AUTONOMOUS AGRICULTURAL MULTIROTOR- A.G. DRONE

A PROJECT REPORT

Submitted by

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in partial fulfillment for the award of the degree

of

BACHELOR OF ENGINEERING

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY

COIMBATORE-641049

(An Autonomous Institution Affiliated to Anna University, Chennai)

APRIL 2015

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BONAFIDE CERTIFICATE

Certified that this project report titled **"AUTONOMOUS AGRICULTURAL MULTIROTOR- A.G DRONE"** is the bonafied work of "**VIGNESH SRINIVAS, THIRUCHITRAMBALAM.K, VENGATESSH.R"** who carried out the project work under my supervision.

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

ACKNOWLEDGEMENT

First we would like to express our praise and gratitude to the Lord, who has showered his grace and blessing enabling us to complete this project in an excellent manner. He has made all things in beautiful in his time.

We express our sincere thanks to our beloved Joint Correspondent, **Shri. Shankar Vanavarayar** for his kind support and for providing necessary facilities to carry out the project work.

We would like to express our sincere thanks to our beloved Principal, **Dr. R. S. Kumar M.E., Ph. D.,** who encouraged us with his valuable thoughts.

We would like to express our sincere thanks and deep sense of gratitude to our HOD, **Dr. Rajeswari Mariappan M.E., Ph. D.,** for her valuable suggestions and encouragement which paved way for the successful completion of the project.

We are greatly privileged to express our deep sense of gratitude to the Supervisor **Mr. S. Govindaraju M.E.**, Professor, for his continuous support throughout the course.

In particular, We wish to thank and express our everlasting gratitude to the Coordinator **Ms. A. Kalaiselvi M.E., (Ph. D)**, Assistant Professor for her expert counselling in each and every steps of project work and we wish to convey our deep sense of gratitude to all teaching and non-teaching staff members of ECE Department for their help and cooperation.

Finally, we thank our parents and our family members for giving us the moral support in all of our activities and our dear friends who helped us to endure our difficult times with their unfailing support and warm wishes.

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ABSTRACT

A quadcopter aka quadrotor is an Micro aerial vehicle (which comes under the category UAV) and has 4 rotors with one pair of props rotating in clockwise direction and the other pair in anticlockwise direction to compensate the gyroscopic effect on the body of the aircraft. The AGdrone is a Quadcopter that is built with capabilities of Autonomous inflight stabilization user manual guided navigation and autonomous navigation using GPS co-ordinates or GPS waypoints, it is equipped with an array of sensors which include MPU 6050 (accelerometer + gyro) Barometer, GPS, and magnetometer and uses Beaglebone black for processing. AGdrone is also equipped with a spraying mechanism which uses a brass nozzle to spray pesticides and is equipped with a camera to enable real time video streaming for crop monitoring by the farmer. The real time video streaming is used to identify areas of the crop affected by the pests or diseases and areas that are suffering from water shortage or drought and areas that are waterlogged. Based on the GPS waypoints provided the AGdrone navigates autonomously to those waypoints while spraying the liquid payload it is carrying.

INTRODUCTION

CHAPTER 1

INTRODUCTION

A quadcopter, also called a helicopter or quadrotor, is a multirotor helicopter that is lifted and propelled by four rotors. Quadcopters are classified as rotorcraft, as opposed to fixed-wing aircraft, because their lift is generated by a set of rotors (vertically orientedpropellers).

Unlike most helicopters, quadcopters use two sets of identical fixed pitched propellers; two clockwise (CW) and two counter-clockwise (CCW). These use variation of RPM to control lift and torque. Control of vehicle motion is achieved by altering the rotation rate of one or more rotor discs, thereby changing its torque load and thrust/lift characteristics.

Early in the history of flight, quadcopter (referred to as 'quadrotor') configurations were seen as possible solutions to some of the persistent problems in vertical flight; torque-induced control issues (as well as efficiency issues originating from the tail rotor, which generates no useful lift) can be eliminated by counter-rotation and the relatively short blades are much easier to construct. A number of manned designs appeared in the 1920s and 1930s. These vehicles were among the first successful heavier-than-air vertical take off and landing (VTOL) vehicles. However, early prototypes suffered from poor performance, and latter prototypes required too much pilot work load, due to poor stability augmentation and limited control authority.

More recently quadcopter designs have become popular in unmanned aerial vehicle (UAV) research. These vehicles use an electronic control system and electronic sensors to stabilize the aircraft. With their small size and agile maneuverability, these quadcopters can be flown indoors as well as outdoors.

There are several advantages to quadcopters over comparably-scaled helicopters. First, quadcopters do not require mechanical linkages to vary the rotor blade pitch angle as they spin. This simplifies the design and maintenance of the vehicle. Second, the use of four rotors allows each individual rotor to have a smaller diameter than the equivalent helicopter rotor, allowing them to possess less kinetic energy during flight. This reduces the damage caused should the rotors hit anything. For small-scale UAVs, this makes the vehicles safer for close interaction. Some small-scale quadcopters have frames that enclose the rotors, permitting flights through more challenging environments, with lower risk of damaging the vehicle or its surroundings.

Due to their ease of both construction and control, quadcopter aircraft are frequently used as amateur model aircraft projects.

Recent developments

In the last few decades, small scale unmanned aerial vehicles (UAVs) have become more commonly used for many applications. The need for aircraft with greater maneuverability and hovering ability has led to current rise in quadcopter research. The four-rotor design allows quadcopters to be relatively simple in design yet highly reliable and maneuverable. Cutting-edge research is continuing to increase the viability of quadcopters by making advances in multi-craft communication, environment exploration, and maneuverability. If all of these developing qualities can be combined together, quadcopters would be capable of advanced autonomous missions that are currently not possible with any other vehicle.

Some current programs include:

- The Bell Boeing Quad TiltRotor concept takes the fixed quadcopter concept further by combining it with the tilt rotor concept for a proposed C-130 sized military transport.

Flying prototype of the Parrot AR.Drone

Parrot AR.Drone 2.0 take-off, Nevada, 2012

- The Aermatica Spa Anteos was the first rotary wing RPA (remotely piloted aircraft) to obtain official permission to fly in the civil airspace, by the Italian Civil Aviation Authority (ENAC), and will be the first able to work in non segregated airspace.
- AeroQuad and ArduCopter are open-source hardware and software projects based on Arduino for the DIY construction of quadcopters.
- Parrot AR.Drone is a small radio controlled quadcopter with cameras attached to it built by Parrot SA, designed to be controllable with by smartphones or tablet devices.
- Nixie is a small camera-equipped drone that can be worn as a wrist band.

Research platform

Quadcopters are a useful tool for university researchers to test and evaluate new ideas in a number of different fields, including flight control theory, navigation, real time systems, and robotics. In recent years many universities have shown quadcopters performing increasingly complex aerial manoeuvres. Swarms of quadcopters can hover in mid-air, in formation, autonomously perform complex flying routines such as flips, darting through hula-hoops and organising themselves to fly through windows as a group.

There are numerous advantages to using quadcopters as versatile test platforms. They are relatively cheap, available in a variety of sizes and their simple mechanical design means that they can be built and maintained by amateurs. Due to the multi-disciplinary nature of operating a quadcopter, academics from a number of fields need to work together in order to make significant improvements to the way quadcopters perform. Quadcopter projects are typically collaborations between computer science, electrical engineering and mechanical engineering specialists.

Because they are so manoeuvrable, quadcopters could be useful in all kinds of situations and environments. Quadcopters capable of autonomous flight could help remove the need for people to put themselves in any number of dangerous positions. This is a prime reason that research interest has been increasing over the years.

