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Design and Development of Quad copter for Surveillance

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Abstract: In the past decade unmanned aerial vehicle (UAVs) has become a topic of interest in many research organizations. UAV can engage in finding unusual objects and they can perform the surveillance. Unmanned Aerial Vehicle (UAVs) is controlled from the control room. Now a day's UAVs used in many sector like rescue, coast guard, Fire departments, Hospitality, Construction, etc. The project exposes that the UAV is controlled to surveillance the desired location and the information of the location and the activities are sending through the mini cam built in the UAV. The capturing clips are simultaneously displayed in the connected computer according to the command. The received Clips of the surveillance location is also been saved. The receiver in the controller fetches the commands and they act according to that. Quad copter can be controlled or they can travel automatically by encoding the map pattern. Quad copter changes direction by manipulating the individual propellers speed and does not requires cyclic and collective pitch control. The Quad copter can perform their mission at any risk places and based on the risk factor no humans are injured or killed.
Keywords: Quad copter, Microcontroller, Wireless Camera.

I. INTRODUCTION

The quad copter is a unique type of UAV which has the ability of Vertical Take Off and Landing (VTOL). The quad copter has an advantage of manoeuvrability due to its inherent dynamic nature.Quadcopter has advantages over the conventional helicopter where the mechanical design is simpler. Besides that, Quad copter changes its direction by manipulating the individual propeller's speed and does not require cyclic and collective pitch control. The Quad copter configuration will also be capable of being remotely controlled to fly a specific pre-determined area such as used for surveillance from a pre-planned route around campus.The quad copter control requires joystick or a remote controller to control it. The quad copter can be controlled by varying the speed of the four rotors and no mechanical linkages are required to vary the rotor blade pitch angles ascompare to a conventional helicopter as shown in Figure 1.Over the past years many groups have worked on the development of UAV. The book Unmanned Aerial Vehiclesby Randal and Beard and Rogelio Lozano give a very extensive explanation about the different types of UAVs and its modelling. The work done on

Quad rotors give a good ideaon the design and stability of the four rotor system.The main applications include they can used for rescue missions, in military for discovering the mines by using certain metal detector in the quad copter and made them fly over the area, in film making, in agriculture and others. Nowadays in most of the developed and developing countries UAVs especially quad copter is being used in Coast Guard maritime search and rescue mission.

Figure 1. Quad copter

1.1 PROJECT OVERVIEW

The ultimate goal of the project is to create a live aerial video feed which can be sent to the computer for the surveillance purpose. This technology can be used for search and rescueoperations, fire fighting, law enforcement, military, news reporting and filming by being able to deploy aerial correspondence much faster than normal ones. The results in providing digital video signal to the computer which will pave us a way for future expansions such as UAV sentience, target tracking and video compression. There are many components to this project and we must decide which areas will bedeveloped by ourselves and which areas will be implemented with many other products.

Determining a UAV based on Application

Choosing a UAV depends upon the application it is being used for:

1. Fixed winged UAVS are used where large forward speed and long distance applications are required.
2. For steady surveillance or small applications the quad-rotor type UAV should be used.
3. When the UAV has critical applications in which it carries costly sensors or an application where fail-safe is required, then a redundant system is required hence hexa rotor or octo-rotor is used.
4. Usually twin rotors are used for medium distance applications and low power consumption applications.
5. Much research is going on the tail sitter UAV or the single rotor UAV. It is very useful for low power application.
6. The UAV supports VTOL and also fixed wing mode when it reaches a particular altitude.

II. CONCEPTUAL DESIGN

There is no particular design for a type of UAV. With new developing research, new designs are proposed. The reason for ongoing research in new designs is unstable nature of the conventional designs. Every new design is aimed to be more stable and manoeuvrable. Lower stability of designs leads to complexity in designing the control system. The stable flight of a UAV heavily depends on the design. The motion of UAV depends on the resultant forces and moments about the centre of gravity. The Newton-Euler Model gives us a good quantitative relation of the forces and torque about the centre of gravity of a rigid body. For example, if a UAV needs to hover at a particular height, the moments about the centre of gravity need to be zero. The forces and moments applied at the centre of gravity depend on the structure and design.

