should be able to support lifting a phone or similar weight, and some minor modifications should be applied to it. The drone could be replaced in such a waythat would fit any other application.

Keywords- Autopilot; Drone; Electronic Speed Control; Quad-copter.

I. INTRODUCTION

With the increased demand for speedy delivery and the obstacles that traditional transportation faces, such as ever-increasing traffic, it is unavoidable that UAVs will become the future and one-stop solution for all of these issues.

An Autopilot drone will undoubtedly be a revolution in any area. An Autopilot drone will make our work easier and these duties more efficient, whether it's for everyday household deliveries of food or medications or for security monitoring.

The main goal of this project is to create an Autopilot Quadcopter Drone that will aid in such duties and make everyone's lives easier and more efficient.

II. METHODOLOGY:

First, we'll learn about quadcopter drone concepts, and then we'll build a drone using some readily accessible drone kits. Also, use accessible algorithms and PID logic to create code.

After that, we'll use manual controls to operate it and test our algorithm's ability to fly the drone with manual controls.

At the same time, we'll be working on an Android app that will receive and deliver GPS coordinatesto the drone. In addition, a real-time view of a drone camera is shown side by side.

After that, we'll write code for autopilot. (obstacle identification and avoidance using ultrasonic sensors)

III. LITERATURE SURVEY

According to the European Drones Outlook Study,the market for drones in agriculture, energy, public safety/security, e-commerce/delivery, mobility and transportation will boom in the next thirty years. It is simple to locate an example. For example, the authors of[2] propose using a drone to collect multispectral photos and ground difference data for precision agriculture. Aside from the numerous military applications, new sensors are being developed for drones, such as those used in [3]: X-ray camera, infrared camera, and metal detectors. In terms of e-commerce and delivery, the literature shows that the use of drones for various reasons is still in its early stages.

There are numerous specialised tools for defining missions for UAVs available today. Drone makers, for example, have built their own tools.

- They allow the user to fly the drone manually orset a set of points that conform to a path to be followed by the UAV.
- They rely on standard map technologies such asGoogle Maps and offer a 2D point of view. • In both cases, the application allows the user to create a flight plan and automatically upload it toa drone for an automatic flight. In the case of Parrot, they employ the MAV Link standard, which is a protocol that is now used by many drones and is used to automate not only flight butalso measurement.

The tools are meant to allow users to interact with them quickly and easily, at the expense of more sophisticated situations and systematic examination specification.

IV. APPLICATIONS

A) Security Surveillance Purposes

- Autopilot Drones can be used for security surveillance purposes in high risk places such as railway stations, stadiums, colleges, big events, etc
- Also, can be used in battlefield places such as war zones, borders, etc.

B) Deliveries

- For daily food & medicines deliveries
- During emergencies such as accidents, can also be used to deliver first aim kits, blood, etc

C) Guide

- Can be used for guiding tourists at famous tourist attractions with a pre-defined path, this will minimise the use of manpower in form of human guides.

D) Tracking

- For special purposes such as by thegovernment or police for tracking illegal activities/persons.
- For finding any particular animal either for domestic or study purposes by tracking its activities.

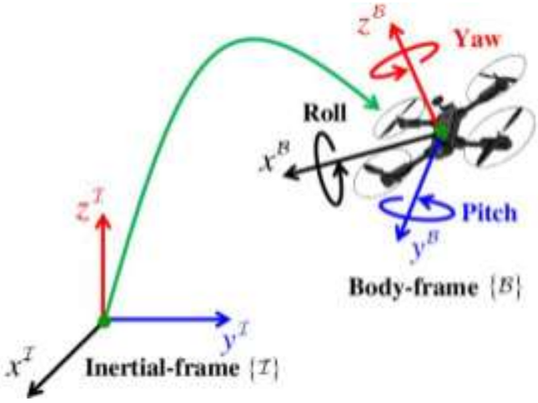
E) Entertainment and Research

- For professional movie shooting
- For reaching remote places where humans cannot travel quickly, there such Autopilot drones can reach quickly during any kind of emergencies or any other task

V. CONCEPT & TECHNIQUES :

The Flight Dynamics:

Before we talk about the 6-DoF and start deriving the quadcopter's dynamics, we need to introduce two frames in which we will work. The first is known as the inertial frame, and it is characterised by its position in relation to the earth, with gravity pointing in the negative z-direction. The body frame, which is defined by the quadcopter's varied orientation, is the latter. My explanation is depicted in the diagram below.