There are several engineering research laboratories currently developing more advanced control techniques and applications for quadcopters. These include mainly MIT's Aerospace Controls Lab, ETH's Flying Machine Arena, and University of Pennsylvania's General Robotics, Automation, Sensing and Perception (GRASP) Lab.

Military and law enforcement

Quadcopter unmanned aerial vehicles are used for surveillance and reconnaissance by military and law enforcement agencies, as well as search and rescue missions in urban environments. One such example is the Aeryon Scout, created by Canadian company Aeryon Labs, which is a small UAV that can quietly hover in place and use a camera to observe people and objects on the ground. The company claims that the machine played a key role in a drug bust in Central America by providing visual surveillance of a drug trafficker's compound deep in the jungle (Aeryon won't reveal the country's name and other specifics).

Commercial use

An example of a commercially produced, camera-equipped, radio-controlled quadcopter. It is battery-operated and includes an HD video recorder.

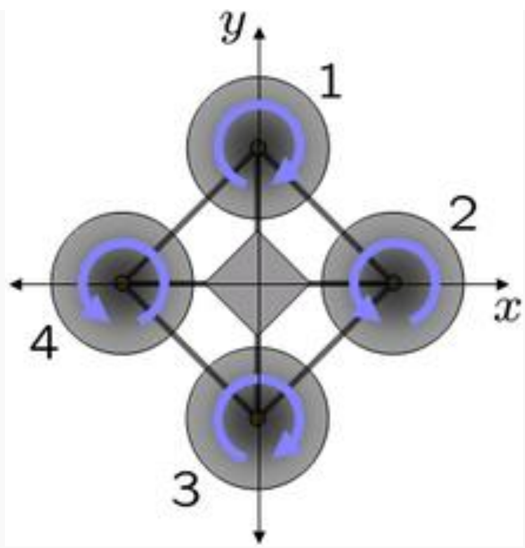
The largest use of quadcopters in the USA has been in the field of aerial imagery. Quadcopter UAVs are suitable for this job because of their autonomous nature and huge cost savings. In the USA, the legality of the use of remotely controlled aircraft for commercial purposes has been a matter of debate. The FAA's stance from 2006 has been that such commercial activity is illegal. However on March 6, 2014, in a court case between Pirker and the FAA, a judge ruled against the FAA's claims, effectively affirming that model aircraft are not covered by the FAA rules.

In December 2014, the FAA released a video detailing many best practices for new drone pilots, including advisories such as keeping their machines below 400 feet and always within visual sight.

In December 2013, the Deutsche Post gathered international media attention with the project Parcelcopter, in which the company tested the shipment of medical products by drone-delivery. Using aMicrodrones md4-1000 quadrocopter packages were flown from a pharmacy across the Rhine River. It was the first civilian package-delivery via drones.

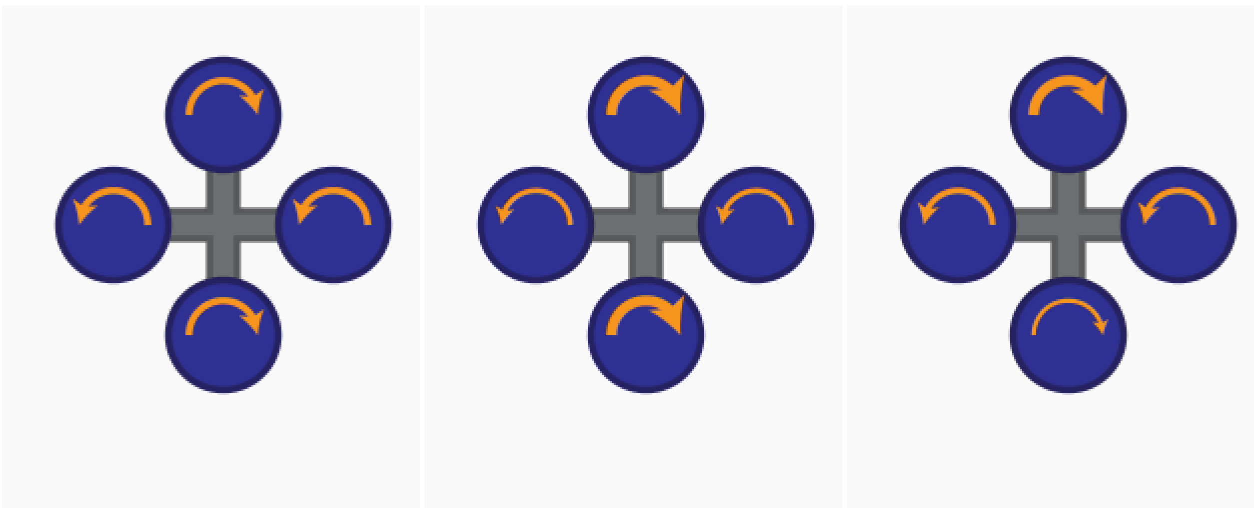
As quadcopters are becoming less expensive media outlets and newspapers are using drones to capture photography of celebrities.

Flight Control:



Schematic of reaction torques on each motor of a quadcopter aircraft, due to spinning rotors. Rotors 1 and 3 spin in one direction, while rotors 2 and 4 spin in the opposite direction, yielding opposing torques for control.

Each rotor produces both a thrust and torque about its center of rotation, as well as a drag force opposite to the vehicle's direction of flight. If all rotors are spinning at the same angular velocity, with rotors one and three rotating clockwise and rotors two and four counterclockwise, the net aerodynamic torque, and hence the angular acceleration about the yaw axis, is exactly zero, which implies that the yaw stabilizing rotor of conventional helicopters is not needed. Yaw is induced by mismatching the balance in aerodynamic torques (i.e., by offsetting the cumulative thrust commands between the counter-rotating blade pairs).



1.1 BLOCK DIAGRAM

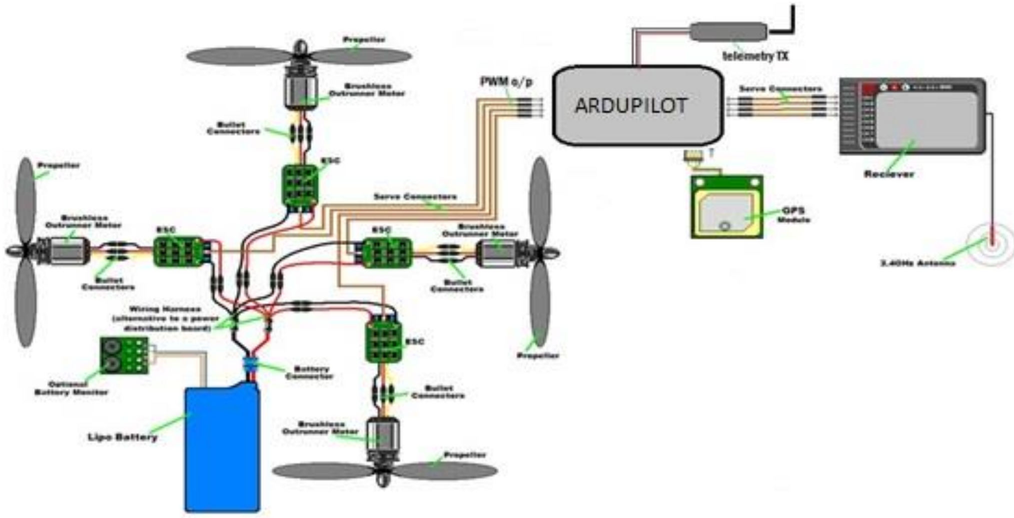
Our system consists of 4 motors, 4 electronic speed control units, 1 lithium polymer battery, 1 ardupilot flight controller board, 1 GPS module and 1 telemetry unit (i.e transmitter and receiver). The propellers are attached to the motors which in turn are connected to an electronic speed control unit individually. All the four separate connections are given a power supply from a lithium polymer battery supply. The motors and the electronic speed control units are controlled by the ardupilot which is the brain of the entire system. An external GPS module has been included in the circuit to provide the gobal positioning data to the flight controller board. The ardupilot based on the gyro signals namely roll, pitch and yaw gives the control conditions to the electronic speed control units, thereby comtrolling the the thrust provided by the motors. The entire system's connection is communicated wirelessly to the user through the telemetry unit.