Figure2. Structure of Quadcopter

2.1 Structure

We have proposed a basic and an advanced structure as shown in Figure 2. The advanced structure can only be implemented once stability is obtained in the basic structure. The advanced structure is more agile and can carry greater payloads.

2.2 Initial structure

The main part of the Quad copter is Frame. As the name indicates, the copter has four arms. The frame should be light as well as rigid to host a LIPO battery, four brushless DC motors (BLDC), controller board, four propellers, a video camera and different types of sensors along with a light frame. The four propellers are not actually identical. The front and the back propellers are tilted to the right, while left and right propellers are tilted to the left. These propellers are attached to the BLDC motors. The speed of these motors is varied by Electronic Speed Controller (ESC). All these parts are mounted on the main frame or chassis of the Quad copter.

We can observe the overview of Quad copter in Figure 3

Figure 3: Different parts of Quad copter

2.3 Advanced structure

The main structure consists of a frame made of Carbon Composite Materials to reduce the weight and increase the payload. Due to this several problems related to the placement of battery on the board is resolved. The board's orientation determines the stability of the copter so it has to be perfectly placed. Hence we rigidly attached the board and battery at the centre of frame along with the motors. We also used Carbon fiber rods in place of aluminium shafts to reduce the weight. The battery was placed on the lower half so as to lower the C.G hence increasing stability. The motors are placed equidistant from the centre on opposite sides. The distance between the motors is roughly adjusted such that there is no aerodynamic interaction between the propeller blades as in Figure 4.

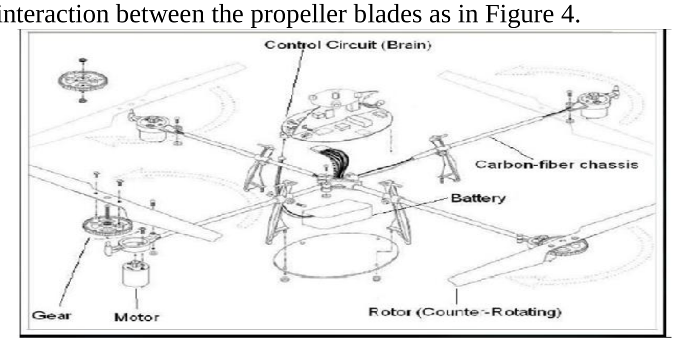

Figure 4: Structure of Quad copter

2.4 BLDC Motors

BLDC motors (Brushless DC) motors do not use brushes for communication. They are electronically commutated and the main advantages of these motors are mainly Better speed vs. torque characteristics, High efficiency with Noiseless operation and very high speed range with longer life. We need an Electronic Speed Controller control the motor. As there are no brushes to wear out the life of BLDC motor is much longer. There is no sparking and much less electrical noise. In a Quad copter we use four BLDC motors. Generally BLDC motors are referred in KVs like 850 KV, 1100 KV, 1400 KV, and 1800 KV. The KV rating on a BLDC motor is equal to RPM per VOLT applied to the motor. So a BLDC motor with a KV rating of 1000 KV will spin at 1000 RPM when 1 volt is applied, if we apply 12 volts the motor will spin at 12000 rpm.

Figure 5 shows the internal structure of BLDC motor and Figure 6 shows the external structure of BLDC motor.