Changing the speed of each motor to a desired value helps control the quad-rotor's location and attitude.

1. Six Degrees of Freedom (6-DOF)

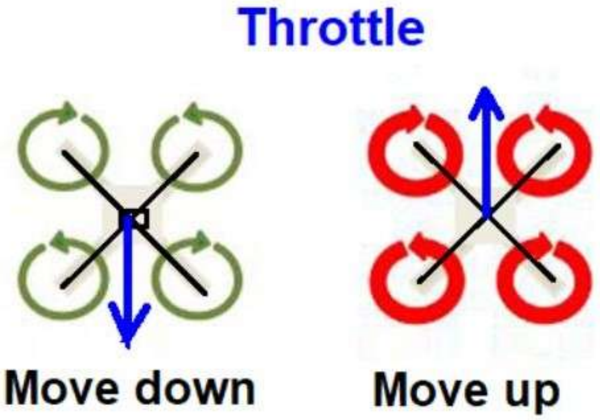
Any time space motion of a rigid body requires six degrees of freedom, which can be separated into two groups: the barycentre and the movement around it. The quad-copter moves longitudinally (forward and backward), vertically (upward and downward), and laterally (forward and backward) using three barycentre movements known as translation motions (right and left). There are also three rotation motions along three axes that cause the drone to rotate between each axis, resulting in roll, pitch, and yaw movements.

When all of the aforementioned motions are combined, we get what's known as the six degrees of freedom. The rotor, which generates a reactive torque, is responsible for the quad-rotor's yaw motion. The size of the reactive torque is proportional to the rotor's speed. When the four rotors rotate at the same speed, the reactive torques equal out and the quad-rotor does not rotate. However, if the four rotors' speeds are not exactly the same, the reactive torque will not be balanced, and the quad-rotors will begin to revolve.

The Throttle (Thrust) Movements:

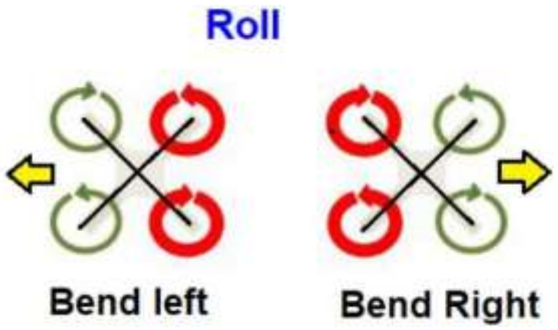
This movement is achieved by reducing or raising the speed of all propellers by the same amount, resulting in a vertical force against the body frame, which lowers or rises the quadrotor. When thequadcopter is in a horizontal position, the vertical direction of the body frame coincides with one of the inertial frames. The thrust delivered, on the other hand, generates both horizontal and vertical accelerations in the inertial frame. Figure 9 depicts the throttle movement in the quadcopter sketch. In this scenario, the propeller speeds I = 1,...,4 are equal to H + A. For each individual. The A (rad/s) is a positive variable that signifies an increment in

relation to a constant value. Because the quadrotor will eventually be influenced by saturations or non-linearities, the A should not be too large.



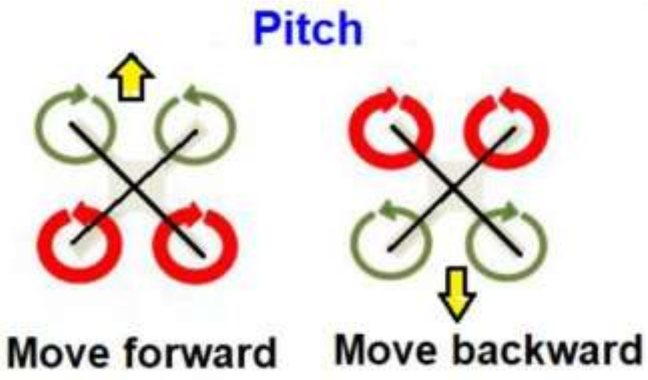
The Roll Movements:

This movement is achieved by reducing or raising the speed of the propellers to the left and right. This causes a torque (figure 10) along the x-axis, causing the quadcopter to tilt side to side (left or right). When hovering, the overall vertical thrust isthe same; hence, this movement only results in a roll angle acceleration. On a quadrotor sketch, Figure 10 depicts the roll movement. The B positive variable is chosen in such a way that the vertical thrust is not affected. It should not be excessively large, as in the preceding situation, because the quadrotor will eventually be damaged by saturations or non-linearities.



