Prototype Specification and Designing a Quadcopter and its Components

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Abstract: This paper illustrate on how to create an aerial Quadcopter with a much diversified area of application. Quadcopter finds extensive application for surveillance purposes in various fields like in the military unmanned aerial vehicles (UAV's) can be used to autonomously patrol the border and wirelessly report suspicious findings by using an array of onboard sensors. This paper has verified that it is possible to build a small-scale Quadcopter that could be used for both military and commercial use.

Keywords: IMU, ESC

I. INTRODUCTION

With few alterations in the design with respect to the intended payload and proper funding quadcopter can serve various commercial purposes also. They can commercially be used for Delivery services (A UK restaurant named Yo Sushi uses drones remote-controlled by waitstaff to deliver burgersprecariouslyto customers' tables. Dominoes is testing pizza delivery by drone.) Health and Safety for example a copter can be implemented to carry a defibrillator and parachute it down to heart attack victims flying at high speeds for providing quick assistance. Less dramatic but equally important, drones could be used to monitor food safety in an era when it's becoming less and less possible for humans to do so.The prototype is an autonomous aerial vehicle (AEV) with the ability to fly independently of an operator all while relaying real-time information to a base station and simultaneously receiving instructions directing our robot to its next task. The robot is designed to be self-sufficient, allowing it to communicate to a base station with little intervention by the users of the system, which in turn allows for a wide range of users and implementation scenarios.

II. DESIGN OF QUADCOPTER

The prototype consists of a lightweightaluminum frame attached to which are fourmotors that receive power from electronic motor controllers that allow communicate with the microprocessor, which will in turn control the speed of each individual motor. This designgives us a very robust and flexible platform when implementingvarious design elements. Using a four brushless motor Quadcopterdesign we are able tochange directions, elevation, and tilt rapidly by simply manipulating how much voltage goes into the motors while the AEV is in the air. We have implemented a multiple-axis accelerometer and gyroscope to allow for multiple degrees of freedom when reading information regarding the status of the Quadcopter. The use of these sensors allows us to maintain stability in constantly changing atmospheric conditions. The system itself is powered by a high capacity lithium polymer battery capable of a high discharge rate, allowing for sustained flights and adequate power supplied to the system at all times. This system, with all of its parts working in harmony, creates a stable and flexible platform on which can be built a system to meet the needs of a variety of users.

III. PROTOTYPESPECIFICATION

Our design goal for a prototype UAV was to build a platform capable of providing stable flight in order to survey the UAV's surroundings. We chose a quad-rotor system that uses an accelerometer and gyroscope to provide stability while in flight. The Quadcopter would also have the ability to carry an extensive payload including IR sensors, night vision camera, or even food and medical supplies.

IV. QUADCOPTER THEORY

Our Quadcopter uses four propellers, each controlled by its own motor and electronic speed controller. Using accelerometers we are able to measure the angle of the Quadcopter in terms of X, Y, and Z and accordingly adjust the RPM of each motor in order to self-stabilize its self. The Quadcopter platform provides stability asa result of the counter rotatingmotors which result in a net moment of zero at the center of the Quadcopter.

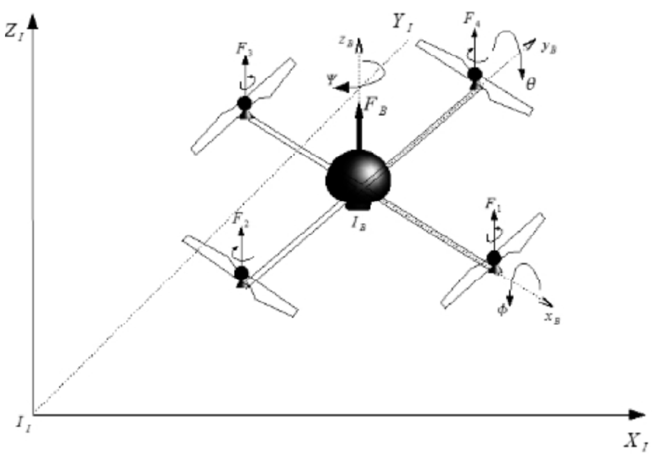

Figure shows net moment at F3 = 0

Using this principle we are able to adjust the speed (RPM as a function of the voltage provided to the motor) of each individual motor in order to correctly manipulate Quadcopter's yaw, tilt, and roll. Tilt and roll can be controlled by changing the speed of the appropriate motors, while yaw control involves delicate balancing of all four motor functions in order to change the moment force applied to the quad.

