GOVERNMENT POLYTECHNIC, GONDIA

REPORT ON

“QUAD-COPTER”

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1. ABSTRACT

The project goal was to design a semi-autonomous Quadcopter capable of self-sustained flight via wireless communications while utilizing a microcontroller. The Quadcopter was designed to be small enough so that costs would be minimized, which is why small motors and propellers are being used. While a PIC microcontroller, accelerometer, and gyroscope are communicating between each other to maintain control.

The scheduler program arranges the following tasks: controller input, sensor data received from the accelerometer, Gyroscope, and Magnetometer. The wireless transceivers use SPI to send control signals to the microcontroller on the quadcopter from the handheld controller unit. The accelerometer/gyroscope and magnetometer both use I2C to send the amount of acceleration, stabilization, and the direction vector. The motors are being controlled by the PWM ports on the PIC microcontroller.

To achieve flight, two of the motors must apply downward force and the other two motors have to apply an upward force. To turn, one pair (left or right side) of motors slows down to turn the copter. To ascend, all motors will increase in speed, and will all decrease in order to descend. To move forward, the front two motors will decrease while the back two motors will increase. And vice versa in order to move in a backwards direction.

Figure: QUAD-COPTER

2. INTRODUCTION

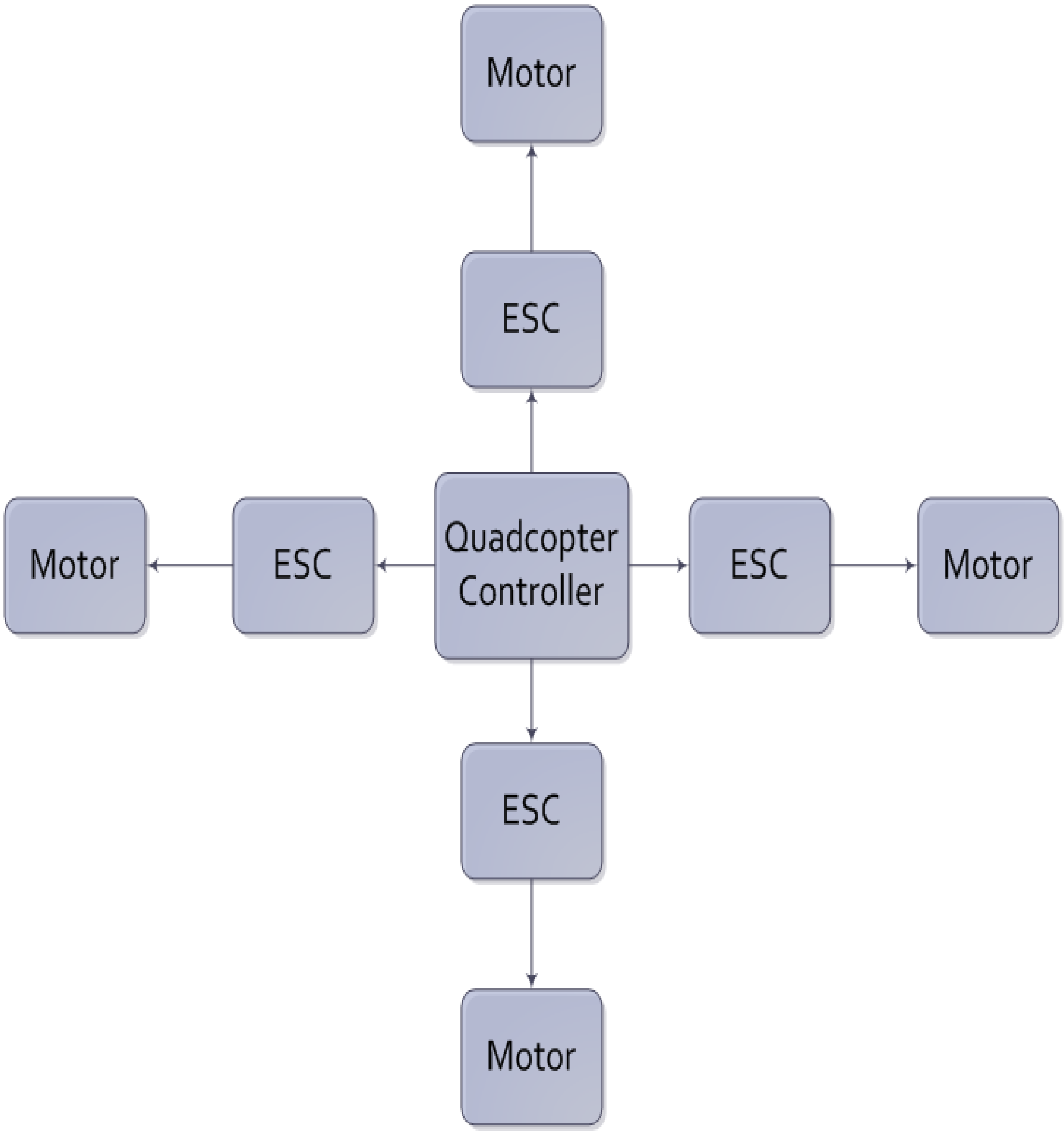
The multirotor helicopter also knows as quad rotor is equipped with four rotors to create lift. It is a true helicopter in that lift force is created by narrow chord horizontally rotating air foils. The quadcopter existence since the 1920s when early manned version named the De Bothezat helicopter was build and successfully flown. First developed and prototypes under U.S. Army contract with the De Bothezat.