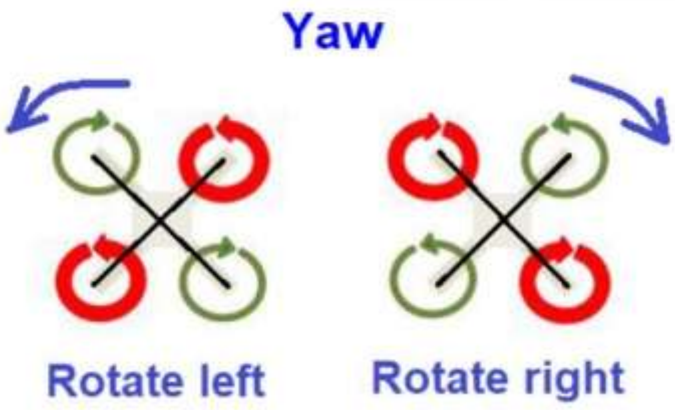
The Pitch Movements:

Pitch movements are similar to roll movements in that they are created by reducing or raising the speed of the propellers at the back and front. This causes a torque (figure 11) in the yaxis, which causes the quadcopter to tilt up and down from front to rear. In hovering, the overall vertical thrust equals the pitch angle acceleration; consequently, this movement provides only a pitch angle acceleration. On a quadrotor sketch, Figure 11 depicts pitch movement. The C positive variable isdetermined, as in the preceding case, so that the vertical thrust remains constant and cannot be too large.



The Yaw Movements:

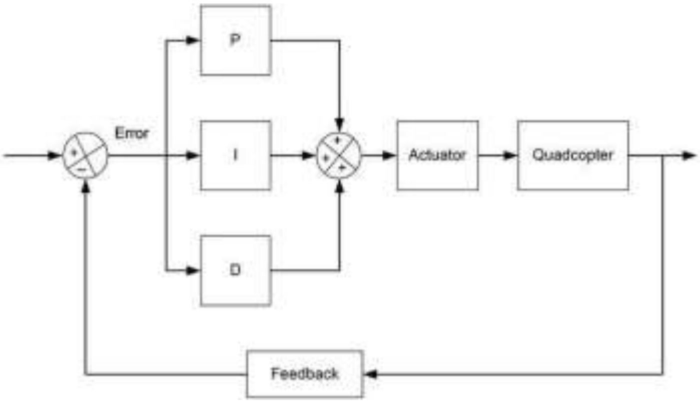
This movement is achieved by reducing or raising the rear and front propeller speeds, as well as increasing and decreasing the right-left couple speed. In terms of the z-axis, this causes a torque, which causes the quadcopter to rotate counter- as previously stated. When hovering, the overall vertical thrust is the same; hence, this movement only results in a yaw angle acceleration. On a clockwise/clockwise while remaining level to the ground. The yaw movement is caused by the fact that the rearfront propellers rotate counter-clockwise while the right-left propellers rotate clockwise (figure 12). As a result, when the overall torque is uneven, the quad-copter twists on itself, quadrotor sketch, Figure 12 depicts the yaw movement.



PID:

PID stands for Proportional, Integral, and Derivative, and it's a feature of flight controller software that receives sensor data and determines how fast the motors should spin to keep the aircraft rotating at the proper speed.

The PID controller's purpose is to reduce "error," which is the difference between a measured value (gyro sensor measurement) and a desired set-point (the desired rotation speed). The "error" can be reduced by changing the control inputs in each loop, which are the motor speeds.



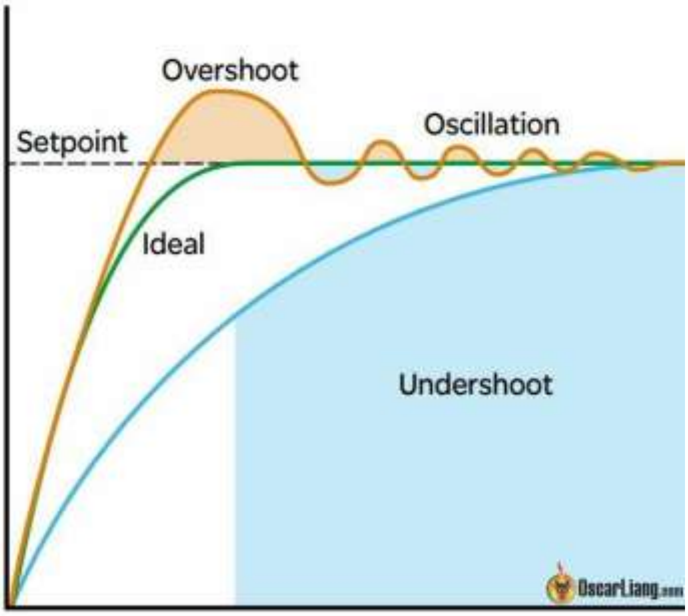
The P term, I term, and D term are the three values in a PID controller:

- "P" is a prediction of future errors – it looks at how fast you are approaching a set-point and counteracts P when it is getting close tominimise overshoot.
- "D" is a prediction of present errors – it looks at how far you are from the set-point and counteracts P when it is getting close tominimise overshoot.
- "I" represents the sum of previous errors; it considers forces that occur over time; for example, if a quad wanders away from a set-point owing to wind, it will spool up motors to compensate.

PID Tuning:
PID tuning can be broken down into three parts: measurement, set-point, and error.

- Sensors on an FPV drone, such as the gyro, measure what's going on, such as how rapidly the drone rotates.
- The ideal condition of the system is the set-point, which specifies how fast the drone should rotate.
- The disparity between measurement and set-point is referred to as error.

A drone's PID system basically seeks to reduce inaccuracy by determining how quickly each motor should spin.
Playing golf is a less accurate but understandable analogy I frequently employ. PID's job is akin to trying to get a golf ball into the hole (set-point). Every time you hit the ball, it may go too far or too short (mistake), but perhaps it will grow closer. You keep doing it until you get it.
PID tuning is similar to refining your golf skills so that you can get the golf ball into the hole with the fewest possible strikes.



Looptime:

The entire process from the PID controller reading sensor input to computing the output is referred to as a "loop." Modern racing drone flight controls can perform thousands of "loops" every second.

The amount of time it takes the FC to complete a loop is referred to as "looptime." The looptime can be measured in milliseconds, however it's more customary to use Hz. Consider the following scenario:

- A loop that lasts one second is equal to one cycle per second, or 1Hz.
- A loop that lasts 1 millisecond (0.001 second) equals 1 kHz.

Flight controllers that can achieve 8KHz looptime are currently relatively popular, and some can even do 32KHz looptime. However, whether faster is better or not is a lengthy debate. Many people choose to remain with8KHz or even lower looptime since there are benefits and drawbacks to achieving 32KHz.

The Effect of Each PID Parameter:

The Effect of Each PID Parameter: Changing PID values has a variety of effects on a quadcopter's behaviour.

Gain (P)

The amount of effort put in by the flight controller to correct errors and attain the desired fly path is measured in P gain (i.e. where the pilot wants the quad to go by moving the transmitter sticks).

Consider it a sensitivity and responsiveness control. The quick response given by a large P gain can even make it appear as if your rates haveincreased.

In general, a larger P gain indicates strongercontrol, while a lower P gain indicates softercontrol.

If P is set too high, the quadcopter will become overly sensitive and will overcorrect, resulting in overshoots and high-frequency oscillations.

You can drop P to reduce oscillations, but if youdo so too much, your quadcopter will become sloppy.

I Obtain

The I term dictates how hard the FC tries to maintain the drone's attitude in the face of external influences like wind and CG drift.

Consider it the rigidity of your quadcopter's stall action and how well it maintains its attitude.

The default I gain in Betaflight works nicely on most configurations. However, if you observe any drifting that isn't caused by a user instruction, raise it. When I is too low, you may find yourself having to use your sticks a lot more to alter the quad's flying direction, especially if the throttle isactive.

When I gain is set too high, your quadcopter will become unduly confined, becoming stiff and unresponsive. It's the same as having a slower reaction time and a smaller P gain. In extreme circumstances, excessive I gain might result in a low frequency oscillation.

Another problem I've discovered that I canaddress or better is "throttle dips."

Because no two ESCs, motors, or propellers are exactly the same in the real world, they will produce varying degrees of thrust even when spinning in the same air. When you punch out and instantly lower your throttle, one motor may raise and decrease RPM more quickly than the others, causing an undesired dip movement.

To "repair" these minor flaws in the flight performance, raise I gain. To avoid introducing unwanted "stiffness" to our quads when using high I gain, Beta flight added a new feature called"Anti Gravity." In a word, it allows you to cruise with a lesser I gain and only enhance your I gain when punching out.