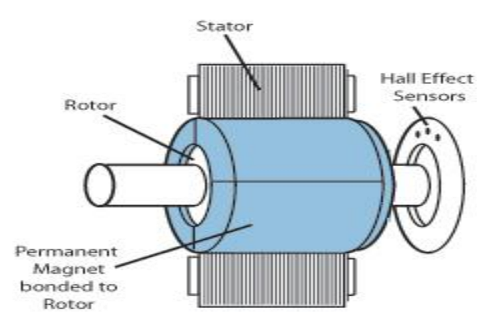

Figure 5: BLDC motor

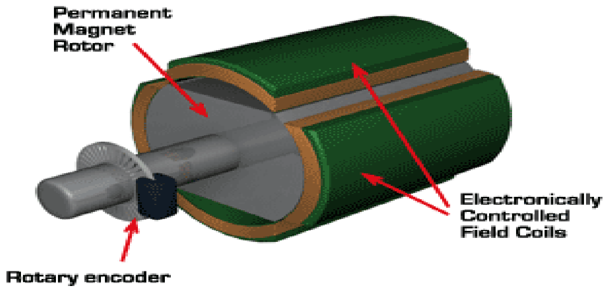

Figure 6: Outer structure of BLDC motor

2.5 Propellers

On each of the brushless motors a propeller is mounted. The 4 propellers are actually not same. If we see the Figure 6 we can observe that the front and back propellers are tilted to the right, while the left and right propellers are tilted to the left. By making the propeller pairs spin in each direction, but also having opposite tilting, all of them will provide lifting thrust without spinning in the same direction. This makes it possible for the Quad copter to stabilize the yaw rotation, which is the rotation around itself.

Some of the standard propeller sizes used for Quad copters is:

1) 1045 – 10'' diameter and 4-5'' pitch – this is the most popular one, good for mid-sized quads.
2) 08545 – 8'' diameter 4.5'' pitch – regularly used in smaller quads.
3) 1245 – 12 diameter and 4.5 pitches – used for longer quads which require lot of thrust.

Figure 7: Front and Rear Propellers

When using high RPM motors you should go for the smaller or mid-sized propellers. A faster rotating propeller (small diameter and small pitch) is used when you have a motor that runs at a high RPM and can provide a decent amount of torque. Larger propellers give more thrust per revolution from the motor.

2.6 Electronic Speed Controller (ESC)

The ESC as used in radio controlled craft performs two primary functions. The first is to act as a Battery Elimination Circuit (BEC) allowing both the motors and the receiver to be powered by a single battery. The second (and primary) function is to take the receiver's and or flight controller's signals and apply the right current to the motors. Each BLDC motor needs an ESC which regulates power to the motor according to the input throttle level. It also provides +5v power for the flight electronics. ESC is built on 32- bit microcontroller and as an array of Mosfets to drive BLDC motor as shown in Figure 8 & 9.

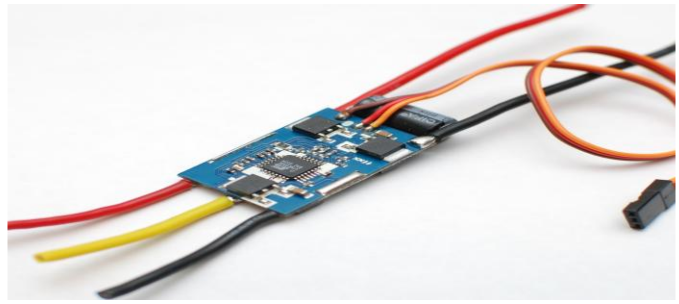

Figure 8: Electronic Speed Controller

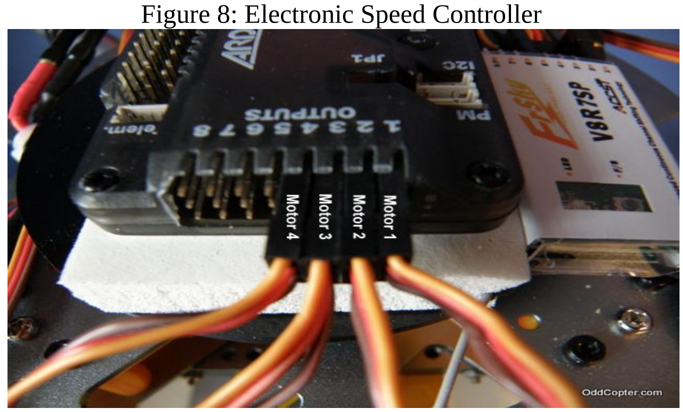

Figure 9: Motor outputs from the APM to the Motors through the ESC

III. LITHIUM POLYMER BATTERY

Lithium Polymer – LIPO are a type of rechargeable battery that has taken the electric RC world by storm, especially for Quad copters. They are the main reasons for electric flight over fuel powered models. Lipo batteries are light in weight & hold huge power in a small package. They have high discharge rates to meet the need of powering Quad copters. Unlike the conventional batteries which have only 1.2 volts per cell, Lipo battery cells are rated at 3.7 volts per cell. So we can get in multiples of 3.7 volts like 7.4 and 11.1 volt batteries. Lipo batteries can be found in packs of everything from a single cell (3.7V) to over 10 cells (37V). The cells are usually connected inseries, making the voltage higher but giving the same amount of amp – hours as shown in the figure 10.