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 itstorque load and thrust/lift characteristics.

Early in the history of flight, quadcopter (then 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.

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.

3. BLOCK DIAGRAM



4. QUAD-COPTER MOVEMENT

An aircraft in flight is free to rotate in three dimensions: pitch, nose up or down about an axis running from wing to wing; yaw, nose left or right about an axis running up and down; and roll, rotation about an axis running from nose to tail. The axes are alternatively designated as lateral, vertical, and longitudinal. These axes move with the vehicle and rotate relative to the Earth along with the craft. These definitions were analogously applied to spacecraft when the first manned spacecraft were designed in the late 1950s.

These rotations are produced by torques (or moments) about the principal axes. On an aircraft, these are produced by means of moving control surfaces, which vary the distribution of the net aerodynamic force about the vehicle'scenter of mass. Elevators (moving flaps on the horizontal tail) produce pitch, arudder on the vertical tail produces yaw, and ailerons (flaps on the wings that move in opposing directions) produce roll. On a spacecraft, the moments are usually produced by a reaction control system consisting of small rocket thrusters used to apply asymmetrical thrust on the vehicle.

In order to fully understand airplane flight dynamics, it is necessary to discuss three physical axes and the three rotations associated with those axes. A light general aviation (GA) airplane with its longitudinal axis running fore and aft through the fuselage. The lateral axis is perpendicular and in the same plane as the longitudinal axis and runs through the wing, intersecting with the longitudinal axes at the CG. The third axes, called the vertical axes, is perpendicular to the other to and also goes through the CG. The three rotational motion associated with each of this axes are describe.

Actual flight path turns are a combination roll and yaw rotation that results pilot initiated motion both the aileron and rudder control surfaces. The quad copter diagrammed in the figure is in X configuration, which is discussed in next section. However, it makes no difference how a quad copter is configured the pitch, roll, and yaw rotation motions will always be the same for each axis.

It would be useful now to describe how airplane flight controls function before describing how the quadcopter flight path controlled. The reason is simply that the radio-controlled (R/C) system is set for controlling the quadcopter, and it is important you to know the “translation” that takes place when you input a control command. For purpose of this discussion, your attention should be focus on the yoke, rudder pedals, and throttle of plane.