Gain (D)

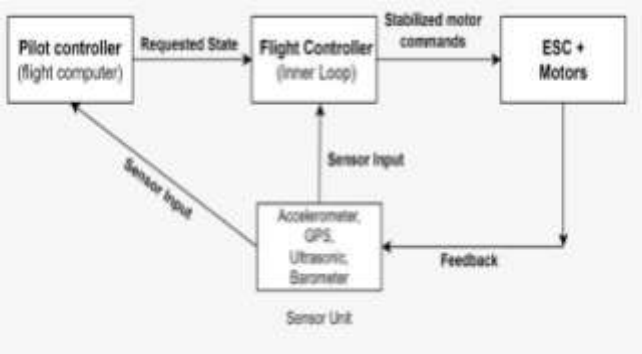
D gain acts as a damper, reducing the over-correction and overshoots that P gain causes. Adding D gain can "soften" and counteract the oscillations created by high P gain, as well as minimise propwash oscillations, similar to how a shock absorber keeps the suspension from becoming bouncy.

When D is too low, your quad will have terrible bounce-backs at the conclusion of a flip or roll, and propwash oscillations in vertical descents will be harsher.

Although increasing D gain can help with these issues, a high D value can cause vibration in your quadcopter by amplifying the noise in the system. This will eventually cause motor overheating and quad oscillation. This article describes why a drone's vibration can be caused by too much D gain.

A decrease in the quad's responsiveness is another adverse effect of too much D increase; this effect is commonly described as "mushy."

VI. BLOCK DIAGRAM



Inner Loop
To operate, an autopilot drone requires at least two layers of control.
The inner loop stabilises the drone at the proper pace or instant, and it regulates all of the drone's motions required to fly or stay in the air.

❖ **Why Not perform stabilization on flight computer**

- The speed of the flight computer is not guaranteed to be continuous.
- Dedicated single task microcontroller for stabilisation ensures safe operation at all times
- Flight computer prone to freezing/crashing

ESC:
An ESC is an electronic circuit that

Outer Loop
The outer loop will act as a drone pilot, sending/generating commands to the drone to get from point A to point B. It will also compute the shortest path required to get to that location by analysing various sensor data. This is the drone's decision-making brain.
regulates and controls the speed of an electric motor. It may also be capable of motor reversing and dynamic braking. In electrically driven radio controlled models, miniature electronic speed controllers are used.

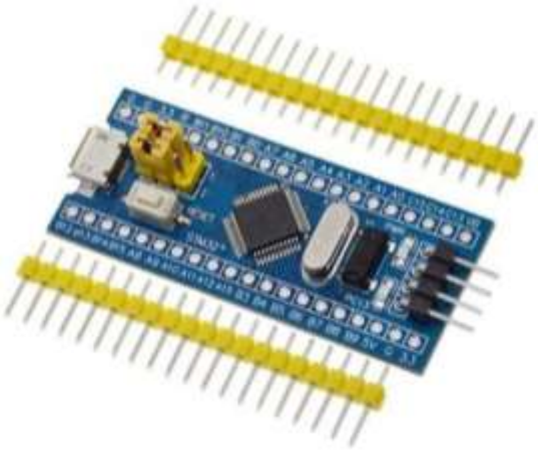
VII. CONTROLLER/IC

A) KK 2.1.5 Multi rotor Flight Control Board

- Size: 50.5mm x 50.5mm x 12mm
- Weight: 21 gram (Inc. Piezo buzzer)
- IC: Atmega644 PA
- Gyro/Acc: 6050MPU
- Auto-level: Yes
- Input Voltage: 4.8-6.0V
- AVR interface: standard 6 pin.
- Signal from Receiver: 1520us (5 channels)

- Signal to ESC: 1520us

B) Flight computer STM32 :



- STM32F401CC in UFQFPN48 package
- ARM® 32-bit Cortex®-M4 MCU withFPU
- 84MHz max MCU frequency
- VDD from 1.7 V to 3.6 V
- 256 KB FLASH
- 64 KB SRAM
- General Purpose Timers
- Watchdog Timers (2)
- On board sensors:
- 3D Accelerometer and 3D Gyroscope: LSM6DSL
- 3D Magnetometer:LIS2MDL
- MEMS Pressure sensor:LPS22HD
- 2 User LEDS
- USART/UART (1)
- I2C (1)
- Firmware Version 1.6
- Bluetooth LE over SPI

VIII. IMPLEMENTATION

- To provide drones with a destination point
- Viewing the drone's camera view
- Tracking the drone's progress to its destination

We also completed the hardware simulation (ROS + VREP).