The use of four rotors allows each individual rotor to have a smaller diameter than the equivalent helicopter rotor, allowing them to possess less kinetic energy during flight. Each rotor produces both a thrust and torque about its center of rotation, as well as a drag force opposite to the vehicle's direction of flight. If all rotors are spinning at the same angular velocity, with rotors one and three rotating clockwise and rotors two and four counterclockwise, the net aerodynamic torque, and hence the angular acceleration about the yaw axis, is exactly zero, implying the take off of the quadcopter.

(APM) is a professional quality IMU autopilot that is based on the Arduino Mega platform. This autopilot can control fixed-wing aircraft, multi-rotor helicopters, as well as traditional helicopters. It is a full autopilot capable of autonomous stabilization, way point based navigation and two way telemetry with xbee wireless modules. Supporting 8 RC channels with 4 serial ports

Electronic speed control or ESC is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake. ESCs are often used on electrically powered radio controlled models, with the variety most often used for brushless motors essentially providing an electronically generated three-phase electric power low voltage source of energy for the motor.

<u>Figure 1</u>



Description:

- Ardupilot- Flight controller board; brain of the entire system.
- Motors & propellers- Used to provide the lift off for the quadcopter.
- Battery- Used to provide power to the entire setup.
- Electronic Speed Control- Used to control the power distributed to the motors based on the signals given by the flight controller board.
- Gps- Provides the global positioning data to the flight controller board.
- Telemetry- Provides the wireless connection between the the quadcopter and user.

HARDWARE DESCRIPTION

CHAPTER 2

2.1 Kk (2.0) MULTI-ROTOR CONTROLLER BOARD

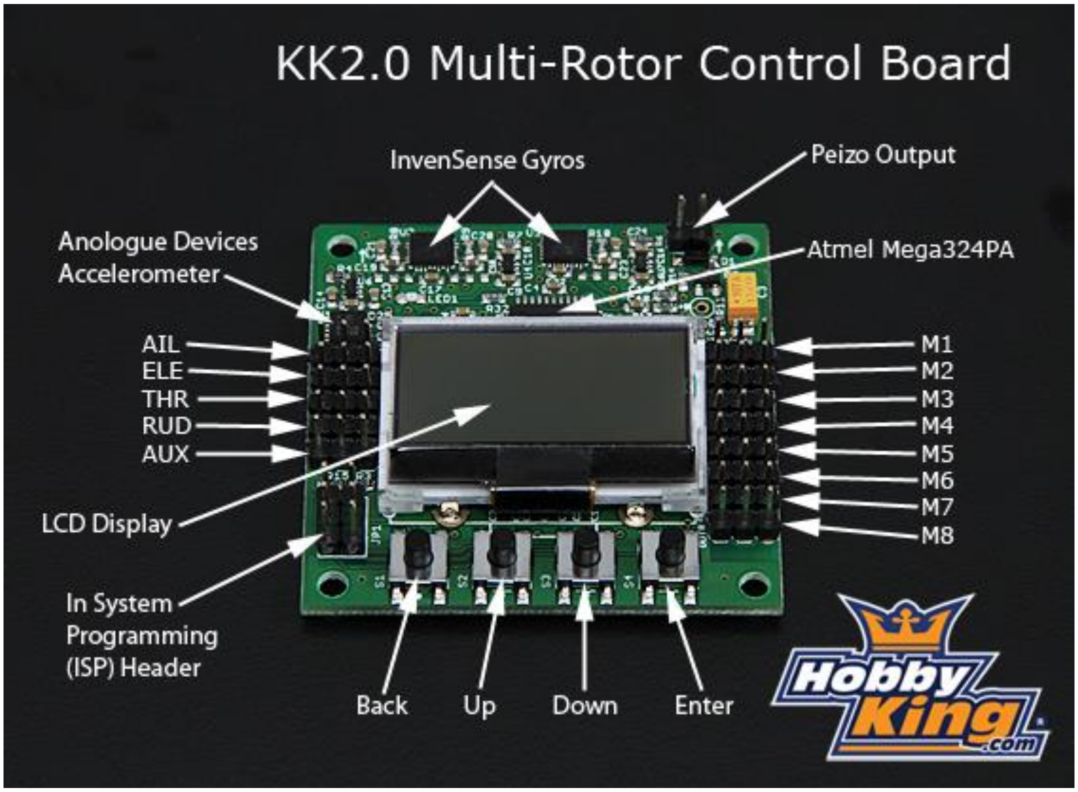
The KK 2.0 Flight Control Board is an inexpensive option for controlling a multi-rotor craft. Its purpose is to stabilize the aircraft during flight. To do this it takes the signal from the three on board gyros (roll, pitch and yaw) then passes the signal to the Atmega324PA IC. The Atmega324PA IC unit then processes these signals according the users selected firmware and passes control signals to the installed Electronic Speed Controllers (ESCs). These signals instruct the ESCs to make fine adjustments to the motors rotational speed which in turn stabilizes your multi-rotor craft.

The KK2.0 Multi-Rotor control board also uses signals from your radio systems receiver (Rx) and passes these signals to the Atmega324PA IC via the ail, ele, thr and rud inputs. Once this information has been processed the IC will send varying signals to the ESCs which in turn adjust the rotational speed of each motor to induce controlled flight (up, down, backwards, forwards, left, right, yaw).

Specification:

- **Size:** 50.5mm x 50.5mm x 12mm
- **Weight:** 21 gram *(including piezo buzzer)*
- **IC:** Atmega324 PA
- **Gyro:** InvenSense Inc.
- **Accelerometer:** Anologue Devices Inc.
- **Auto-level:** Yes
- **Input Voltage:** 4.8-6.0V
- **AVR interface:** standard 6 pin.
- **Signal from Receiver:** 1520us (5 channels)
- **Signal to ESC:** 1520us

Figure 2


KK2.0 Multi-Rotor Control Board
InvenSense Gyros
Peizo Output
Anologue Devices Accelerometer
Atmel Mega324PA
AIL
ELE
THR
RUD
AUX
M1
M2
M3
M4
M5
M6
M7
M8
LCD Display
In System Programming (ISP) Header
Back
Up
Down
Enter
HobbyKing.com

2.2 ARDUPILOT

The APM 2.6 is a complete open source autopilot system and the bestselling technology that won the prestigious 2012 Outback Challenge UAV competition. It allows the user to turn any fixed, rotary wing or multirotor vehicle (even cars and boats) into a fully autonomous vehicle; capable of performing programmed GPS missions with waypoints.

This revision of the board has no onboard compass, which is designed for vehicles (especially multicopters and rovers) where the compass should be placed as far from power and motor sources as possible to avoid magnetic interference. APM 2.6 is designed to be used with the 3DR uBlox GPS with Compass, so that the GPS/Compass unit can be mounted further from noise sources.