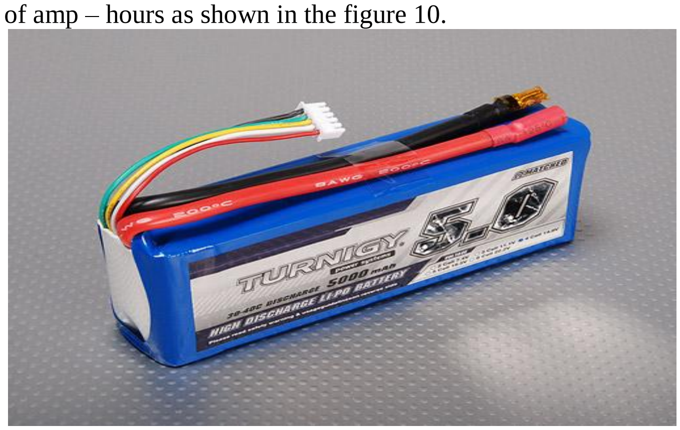

Figure 10: LIPO Battery

3.1 LITHIUM CHARGER

LIPO battery should not be charged with a normal charger. A 11.1 volt RC LIPO battery cell is 100% charged when it reaches 12.6 volts. Charging it past that will ruin the battery cell and possibly cause it to catch fire. A good charger should have the following specifications:

1) Reverse polarity protection.
2) Charge temperature-must not be charged

Figure 11: Lithium Charger

3) Discharge current position to prevent damage due to short circuits.
4) Charge voltage – a permanent fuse opens if too much voltage is applied to the battery terminals.
5) Overcharge protection – stops charge when voltage per cell rises above 4.30 volts.
6) Over discharge protection – stops discharge when battery voltage falls below 2.3 volts per cell.
7) A fuse opens if the battery is ever exposed to temperature above 100^{o}C.
Always place the battery on a concrete floor while charging and do not leave it unattached. Lipo batteries are always safe to use when you follow the essential rules of handling.

3.2 Instrumentation

Along with a stable structure comes the need for study instruments. The selection of instruments may vary with different applications. It is very important to understand how each instrument on the copter is independent with each other. Synchronization among reasonably compatible instruments is required for stable flight.

3.3 Motor, Propeller Selection and Controller board

Selection of BLDC depends on a lot of parameter. For such a model, motor requirements would be high KV (rpm/volts) ratings and high thrust. The motor should have less weight and have high efficiency. The rating of the motors depends on the specification of propeller blade and payload required. The thrust produced depends on the diameter and the pitch of the propeller. The table below gives a approximate weight of the individual components of the quad rotor. The selection of BLDC, Electronic Speed Controller and the battery vastly depend on the payload. If payload is high, a motor would need to have high ratings. A higher rating motor would have more weight and size. The electronic speed controllers ratings depend on the ratings of the brushless DC Motors as higher rating BLDC require higher current rating ESCs. Similarly higher rating components would require a higher rating battery. Thus a selection of instruments in a UAV is done as a set and not individually after through research.

Table 1: Payload Calculations

ITEM	QUANTITY	WEIGHT
Brushless DC motor	4	49x4=196 grams
Frame	1	500 grams
Control board	1	50 grams
Li-Po battery	1	200 grams
Microcontroller	1	60 grams
Video camera	1	100 grams
Miscellaneous	1	50 grams

Total approximate weight of the copters = 1156 grams
Thrust produced by one motor = 600 grams
Thrust produced by four motors = 600x4 = 2400 grams
Working efficiency of the motor = 60%
Payload capacity of the motors = 0.6x2400 =1440 grams

Thus, the UAV can bear an extra load of around 284 grams. The extra 284 grams could be used to carry a small amount of load for transferring purpose. To increase the Payload, the motors need to be changed and consequently an entire new set of BLDC motors, ESCs, and battery would be required.