Choosing components:

Since we're developing an autopilot drone, the first thing it should do is fly, we'll need to find appropriate propellers and motors to provide the necessary torque. As a result, we initially computed the approximate weight of our drone bytaking into account the following component weights:

component	Weight in gm	quantity	Total weight
BLDC motors (1400KV)	60	4	240
LIPO Battery	200	1	200
frame	600	1	600

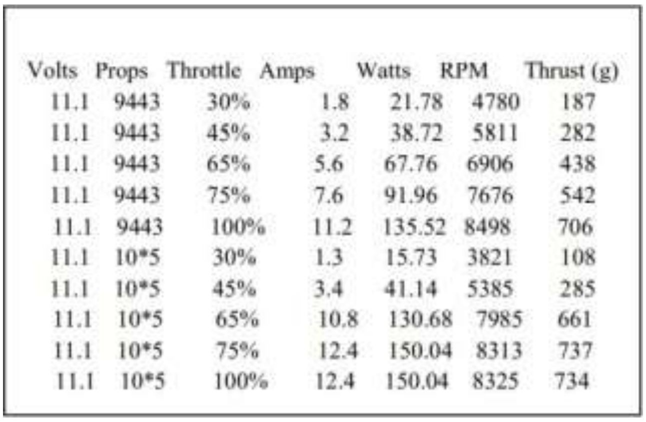
propellers	3.5	4	14 ~ = 15
Flite controller +flite computer	50	2	100
ESC	35	4	140

Total = 1300 gm

As a result, every general-purpose drone may require some additional mountings, therefore based on an approximate weight of 700 gm, our ultimate drone weight became 2000 gm = 2kg.

As a result, we should consider propellers that create 2000/4(4 propellers) 500gm thrust to lift our drone.

Selection of Propellers:



Volts	Props	Throttle	Amps	Watts	RPM	Thrust (g)
11.1	9443	30%	1.8	21.78	4780	187
11.1	9443	45%	3.2	38.72	5811	282
11.1	9443	65%	5.6	67.76	6906	438
11.1	9443	75%	7.6	91.96	7676	542
11.1	9443	100%	11.2	135.52	8498	706
11.1	10*5	30%	1.3	15.73	3821	108
11.1	10*5	45%	3.4	41.14	5385	285
11.1	10*5	65%	10.8	130.68	7985	661
11.1	10*5	75%	12.4	150.04	8313	737
11.1	10*5	100%	12.4	150.04	8325	734

The above chart from reference [9] and above calculations we can confirm that the propeller of **size 10*5** is best

BLDC motor selection:

From above calculations of propeller we require minimum rpm of 7985 ~ =8000+1000=9000 and as we have battery of 11.1V as we are considering 9V as output

KV rating for BLDC=9000/9=1000 KV

As we require minimum of 1000 KV rating we are approximating it at **1400KV**

Frame selection:

as we have propeller of 10*5 that means diameter of 10 inch and pitch of 5 inch by considering clearance of 2 inch

⇨ 10+1=11inch

As 1 inch = 2.54cm

⇨ 12*2.54=27.94 cm

So we need minimum of **28 cm** gap in between adjacent propellers

We can get this specification in F540 Quadcopter.

IX. LIST OF COMPONENTS

Sr. No.	component	Component name		
1	Frame	F450 Quadcopter Frame 4-Axis	1	680
2	BLDC Motors	A2212 10T 1400KV Brushless Motor	4	340
3	ESC	ReadytoSky 40A 2-4S ESC	4	560
4	Propeller	Orange HD Propellers 1045(10X4.5) pair	2	260
5	Flight controller	KK 2.1.5 Multi-Rotor LCD Flight Control Board	1	1850
6	accelerometer	MPU 6000/MPU 6050	1	778
7	Power distribution board	PDB-XT60 with BEC 5V and 12V	1	490
8	RC receiver	Fly Sky FS-CT6B 6-Channel 2.4 Ghz	1	2249
9	RC controller			
10	Battery	Orange 11.1V 3S LiPo Drone Battery	1	1400
11	Flight computer	stm32	1	780
12	ultrasonic	ultrasonic sensor	4	75
		Total = 12383		

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