(APM) is a professional quality IMU autopilot that is based on the Arduino Mega platform. This autopilot can control fixed-wing aircraft, multi-rotor helicopters, as well as traditional helicopters. It is a full autopilot capable of autonomous stabilization, way point based navigation and two way telemetry with xbee wireless modules. Supporting 8 RC channels with 4 serial ports

APM 2.6 requires a GPS unit with an onboard compass or an external compass module for full autonomy. If you are using APM 2.6 with a GPS module that does not have a compass sensor, you must use a stand-alone external compass.

System components

- A Pixhawk, APM2 or PX4 autopilot loaded with the latest version of the ArduCopter firmware
- Mission Planner software — gives you an easy point-and-click setup/configuration, and a full-featured ground control interface.
- A suitable MultiCopter or Helicopter for your mission.
- Plus many other useful options: e.g. data radios, which allow two-way wireless telemetry and control between the vehicle and your computer.

FEATURES:

- Full mission scripting with point-and-click desktop utilities
- Can support hundreds of 3D waypoints
- Two-way telemetry and in-flight command using the powerful MAVLink protocol
- Choice of free Ground Stations, including the state-of-the-art HK GCS, which includes mission planning, in-air parameter setting, on-board video display, voice synthesis, and full datalogging with replay.
- Autonomous takeoff, landing and special action commands such as video and camera controls
- Supports full "hardware-in-the-loop" simulation with Xplane and Flight Gear
- 4MB of onboard data-logging memory. Missions are automatically datalogged and can be exported to KML
- Built-in hardware failsafe processor, can return-to-launch on radio loss.

Figure 3

2.3 BRUSHLESS MOTORS

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. Additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent of DC bus usage/efficiency) and frequency (i.e. rotor speed).

The rotor part of a brushless motor is often a permanent magnet synchronous motor, but can also be a switched reluctance motor, or induction motor.

Brushless motors may be described as stepper motors; however, the term stepper motor tends to be used for motors that are designed specifically to be operated in a mode where they are frequently stopped with the rotor in a defined angular position.

Brushless motors can be constructed in several different physical configurations: In the 'conventional' (also known as inrunner) configuration, the permanent magnets are part of the rotor. Three stator windings surround the rotor. In the outrunner (or external-rotor) configuration, the radial-relationship between the coils and magnets is reversed; the stator coils form the center (core) of the motor, while the permanent magnets spin within an overhanging rotor which surrounds the core. The flat or axial flux type, used where there are space or shape limitations, uses stator and rotor plates, mounted face to face. Outrunners typically have more poles, set up in triplets to maintain the three groups of windings, and have a higher torque at low RPMs. In all brushless motors, the coils are stationary.

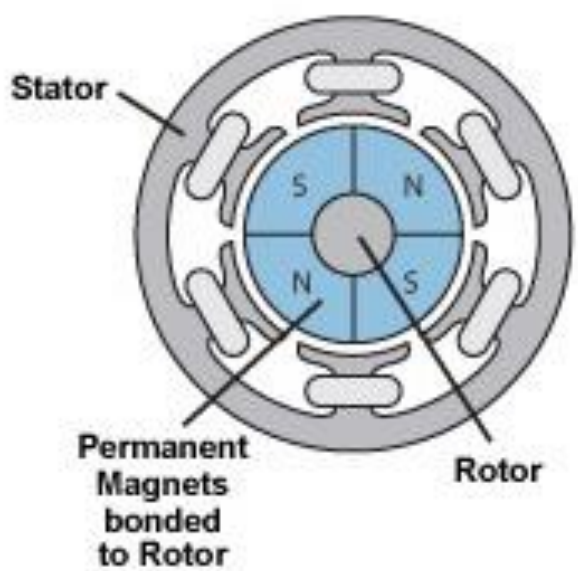
There are two common electrical winding configurations; the delta configuration connects three windings to each other (series circuits) in a triangle-like circuit, and power is applied at each of the connections. The Wye (Y-shaped) configuration, sometimes called a star winding, connects all of the windings to a central point (parallel circuits) and power is applied to the remaining end of each winding.

A motor with windings in delta configuration gives low torque at low speed, but can give higher top speed. Wye configuration gives high torque at low speed, but not as high top speed.

Although efficiency is greatly affected by the motor's construction, the Wye winding is normally more efficient. In delta-connected windings, half voltage is applied across the windings adjacent to the driven lead (compared to the winding directly between the driven leads), increasing resistive losses. In addition, windings can allow high-frequency parasitic electrical currents to circulate entirely within the motor. A Wye-connected winding does not contain a closed loop in which parasitic currents can flow, preventing such losses.

From a controller standpoint, the two styles of windings are treated exactly the same.

Figure 4



The Brushless DC (BLDC) motor is the ideal choice for applications that require high reliability, high efficiency, and high power-to-volume ratio. Generally speaking, a BLDC motor is considered to be a high performance motor that is capable of providing large amounts of torque over a vast speed range. BLDC motors are a derivative of the most commonly used DC motor, the brushed DC motor, and they share the same torque and speed performance curve characteristics. The major difference between the two is the use of brushes. BLDC motors do not have brushes (hence the name “brushless DC”) and must be electronically commutated.

Commutation is the act of changing the motor phase currents at the appropriate times to produce rotational torque. In a brush DC motor, the motor assembly contains a physical commutator which is moved by means of actual brushes in order to move the rotor. With a BLDC motor, electrical current powers a permanent magnet that causes the motor to move, so no physical commutator is necessary.

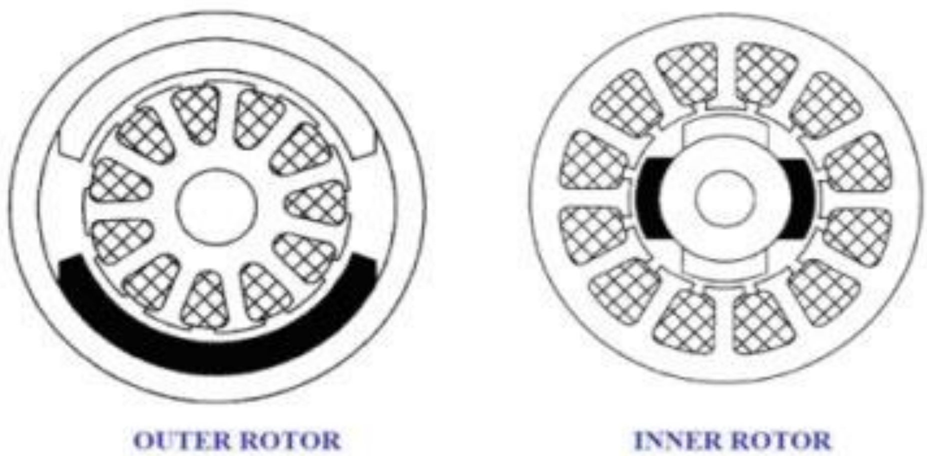
A BLDC motor is highly reliable since it does not have any brushes to wear out and replace. When operated in rated conditions, the life expectancy is over 10,000 hours. For long term applications, this can be a tremendous benefit. Whenever a motor breaks down or needs to be replaced, your project, or part of it, must be shut down. This costs you time and money, perhaps a great deal depending on how long it takes to replace the worn part or parts and get the application started again. Although a BLDC motor may cost more than a brushless motor, it will often more than pay for itself in the amount of work time saved.

BLDC Motor Construction and Operating Theory

To understand why a BLDC motor is so effective, it’s important to have a good understanding of how it works. There are actually two different types, with different benefits and drawbacks. While either one will probably be effective for most jobs, you may wish to familiarize yourself with both types, just in case one would be more appropriate for your project or application than the other.

Any BLDC motor has two primary parts; the rotor, the rotating part, and the stator, the stationary part. Other important parts of the motor are the stator windings and the rotor magnets.