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NAME	AXIS	DESCRIPTION
PITCH	Lateral	Rotation around the lateral axis that results in climb or descent
ROLL	Longitudinal	Rotation around the longitudinal axis that results in straight line roll but no turn to either side
YAW	Vertical	Rotation around the vertical axis that results in a turn to left or right

3.1 Vertical axis (yaw)

The vertical yaw axis is defined to be perpendicular to the wings with its origin at the center of gravity and directed towards the bottom of the aircraft. Yaw moves the nose of the aircraft from side to side. A positive yaw, or heading angle, moves the nose to the right. The rudder is the primary control of yaw

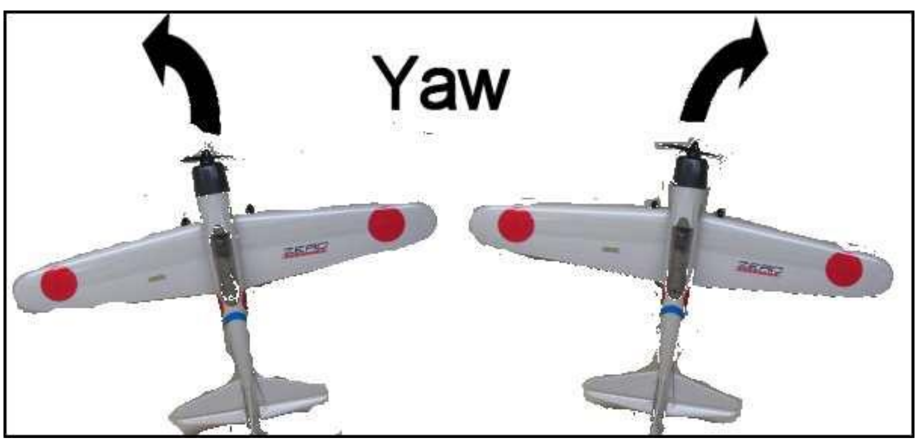


Figure : YAW movement

3.2 Lateral axis (pitch)

The pitch axis (also called lateral or transverse axis) passes through the plane from wingtip to wingtip. Pitch moves the aircraft's nose up and down. A positive pitch angle raises the nose and lowers the tail. The elevators are the primary control of pitch.

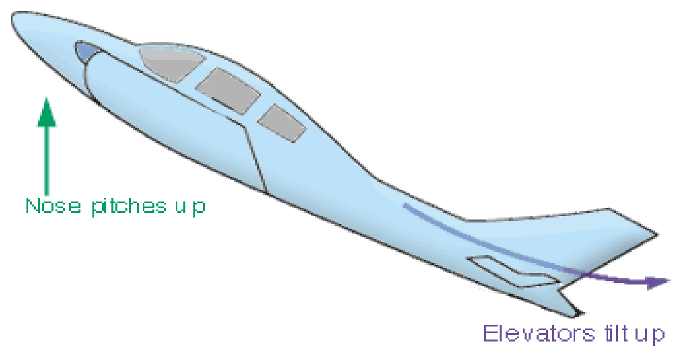


Figure: PITCH movement

3.3 Longitudinal (roll)

The roll axis (or longitudinal axis) passes through the plane from nose to tail. The angular displacement about this axis is called bank.The pilot changes bank angle by increasing the lift on one wing and decreasing it on the other. A positive roll angle lifts the left wing and lowers the right wing. The ailerons are the primary control of bank. The rudder also has a secondary effect on bank.

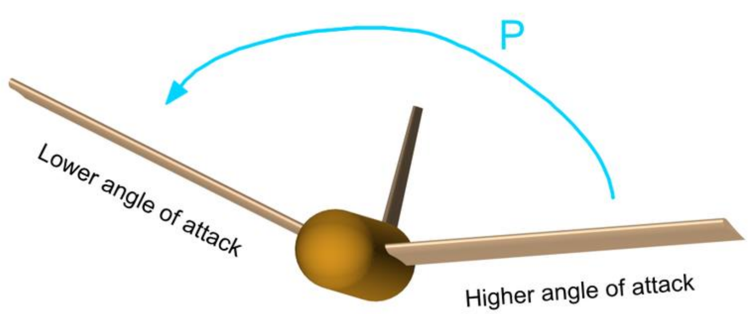


Figure : ROLL movement

5. BRUSHLESS MOTOR

Brushless DC electric motor (BLDC motors, BL motors) also known aselectronically commutated motors (ECMs, EC motors) are synchronous motorsthat 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. This page describes more general brushless motor principles, though there is overlap.