Table 2: Control Scheme of Quad copter

Direction	Motor 1	Motor 2	Motor 3	Motor 4
Z + (Up)	+	+	+	+
Z - (Down)	-	-	-	-
X + (Left)	+	0	0	+
X – (Right)	0	+	+	0
Y + (Forward)	+	+	0	0
Y - (Backward)	0	0	+	+

3.4 Control Board & Mechanism

The purpose of control board is to stabilize the copter during flight. To do this inputs from Gyroscope (roll, pitch, and yaw) are sent to At mega microcontroller. The microcontroller the processes these signals according to the code burnt in it. It passes the control signals to the Electronic Speed Controllers (ESCs). These signals instruct the ESCs to make fine

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adjustments to the motors rotational speed which in turn stabilizes the Quad copter. The control board also uses signals from the radio system receiver (Rx) and passes these signals to the AT mega microcontroller via the aileron, elevator, throttle, and rudder inputs. Once this information has been processed the IC will send varying signals to the ESCs which will adjust the rotational speed of each motor to induce controlled flight (up, down, backwards, forwards, left, right, yaw) as shown in the Figure 12
The three adjustable potentiometers increase or decrease gyro gain for all three axis (Roll, Pitch, and Yaw) and can be used to calibrate the ESCs and reverse the gyro directions if necessary during pre-flight setup.

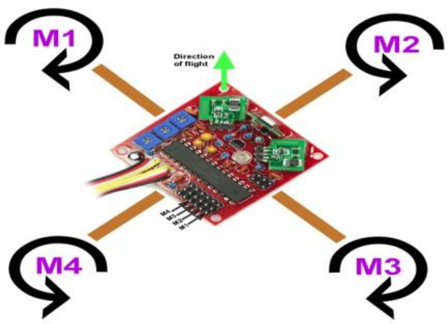

Figure 12: Control Mechanism

3.5 Flight Platform

There are various types of Quad copter platform for designing methodology. The project objective is to reduce the cost of already existing methods and make the quad copter comfortable and user friendly. The frames or arms of the quad copter are made of carbon composites to reduce the weight of the vehicle. So, the quad copter designis based on the embedded system platform. In embedded system, it consists of microcontrollers which control the overall performance of quad copter such as flying mechanism and live streaming of videos. After the microcontroller, the electronic speed controller (ESC) is to be used to control the propeller speed depending on the signal from the computer. The power supply of the quad copter is achieved by the battery. As the application is surveillance it requires long life battery which is capable of giving power for longer duration more than one hour. Lithium polymer battery satisfies this requirement. These requirements make sure that the quad copter maintains stable flight while moving or hovering.

3.6 Flight Mechanism

Quad copter can described as small vehicle with four propellers attached to rotor located at cross frame. This aim for fixed pitch rotors are used to control the vehicle motion. The speeds of these four rotors are independent. By independent, pitch, roll, and yaw attitude of the vehicle can be controlled easily. There are six major operations or movement which has to be controlled. They are Take off, Landing, Forward, Backward, Right and Left motion.

3.7 Take –Off and Landing Motion Mechanism

Take-off is movement of Quad copter that lifts up from ground to hover position and landing position is versa of take-off Position. Take-off (landing) motion is controlled by increasing (decreasing) speed of four rotors simultaneouslywhich means changing the vertical motion. The takeoffand landing motions of Quad copter as shown below in the Figure 13.