There are two basic BLDC motor designs: **inner rotor and outer rotor design**.



In an outer rotor design, the windings are located in the core of the motor. The rotor magnets surround the stator windings as shown here. The rotor magnets act as an insulator, thereby reducing the rate of heat dissipation from the motor. Due to the location of the stator windings, outer rotor designs typically operate at lower duty cycles or at a lower rated current. The primary advantage of an outer rotor BLDC motor is relatively low cogging torque.

In an inner rotor design, the stator windings surround the rotor and are affixed to the motor's housing as shown here. The primary advantage of an inner rotor construction is its ability to dissipate heat. A motor's ability to dissipate heat directly impacts its ability to produce torque. For this reason, the overwhelming majority of BLDC motors use an inner rotor design. Another advantage of an inner rotor design is lower rotor inertia.

BLDC Motor Advantages:

If you’re still not sure whether or not this motor is right for you, here is a basic breakdown of some of the primary advantages of the BLDC motor.

- High Speed Operation – A BLDC motor can operate at speeds above 10,000 rpm under loaded and unloaded conditions.
- Responsiveness & Quick Acceleration – Inner rotor Brushless DC motors have low rotor inertia, allowing them to accelerate, decelerate, and reverse direction quickly.
- High Power Density – BLDC motors have the highest running torque per cubic inch of any DC motor.
- High Reliability – BLDC motors do not have brushes, meaning they are more reliable and have life expectancies of over 10,000 hours. This results in fewer instances of replacement or repair and less overall down time for your project.

DYS 2826-13 1000kv Brushless Motor for X-copter Quadcopter

Description:

- Weight: 50g
- For 3D plane flying weight including battery of approx. 340-454g/12-16oz.
- or normal flying weight of approx. 340-680g/12-24oz.
- 3s battery will give you more rpm/more power(volts x amps = watts).
- Max Thrust 660g/23.28oz with 11.1v & 1050 prop.

Specification:

- Model No.: 2826-13
- Rpm/V: 1000 KV
- Weight: 50g
- Motor Dimensions: Φ27.7*26.3mm
- Shaft Size: Φ3.17*37mm
- Battery Opernating: 2-3 Lipo
- Idle current: 0.5A
- Load current: 7.2A
- Power (Watt): 100
- ESC(A): 30A
- Ri(M Ω): 0.13
- Prop/recom: 9x6/9x3.8/10x50

Optional Accessories below are not included.

- Prop: 1050(10"x5 pitch).
- ESC: 20-30A
- Battery: 2s-3s/7.4v-11.1v Lipo; 1300-2200mAh 15C or higher, I would use 3s 1300-1800mAh for 12oz 3D, 1800-2200mAh for 16oz 3D.

Figure 5

2.4 ELECTRONIC SPEED CONTROLLER

Electronic speed control or ESC is an electronic circuit with the purpose to vary an electric motor's speed, its direction and possibly also to act as a dynamic brake. ESCs are often used on electrically powered radio controlled models, with the variety most often used for brushless motors essentially providing an electronically generated three-phase electric power low voltage source of energy for the motor.

An ESC can be a stand-alone unit which plugs into the receiver's throttle control channel or incorporated into the receiver itself, as is the case in most toy-grade R/C vehicles. Some R/C manufacturers that install proprietary hobby-grade electronics in their entry-level vehicles, vessels or aircraft use onboard electronics that combine the two on a single circuit board.

Function:

Regardless of the type used, an ESC interprets control information not as mechanical motion as would be the case of a servo, but rather in a way that varies the switching rate of a network of field effect transistors, or FETs. The rapid switching of the transistors is what causes the motor itself to emit its characteristic high-pitched whine, especially noticeable at lower speeds. It also allows much smoother and more precise variation of motor speed in a far more efficient manner than the mechanical type with a resistive coil and moving arm once in common use.

Most modern ESCs incorporate a battery eliminator circuit (or BEC) to regulate voltage for the receiver, removing the need for separate receiver batteries. BECs are usually either linear or switched mode voltage regulators.

DC ESCs in the broader sense are PWM controllers for electric motors. The ESC generally accepts a nominal 50 Hz PWM servo input signal whose pulse width varies from 1 ms to 2 ms. When supplied with a 1 ms width pulse at 50 Hz, the ESC responds by turning off the DC motor attached to its output. A 1.5 ms pulse-width input signal drives the motor at approximately half-speed. When presented with 2.0 ms input signal, the motor runs at full speed.

Brushless ESC:

ESC systems for brushed motors are very different by design; as a result brushed ESC's are not compatible with brushless motors. Brushless ESC systems basically drive tri-phase brushless motors by sending a sequence of signals for rotation. Brushless motors, otherwise called outrunners or inrunners, have become very popular with radio controlled airplane hobbyists because of their efficiency, power, longevity and light weight in comparison to traditional brushed motors. However, brushless AC motor controllers are much more complicated than brushed motor controllers.

The correct phase varies with the motor rotation, which is to be taken into account by the ESC: Usually,back EMF from the motor is used to detect this rotation, but variations exist that use magnetic (Hall Effect) or optical detectors. Computer-programmable speed controls generally have user-specified options which allow setting low voltage cut-off limits, timing, acceleration, braking and direction of rotation. Reversing the motor's direction may also be accomplished by switching any two of the three leads from the ESC to the motor.

Specification:

- Running current:30A (Output: Continuous 30A, Burst 40A up to 10 Secs.)
- Input Voltage: 2-5S Lipo / 5-12 cell NiMh
- BEC: 2A / 5V (Linear mode)
- Size: 46mm (L) * 26mm (W) * 11mm (H)
- Weight: 23g
- With SimonK updated firmware for multicopter

Features:

1) Drive tube and high-power Mos, and Mos tube plus a separate heat sink, Extreme low output resistance of the PCB(printed circuit board), super current endurance.

2) The power input uses extreme low output resistance greatly enhance the power

stability, and has the protective effect on the battery.

3) Safety electrical function: when the power is turned on, regardless of the throttle stick in any position does not start the motor immediately, to avoid personal injury.

4) Separate voltage regulator IC for microprocessor. providing good anti-jamming capability.

5) Supported motor speed (Maximum): 210000 RPM (2 poles), 70000 RPM (6 poles)

ESC Firmware:

Most modern ESC contain a microcontroller interpreting the input signal and appropriately controlling the motor using a built in program, or firmware. In some cases it is possible to change the factory built-in firmware for an alternate, publicly available, open source firmware. This is done generally to adapt the ESC to a particular application. Some ESCs are factory built with the capability of user upgradable firmware. Others require soldering to connect a programmer.

Figure 6


dys
30A
BEC 5V/2Amp
2-5LiPo/ 5-12 NiMh
Programmable ESC V2
For Multicopter Brushless Motor Using Only
A
B
C

2.5 LIPO BATTERY

A lithium polymer battery, or more correctly lithium-ion polymer battery (abbreviated variously as LiPo, LIP, Li-poly and others), is a rechargeable battery of lithium-ion technology in a pouch format. Unlike cylindrical and prismatic cells, LiPos come in a soft package or pouch, which makes them lighter but also lack rigidity.

The denomination “lithium polymer” has caused confusion among battery users. It may be interpreted in two ways. Originally, “lithium polymer” stood for a developing technology using a polymer electrolyte instead of the more common liquid electrolyte. The result is a “plastic” cell, which theoretically could be thin, flexible, and manufactured in different shapes, without risk of electrolyte leakage. This technology has not been fully developed and commercialized, and research is ongoing.