Brushed DC motors develop a maximum torque when stationary, linearly decreasing as velocity increases. Some limitations of brushed motors can be overcome by brushless motors; they include higher efficiency and a lower susceptibility to mechanical wear. These benefits come at the cost of potentially less rugged, more complex, and more expensive control electronics.

A typical brushless motor has permanent magnets which rotate around a fixed armature, eliminating problems associated with connecting current to the moving armature. An electronic controller replaces the brush/commutator assembly of the brushed DC motor, which continually switches the phase to the windings to keep the motor turning. The controller performs similar timed power distribution by using a solid-state circuit rather than the brush/commutator system.

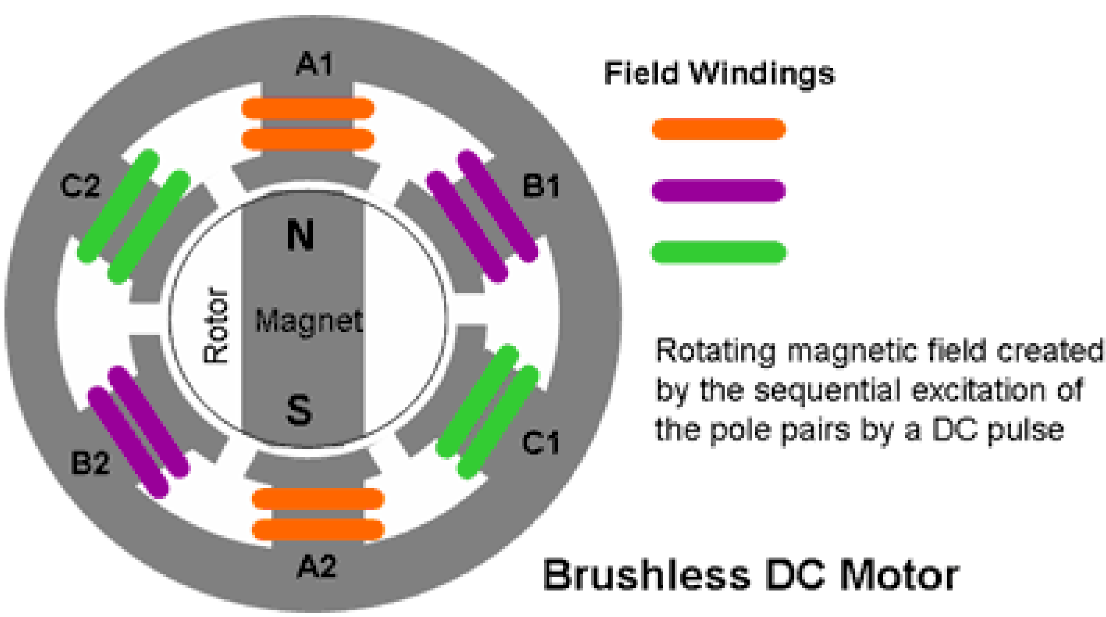
Brushless motors offer several advantages over brushed DC motors, including high torque to weight ratio, more torque perwatt (increased efficiency), increased reliability, reduced noise, longer lifetime (no brush and commutator erosion), elimination of ionizing sparks from the commutator, and overall reduction of electromagnetic interference (EMI). With no windings on the rotor, they are not subjected to centrifugal forces, and because the windings are supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling.

This in turn means that the motor's internals can be entirely enclosed and protected from dirt or other foreign matter.

Brushless motor commutation can be implemented in software using a microcontroller or microprocessor computer, or may alternatively be implemented in analogue hardware, or in digital firmware using an FPGA. Commutation with electronics instead of brushes allows for greater flexibility and capabilities not available with brushed DC motors, including speed limiting, "micro stepped" operation for slow and/or fine motion control, and a holding torque when stationary.

The maximum power that can be applied to a brushless motor is limited almost exclusively by heat; too much heat weakens the magnets and may damage the winding's insulation.

When converting electricity into mechanical power, brushless motors are more efficient than brushed motors. This improvement is largely due to the brushless motor's velocity being determined by the frequency at which the electricity is switched, not the voltage. Additional gains are due to the absence of brushes, which reduces mechanical energy loss due to friction. The enhanced efficiency is greatest in the no-load and low-load region of the motor's performance curve. Under high mechanical loads, brushless motors and high-quality brushed motors are comparable in efficiency.