V. DESIGNING A QUADCOPTER AND ITS COMPONENTS

A. Software used

1. Solidworks 2012 edition.
2. Mechanical APDL(ANSYS).

B. Components Designed

1. Quadcopter arms
2. Cover plates
3. Arm Assembly
4. Riser foot
5. Riser foot drawing
6. Motor body
7. Propeller
8. Basic frame assembly

1. Quadcopter arm and cover plates

   Material used polished aluminum extrude

Figure 2: Arm of Quadcopter

2. COVER PLATE

   Material used aluminum sheet

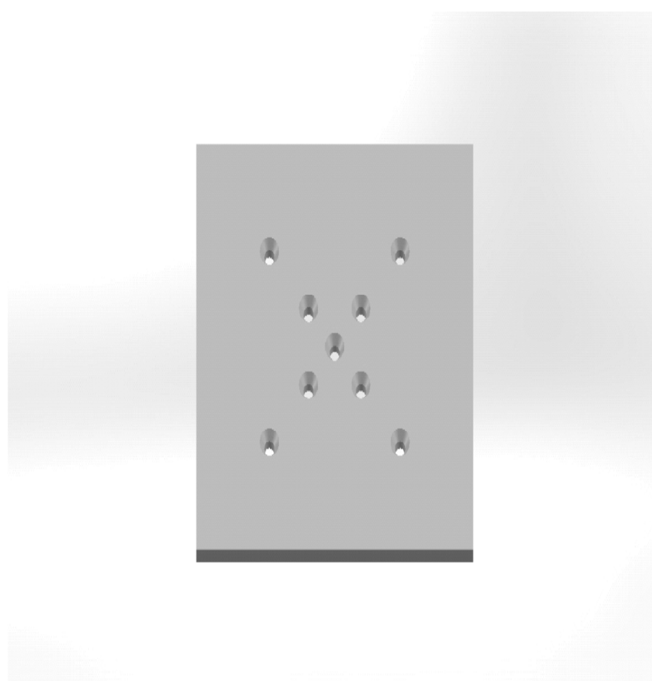

Figure 3: Cover Plate

3. Basic arm assembly

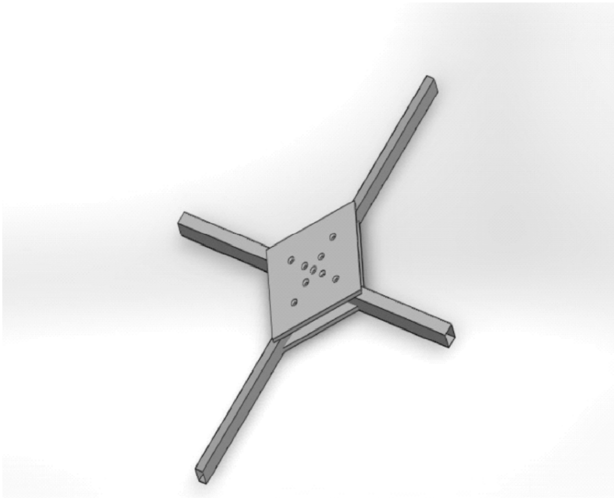

Figure 4: Basic Assembly

4. Riser foot

   Material used Teak wood

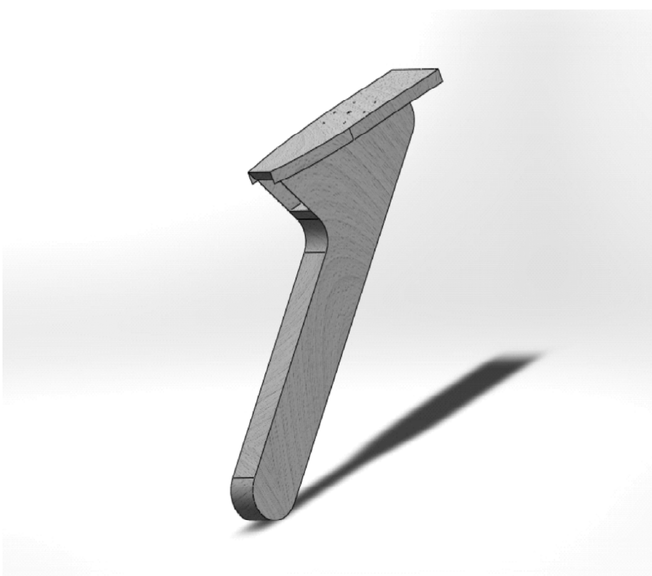

Figure 5: Leg

5. Riser foot drawing

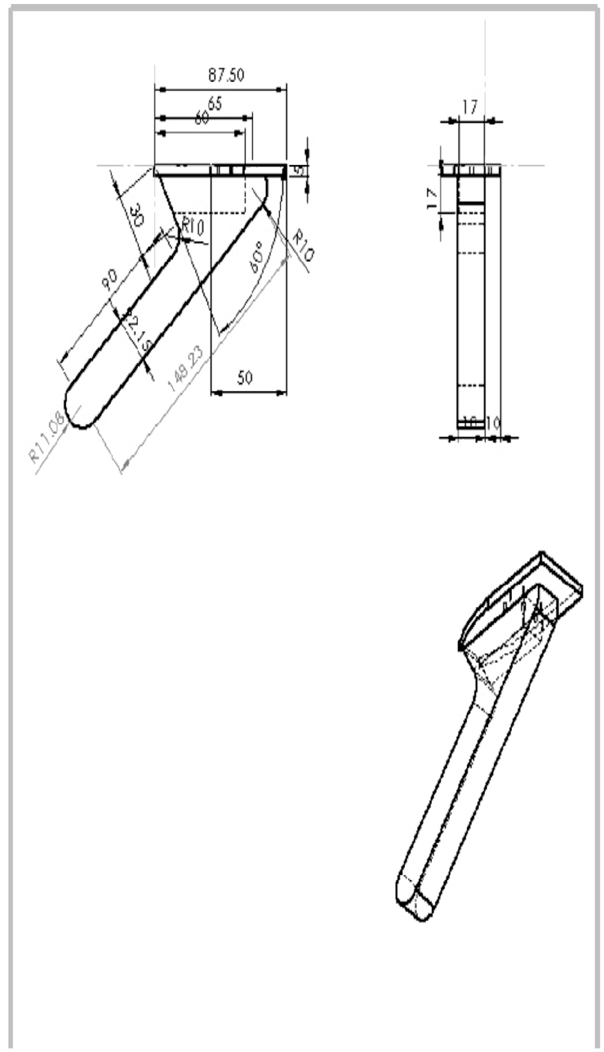

Figure 6: Drawing

6. Brush Motor body

   Material used Brushed aluminium

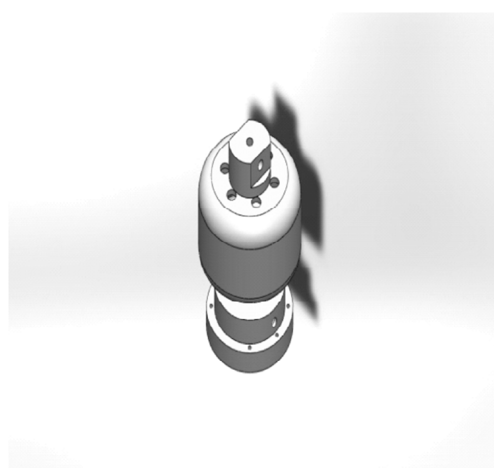

Figure 7: Motor Body

7. 10*4.7 Propeller

   Material: low gloss plastic

Figure 8: Propeller

8. Quadcopter basic frame assembly:

Figure 9: Assembly

VI. BRUSHLESS MOTORS