The second meaning appeared when some manufacturers started applying the “polymer” denomination to lithium-ioncells in pouch format. This is the most extended use nowadays, where “polymer” went from indicating a “polymer electrolyte” to mean a “polymer casing”, that is, the soft, external pouch. While the design is usually flat, and lightweight, it is not a true polymer cell, as the electrolyte is still in liquid form, albeit it may be “plasticized” or “gelled” through a polymer additive. These cells are sometimes known as “LiPo”, however, from the technological point of view, they are the same as the ones marketed simply as “Li-ion”, as the underlying electrochemistry is the same.

The name “lithium polymer” (LiPo) is more widespread among users of radio-controlled models, where it may indicate a single cell or a battery pack with cells connected in series or parallel. The more general term “lithium-ion” (Li-ion) is used almost everywhere else, including consumer electronics such as mobile phones and notebook computers, and battery electric vehicles.

The polymer hype of the early 2000s is still going strong, but most users cannot distinguish between a regular Li-ion and one with polymer architecture. While many people identify the term “polymer” as a “plastic,” polymers range from synthetic plastics to natural biopolymers and proteins that are from a fundamental biological structure.

Lithium-polymer differs from other battery systems in the type of electrolyte used. The original polymer design dating back to the 1970s used a solid (dry) polymer electrolyte that resembles a plastic-like film. This insulator allows the exchange of ions (electrically charged atoms) and replaces the traditional porous separator that is soaked with electrolyte. A solid polymer has a poor conductivity at room temperature and the battery must be heated to 60°C (140°F) and higher to enable current flow. The much anticipated “true plastic battery” promised in the early 2000s did not materialize as the conductivity could not be attained at ambient temperature.

To make the modern Li-polymer battery conductive at room temperature, gelled electrolyte has been added. All Li-ion polymer cells today incorporate a micro porous separator with some moisture. Li-polymer can be built on many systems, such as Li-cobalt, NMC, Li-phosphate and Li-manganese, and is not considered unique battery chemistry. Most Li-polymer packs are for the consumer market.

With gelled electrolyte added, what is the difference between a normal Li ion and Li ion polymer? As far as the user is concerned, lithium polymer is essentially the same as lithium-ion. Both systems use identical cathode and anode material and contain a similar amount of electrolyte. Li-polymer is unique in that a micro porous electrolyte replaces the traditional porous separator. Li-polymer offers slightly higher specific energy and can be made thinner than conventional Li-ion.

Li-polymer cells also come in a flexible foil-type case (polymer laminate or pouch cell) that resembles a food package. While a standard Li-ion needs a rigid case to press the electrodes together, Li-polymer uses laminated sheets that do not need compression. A foil-type enclosure reduces the weight by more than 20 percent over the classic hard shell. Thin film technology liberates design as the battery can be made into any shape, fitting neatly into stylish mobile phones and laptops. Li-polymer can also be made very slim to resemble a credit card. [BU-301a: Types of Battery Cells]

Charge and discharge characteristics of Li-polymer are identical to other Li-ion systems and do not require a special charger. Safety issues are also similar in that protection circuits are needed. Gas buildup during charge can cause some prismatic and pouch cells to swell and equipment manufacturers must make allowances for expansion. Li-polymer in a foil package may be less durable than Li-ion in the cylindrical package.

Solid Electrolyte with Lithium-metal Batteries

Research with the solid electrolyte (SE) continues and attempts are made by using metallic lithium as anode material. Solid lithium has a higher energy density than in modified lithium-ion form, but lithium anodes have been tried before and battery manufacturers were forced to discontinue production because of safety issues. Lithium tends to form metal filaments, or dendrites, that cause short circuits. Scientists are trying to overcome this invasion by using specially designed separators and other remedies.

The key objectives for the so-called "solid state lithium ion battery" are achieving sufficient conductivity at room temperature and below and delivering a high enough cycle count, a weak point with most new battery designs. Prototypes of the solid state lithium ion only reach 100 cycles. Targeted applications are load 37evelling for renewable energy source and fulfilling the need for personal transportation in cars that are non-polluting, charge in minutes and do not prompt range anxiety. Commercialization can take 10 years or longer.

Working Principle:

Just as with other lithium-ion cells, LiPos work on the principle of intercalation and de-intercalation of lithium ions from a positive electrode material and a negative electrode material, with the liquid electrolyte providing a conductive medium. To prevent the electrodes from touching each other directly, a microporous separator is in between which allows only the ions and not the electrode particles to migrate from one side to the other.

Charging:

Just as with other kinds of lithium-ion cells, the voltage of a LiPo cell depends on its chemistry and varies from about 2.7-3.0 V (discharged) to about 4.20-4.35 V (fully charged), for cells based on lithium-metal-oxides (such as $LiCoO_2$), and around 1.8-2.0 V (discharged) to 3.6-3.8 V (charged) for those based on lithium-iron-phosphate ($LiFePO_4$).

The exact voltage ratings should be specified in product data sheets, with the understanding that the cells should be protected by an electronic circuit that won't allow them to overcharge nor over-discharge under use.

For LiPo battery packs with cells connected in series, a specialised charger may monitor the charge on a per-cell basis so that all cells are brought to the same state of charge (SOC).

Specification:

Minimum Capacity: **2200mAh (True 100% Capacity)**
Configuration: **3S1P / 11.1v / 3Cell**
Constant Discharge: **20C**
Peak Discharge (10sec): **30C**
Pack Weight: **188g**
Pack Size: **103 x 33 x 24mm**
Charge Plug: **JST-XH**
Discharge Plug: **XT60**

Capacity(mAh)	2200
Config (s)	3
Discharge ©	20
Weight (g)	188
Max Charge Rate ©	2
Length-A(mm)	103
Height-B(mm)	33
Width-C(mm)	24

Figure 7

2.6 REMOTE CONTROLLER

In consumer electronics, a remote control is a component of an electronic device, used to operate the device wirelessly from a short distance. Remote control is a convenience feature for the consumer, and can allow operation of devices that are out of convenient reach for direct operation of controls.

Commonly, remote controls are Consumer IR devices which send digitally-coded pulses of infrared radiation to control functions such as power, volume, tuning, temperature set point, fan speed, or other features. Remote controls for these devices are usually small wireless handheld objects with an array of buttons for adjusting various settings. For many devices, the remote control contains all the function controls while the controlled device itself has only a handful of essential primary controls.

Transmitter Specification:

*Channels：6

*Charger port: Yes

*Frequency band: 2.4GHz

*Simulator port: PS-2

*Power resource：1.5V

*Program type: GFSK

*Modulation type:FM

*RF power：19db

*Static current：≤250Ma

*Voltage display type：LED

*Size：189*97*218mm

*Weigth: 575g

*Color: black

*Antenna length：26mm

*Heli-140/Heli-120/Heli-90/Acro

*Thro Cuv: Programmable

*Pith Cuv: Programmable

*Support multiple user model

*Support trim movement

*Support rudder angle overturned

*Support rudder angle adjustment

*Support both hand software adjustment

*Support swashplate adjustment

*Support programmable channel output

*Channels：6 (Pitch curve)

Reciever Specification:

*Frequency band: 2.4GHz

*Power resource：1.5V

*4 “AA”Battery

*Program type: GFSK

*Modulation type: FM

*RF Receiver sensitivity：-76db

*Static current：≤85mA

*Size：45*23*13.5mm

*Size：25*16.8*6.5mm

*Weigth: 12g

*Color: Gray semi-transparent

Figure 8

SOFTWARE DESCRIPTION

CHAPTER 3

3.1 MISSION PLANNER

Mission Planner is a ground control station for APM:Plane, APM:Copter and APM:Rover. It is compatible with Windows only. Mission Planner can be used as a configuration utility or as a dynamic control supplement for your autonomous vehicle.