6. ELECTRONIC SPEED CONTROL

An 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 powerlow 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.

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.

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.

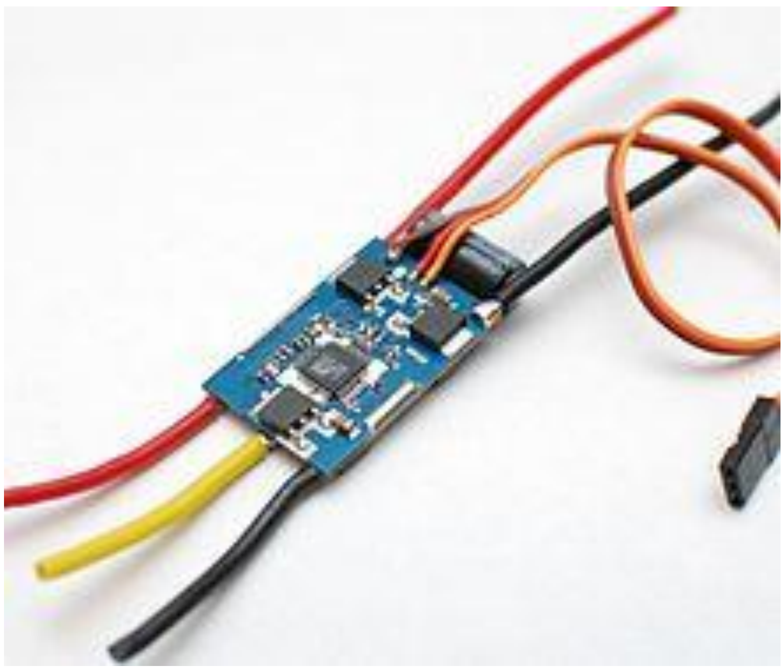


Figure : Electronic speed control

7. PROPELLER

A propeller is a type of fan that transmits power by converting rotational motion into thrust. A pressure difference is produced between the forward and rear surfaces of the airfoil-shaped blade, and a fluid (such as air or water) is accelerated behind the blade.

An aircraft propeller or airscrew converts rotary motion from a piston engine, a turboprop or an electric motor, to provide propulsive force. Its pitchmay be fixed or variable. Early aircraft propellers were carved by hand from solid or laminated wood, while later propellers were constructed of metal. Modern designs use high-technology composite materials.

The propeller attaches to the crankshaft of a piston engine, either directly or through a reduction unit. A light aircraft engine may not require the complexity of gearing, which is essential on a larger engine or on a turboprop aircraft.

A well-designed propeller typically has an efficiency of around 80% when operating in the best regime.The efficiency of the propeller is influenced by the angle of attack (α). This is defined as $\alpha = \Phi - \theta$, where θ is the helix angle (the angle between the resultant relative velocity and the blade rotation direction) and Φ is the blade pitch angle. Very small pitch and helix angles give a good performance against resistance but provide little thrust, while larger angles have the opposite effect. The best helix angle is when the blade is acting as a wing producing much more lift than drag. Angle of attack is similar to advance ratio, for propellers.

Figure : Propellers

8. 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 less rigid.

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. These batteries are available although the 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-ion cells 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.

Figure : Battery

9. ADVANTAGES

- Small scale UAV’S makes the vehicles safer for close interactions.
- Quad copters do not require mechanical linkages to vary the rotor blade pitch angle as they spin.
- This implies the design and maintenance of the vehicle.
- The use of four rotors allows each individual rotor to have smaller diameter than the equivalent

10. DISADVANTAGES

- The most significant problem to date have been an ambitious development schedule coupled with very limited funds.
- The ambition is followed by complexity in calculation and designing.

11. REFERENCE

LINKS

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- www.instructables.com/id/Scratch-**build**-your-own-quad-copter/
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- www.popularmechanics.com/.../whats-so-great-about-**brushless**-motor-p
- www.**propeller**.se/

BOOK

- “Build your own Quad Copter” by Donald Norris