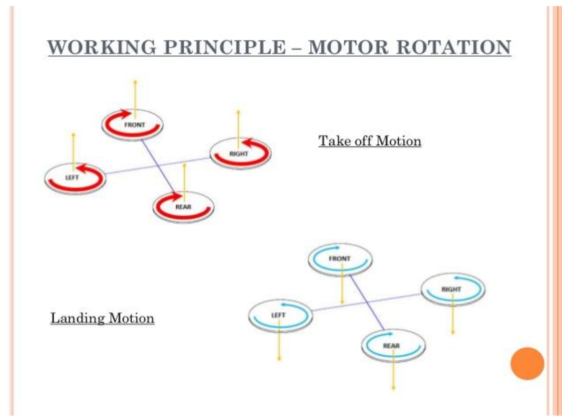

Figure 13: Take off and Landing Motion

3.7.1 Forward and Backward Motion

Forward (backward) motion is controlled by increasing (decreasing) speed of rear (front) rotor. Decreasing (increasing) rear (front) rotor speed simultaneously will affect the pitch angle of the Quad copter. The forward and backward motion of the quad copter is shown in the Figure 14.

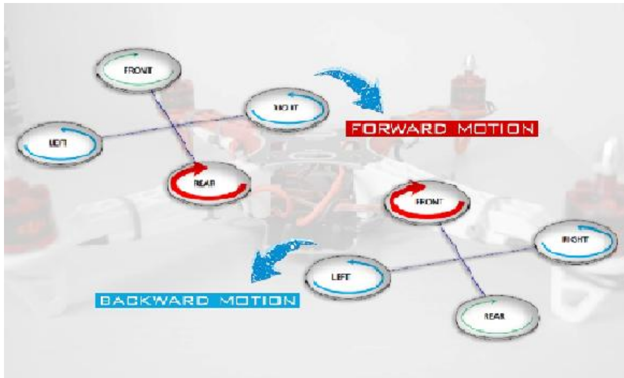

Figure 14: Forward and Backward Motion

3.7.2 Left and Right Motion

For left and right motion, it can control by changing the yaw angle of Quad copter. Yaw angle control by increasing (decreasing) counter-clock wise rotors speed while decreasing (increasing) clockwise rotor speed as shown in the Figure 15.

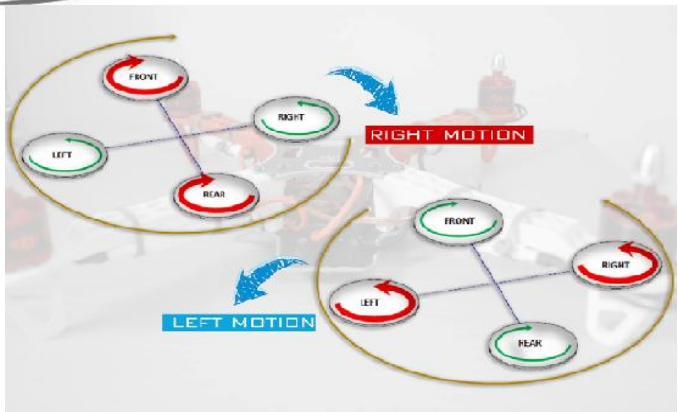

Figure 15: Left and Right motion

The Roll, Pitch and Yaw of Quad copter will decide the movement or motion in particular direction. It can be varied to make the Quad copter travel in desired motion by varying the speed of rotors by the help of Electronic speed controller. The motion of Roll, Pitch and Yaw are shown in below Figures 16(a), (b), (c).