Algorithm:

Step 1: Download the mission planner software an install it in the host computer.

Step 2: Start the mission planner software.

Step 3: Connect the ardupilot board to the mission planner software using mavlink.

Step 4: Load the firmware (the software) into the autopilot (APM, PX4…) that controls your vehicle.

Step 5: Setup, configure, and tune your vehicle for optimum performance.

Step 6: Plan, save and load autonomous missions into you autopilot with simple point-and-click way-point entry on Google or other maps.

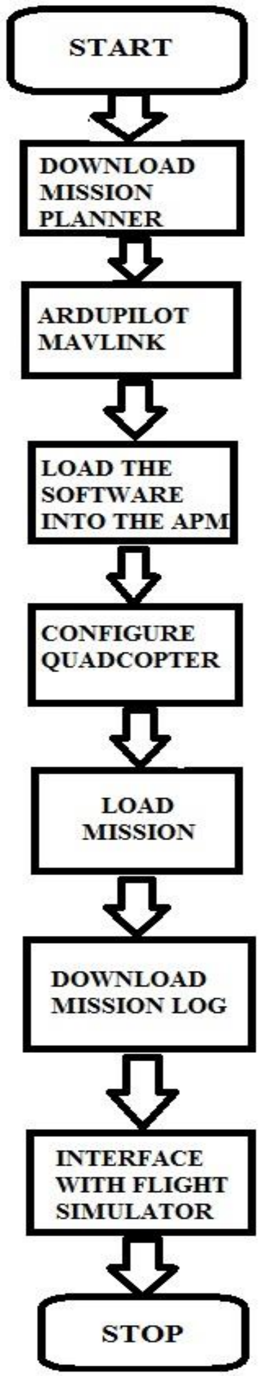
Step 7: Download and analyze mission logs created by your autopilot.

Step 8: Interface with a PC flight simulator to create a full hardware-in-the-loop UAV simulator.

With appropriate telemetry hardware you can:

- Monitor your vehicle's status while in operation.
- Record telemetry logs which contain much more information the the on-board autopilot logs.
- View and analyze the telemetry logs.
- Operate your vehicle in FPV (first person view)

Flow Chart:


START
DOWNLOAD MISSION PLANNER
ARDUPILOT MAVLINK
LOAD THE SOFTWARE INTO THE APM
CONFIGURE QUADCOPTER
LOAD MISSION
DOWNLOAD MISSION LOG
INTERFACE WITH FLIGHT SIMULATOR
STOP

Initially download the mission planner software an install it in the host computer. One the software has been installed, open the mission planner software,now Connect the ardupilot board to the mission planner software using a micro usb wire to the host computer, then click on the mavlink connection in the mission planner software. Then load the firmware (the software) coding into the autopilot (APM, PX4…) that controls your vehicle using the mavlink. The firmware downloaded into the ardupilot provide te desing parameters for the quadcopter. Now setup, configure, and tune your vehicle for optimum performance. Plan, save and load autonomous missions into you autopilot with simple point-and-click way-point entry on Google or other maps. By choosing the waypoint for the copter we can autonomously make it fly without the aid of an external remote control. Download and analyze mission logs created by your autopilot. Finally, interface with a PC flight simulator to create a full hardware-in-the-loop UAV simulator.

Figure 10


FLIGHT DATA
FLIGHT PLAN
INITIAL SETUP
CONFIG/TUNING
SIMULATION
TERMINAL
HELP
DONATE
COM3
115200
CONNECT
DISARMED
timeInAir: 00:00:00
GPS: No GPS
Quick
Actions
Status
Servo
Telemetry Logs
Altitude (m)
0.00
GroundSpeed (m/s)
0.00
Dist to WP (m)
0.00
Yaw (deg)
0.00
Vertical Speed (m/s)
0.00
Distance to Home (m)
0.00
hdop: 0.0
Sats: 0
Current Heading
Direct to current WP
Target Heading
GPS Track (Black)
GEO
0.000000 0.000000 0.00
Tuning
Auto Pan
Zoom
1.9

3.2 SOFTWARE CODING FOR THE QUADCOPTER

```
#include <math.h>
#include <stdio.h>
#include <AP_GPS.h>            // ArduPilot GPS library
#include <DataFlash.h>         // ArduPilot Mega Flash Memory Library
#include <AP_Compass.h>        // ArduPilot Mega Magnetometer Library
#include <AP_Math.h>           // ArduPilot Mega Vector/Matrix math Library
#include <AP_Curve.h>          // Curve used to linearlise throttle pwm to thrust
#include <AP_InertialSensor.h>  // ArduPilot Mega Inertial Sensor (accel & gyro)
Library
#include <AP_Mission.h>        // Mission command library
#include <AC_PosControl.h>      // Position control library
#include <RC_Channel.h>        // RC Channel Library
#include <AP_Motors.h>         // AP Motors library

// key aircraft parameters passed to multiple libraries
static AP_Vehicle::MultiCopter aparm;

// Local modules
#include "Parameters.h"
// Heli modules


static AP_GPS  gps;

// flight modes convenience array
static AP_Int8 *flight_modes = &g.flight_mode1;

static AP_Baro barometer;

static Compass compass;

AP_InertialSensor ins;

// Inertial Navigation EKF
#if AP_AHRS_NAVEKF_AVAILABLE
```

```
AP_AHRS_NavEKF ahrs(ins, barometer, gps);
#else
AP_AHRS_DCM ahrs(ins, barometer, gps);
#endif

#if CONFIG_HAL_BOARD == HAL_BOARD_AVR_SITL
SITL sitl;
#endif



////////////////////////////////////////////////////////////////////////////////
// Radio
////////////////////////////////////////////////////////////////////////////////
// This is the state of the flight control system
// There are multiple states defined such as STABILIZE, ACRO,
static int8_t control_mode = STABILIZE;
// Structure used to detect changes in the flight mode control switch
static struct {
    int8_t debounced_switch_position;   // currently used switch position
    int8_t last_switch_position;        // switch position in previous iteration
    uint32_t last_edge_time_ms;         // system time that switch position was last
changed
} control_switch_state;

static RCMapper rcmap;

// board specific config
static AP_BoardConfig BoardConfig;

// receiver RSSI
static uint8_t receiver_rssi;

////////////////////////////////////////////////////////////////////////////////
// Failsafe
////////////////////////////////////////////////////////////////////////////////

static struct {
    uint8_t rc_override_active  : 1; // 0   // true if rc control are overwritten by ground
station
```

```
    uint8_t radio              : 1; // 1   // A status flag for the radio failsafe
    uint8_t battery            : 1; // 2   // A status flag for the battery failsafe
    uint8_t gcs                : 1; // 4   // A status flag for the ground station failsafe
    uint8_t ekf                : 1; // 5   // true if ekf failsafe has occurred

    int8_t radio_counter;                  // number of iterations with throttle below
throttle_fs_value

    uint32_t last_heartbeat_ms;            // the time when the last HEARTBEAT
message arrived from a GCS – used for triggering gcs failsafe
} failsafe;

////////////////////////////////////////////////////////////////////////////////
// Motor Output
////////////////////////////////////////////////////////////////////////////////

#if FRAME_CONFIG == QUAD_FRAME
 #define MOTOR_CLASS AP_MotorsQuad
#endif

////////////////////////////////////////////////////////////////////////////////
// GPS variables
////////////////////////////////////////////////////////////////////////////////

// We use atan2 and other trig techniques to calaculate angles
// We need to scale the longitude up to make these calcs work
// to account for decreasing distance between lines of longitude away from the
equator
static float scaleLongUp = 1;
// Sometimes we need to remove the scaling for distance calcs
static float scaleLongDown = 1;

////////////////////////////////////////////////////////////////////////////////
// Location & Navigation
////////////////////////////////////////////////////////////////////////////////

// This is the angle from the copter to the next waypoint in centi-degrees
static int32_t wp_bearing;
// The location of home in relation to the copter in centi-degrees
static int32_t home_bearing;
```

```
// distance between plane and home in cm
static int32_t home_distance;
// distance between plane and next waypoint in cm.
static uint32_t wp_distance;
static uint8_t land_state;            // records state of land (flying to location,
descending)

////////////////////////////////////////////////////////////////////////////////
// Auto
////////////////////////////////////////////////////////////////////////////////

static AutoMode auto_mode;   // controls which auto controller is run


////////////////////////////////////////////////////////////////////////////////
// SIMPLE Mode
////////////////////////////////////////////////////////////////////////////////
// Used to track the orientation of the copter for Simple mode. This value is reset at
each arming
// or in SuperSimple mode when the copter leaves a 20m radius from home.
Static float simple_cos_yaw = 1.0;
static float simple_sin_yaw;
static int32_t super_simple_last_bearing;
static float super_simple_cos_yaw = 1.0;
static float super_simple_sin_yaw;


// Stores initial bearing when armed – initial simple bearing is modified in super
simple mode so not suitable
static int32_t initial_armed_bearing;

////////////////////////////////////////////////////////////////////////////////
// Throttle variables
////////////////////////////////////////////////////////////////////////////////

static float throttle_average;            // estimated throttle required to hover
static int16_t desired_climb_rate;         // pilot desired climb rate – for logging
purposes only

////////////////////////////////////////////////////////////////////////////////
```

```
// Inertial Navigation
////////////////////////////////////////////////////////////////////////////////
static AP_InertialNav_NavEKF inertial_nav(ahrs);

////////////////////////////////////////////////////////////////////////////////

// Attitude, Position and Waypoint navigation objects
// To-Do: move inertial nav up or other navigation variables down here

////////////////////////////////////////////////////////////////////////////////

#if FRAME_CONFIG == QAUAD_FRAME
AC_AttitudeControl_Heli attitude_control(ahrs, aparm, motors, g.p_stabilize_roll,
g.p_stabilize_pitch, g.p_stabilize_yaw,
                        g.pid_rate_roll, g.pid_rate_pitch, g.pid_rate_yaw);
#else
AC_AttitudeControl attitude_control(ahrs, aparm, motors, g.p_stabilize_roll,
g.p_stabilize_pitch, g.p_stabilize_yaw,
                        g.pid_rate_roll, g.pid_rate_pitch, g.pid_rate_yaw);
#endif

////////////////////////////////////////////////////////////////////////////////
```

WORKING

CHAPTER 4

4.1 MARKET ANALYSIS

Existing Solutions:

Manned planes:

This is a high risk method of spraying pesticides, high risk both in terms of low altitude high speed flying and exposure to toxic chemicals that are being sprayed. Moreover this method can be used only to spray the chemicals and not monitor the entire crop spread area.

Figure 11

Researchers found that the combined exposure to ziram, maneb and paraquat near any workplace increased the risk of Parkinson's disease threefold, while combined exposure to ziram and paraquat alone was associated with an 80 percent increase in risk.

Yamaha RMAX:

There are more than 2,500 Yamaha RMAX helicopters in use over 2.5 million acres of rice fields in America. Pilotless choppers are also well on their way to being approved for use in Australia, mainly for weed control.

Figure 12

The RMAX is equipped with one 8-liter tank on either side of the fuselage, giving it the capacity to carry slightly more than 4 gallons of liquid before having to be refilled. At full spray it can operate for about 10 to 15 minutes and cover about four to 12 acres per hour, which makes it obviously faster than a tractor. The helicopter is operated by a two-person team – a controller and spotter – who must pass written tests and be FAA certified.)

Disadvantages faced by existing solutions:

i) Manned plane:

1) High cost
2) Pilot license and training needed
3) Applies only for large scale spraying
4) They do not provide aerial video streaming
5) Maintenance cost high
6) Requires constant communication with air traffic control
7) not autonomous, flies under pilot control

ii) Yamaha RMAX :

1) two men crew (operator + spotter) needed
2) high cost
3) requires extensive special training
4) needs FAA and similar aviation authority approval
5) High fuel consumption and pollution

6) applies to medium to large area fields only
7) not autonomous, flies under operator control

Proposed solution:

An autonomous agricultural quadcopter with two main applications in mind which are autonomous pesticide or chemical spraying and crop monitoring through real time aerial video streaming and autonomous navigation using GPS co-ordinates or GPS waypoints

Advantages of our solution:

1) Autonomous operation
2) Ease of operation
3) Low cost
4) No extensive or special training required
5) Improved and autonomous flight stability
6) Features position hold, altitude hold and an array of flight modes
7) Live aerial video streaming
8) Can be upgraded for thermal imaging and infrared imaging and night vision
9) Applies to small, medium and large crop area operation
10) Electric powered, no emission
11) Can fly for 30 minutes uninterrupted

4.2 PROJECT EXECUTION PLAN

i) Proposal to prototype:

- we are going to build a small scaled version of our original product
- Initially we will control it with a controller in order to achieve optimum design and function.
- The prototype will be tested on a farm land to check if it serves the desired application.

ii) Prototype to product:

- Based on the results from our prototype we will design our original product.
- We will make the product autonomous.
- Check if stability control is maintained in the autonomous flight.
- A comparison will be plotted for, efficiency of AUTOMOUS flight (vs) efficiency of REMOTE CONTROLLED flight.

QUADCOPTER

Figure 13

CONCLUSION

CHAPTER 5

Result:

The hardware components were interfaced as per the block diagram into a single working system. The kk 2.0 flight controller was programmed and calibrated to work as required by the user. A flying quadcopter which is controlled by a remote transmitter held by the user was achieved. The ardupilot board calibration was not successful, though the coding for the system was successful on compilation, as a result autonomous flight was not achieved, thereby impedeing the progress any further. Agricultural farming will be completely revolutionzed by incorporating digital image processing, wherein the quadcopter will no longer need the user's continuous monitoring and will autonomously be able to detect pest affected crops and apply the required pesticide using its own artificial intelligence.

REFERENCES

1) UNMANNED AERIAL VEHICLE “RC QUADCOPTER”
International Journal of Students Research in Technology & ManagementVol 1(3), May 2013, ISBN 978-93-83006-01-4, pg 339-341

2) QUADCOPTER CONTROL IN THREE DIMENSIONAL SPACE
Karl LaFleur *et al* 2013 *J. Neural Eng.* 10 046003
Received 10 March 2013, accepted for publication 2 May 2013
Published 4 June 2013

3) QUADCOPTER FOR AGRICULTURAL SURVEILLANCE
Parth N. Patel1 , Malav A. Patel2 , Rahul M. Faldu3 and Yash R. Dave4
Advance in Electronic and Electric Engineering. ISSN 2231-1297, Volume 3, Number 4 (2013), pp. 427-432 © Research India Publications

4) STARTUP GUIDE FOR ARDUPILOT
http://copter.ardupilot.com/wiki/introduction/quick-start-guide/

5) CODE BASE FOR ARDUPILOT
https://github.com/diydrones/ardupilot

6) LEARN HOW TO BUILD A QUADCOPTER
https://www.hoverflytech.com

7) APM 2.5 CONTROLLER BASIC SETUP GUIDE
https://www.unmannedtechshop.co.uk/fea...

8) YAMAHA ROVER CORPORATION
rmax.yamaha-motor.com.au