Figure 16(a) Roll

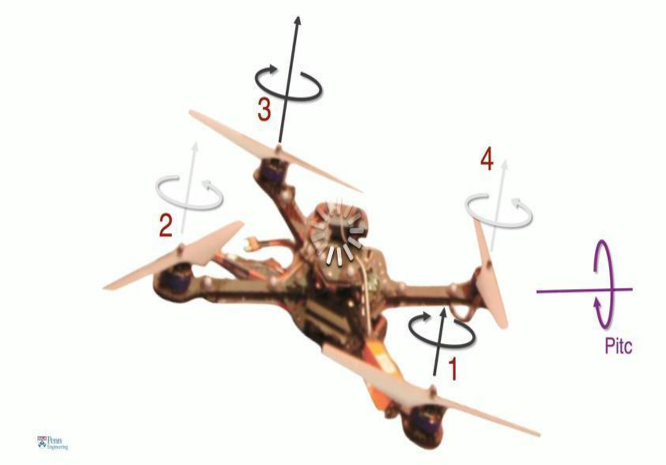

Figure 16(b) Pitch

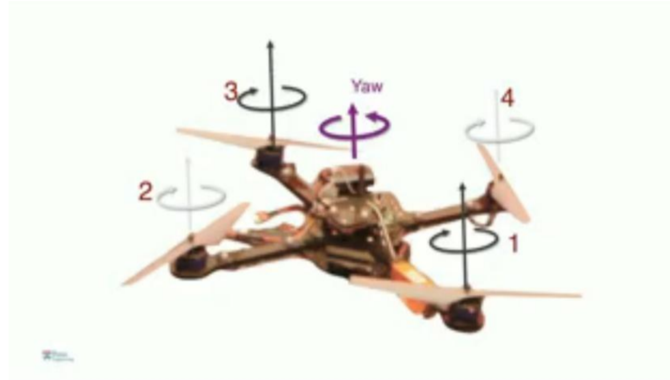

Figure 16(c) Yaw

3.7.3 AT Mega (16-bit) Microcontroller

The AT Mega microcontroller provides a set of digital and analog I/O pins that can be interfaced to various expansion boards ("shields") and other circuits. The boards feature serial communications interfaces, including USB on some models, For loading programs from personal computers. For programming the microcontrollers, the Arduino project provides an integrated development environment (IDE) based on the Processing project, which includes support for the C and C++ programming languages.The ATmega328 is a single chip micro-controller created by Atmel and belongs to the megaAVR series.In these project the microcontroller is programmed by the software's called Embedded C, Keil, and Proload. The various parameters included in the microcontroller are listed in the below table 3, along with block diagram in Figure 17.

Table 3: Parameters of Microcontroller

PARAMETERS	VALUE
Flash	32 Kbytes
Ram	2 Kbytes
Pin count	28
Max. operating frequency	20MHZ
CPU	8-bit AVR
Touch channels	16
Hardware	No
Max I/O pins	26
External interrupts	24
USB interface	No

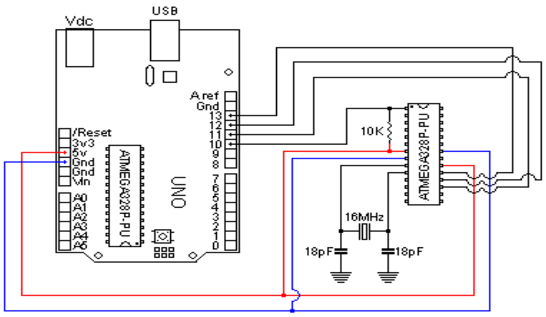

Figure 17 Block diagram of Microcontroller

6. Flight validation and Testing

The structure was built bit by bit. The motors were first tested with different speeds and thrust characteristics were obtained. It was noticed that for a particular speed maximum thrust was obtained. Any speed above it or below it reduced the thrust. This was tested using a spring arrangement where one end the spring was attached to the motor and the other was attached to the ground. The spring stiffness was known. Observing the deflection, the thrust applied by the motor could be predicted. The remote needs to be calibrated so that for a given input, themotors get the same pulse at the starting for takeoff. Small mechanical inaccuracies in fabrication are taken care of by introducing trim setting in the remote unit.

IV. CONCLUSION

In this paper we presented the mechanical structure and described all the parts comprising the development of unmanned aerial vehicle – Quad copter. Such a design will be a good solution for a quad rotor design when its dimension and cost are the main constraints. The Quad copter configuration has a greater stability as compared to the other configurations. In addition to that, the quad copter is able to hover close to its target, unlike its other counter parts.

The project going to play a major role in civilized countries. In all civilized countries surveillance of the terrestrial areas is very important. The core intention of the project is to study the complete designing process of quad copter from the engineering prospective and improving their balance and stability system. The main goal of the project is to use the quad copter for the civil surveillance and live telecasting of the video obtained. This will also be able to shoot the videos and record it for the film industries, managing, traffics and other applications.

Quad copter will be able to do surveillance by live recording the video and provide security for selected areas. Our work is to implement the wireless camera in that quad copter to record that video and dual antenna to transmit the acquired video signal to the control room. The future work consists of developing a prototype of Quad copter which can be used for surveillance.

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