Brushless DC electric motor 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. Two key performance parameters of brushless DC motors are the motor constants Kv and Km (which are numerically equal in SI units). They are a bit similar to normal DC motors in the way that coilsand magnets are used to drive the shaft. Though the brushless motors do not have a brush on the shaft which takes care of switching the power direction in the coils, and this is why theyare called brushless. Instead the brushless motors have three coils on theinner (center) of the motor, which is fixed to the mounting.

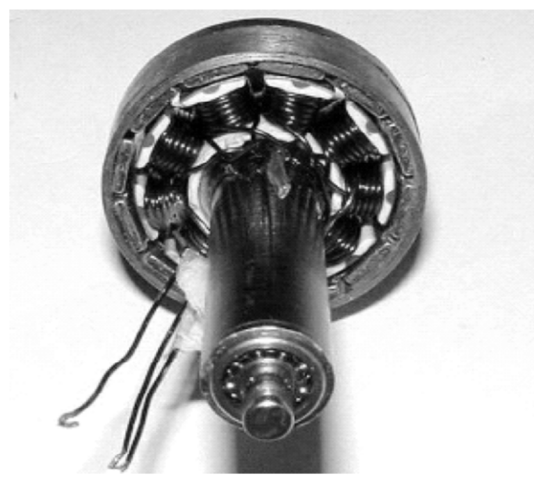

Figure 10: Brushless Motors

On the outer side it contains a number of magnets mounted to a cylinder that is attached to the rotating shaft. So the coils are fixed which means wires can go directly to them and therefore there is no need for a brush. Generally brushless motors spin in much higher speed and use less power at the same speed than DC motors. Also brushless motors don't lose power in the brush-transition like the DC motors do, so it's more energy efficient.

Brushless motors come in many different varieties, where the size and the current consumption differ. When selecting your brushless motor you should take care of the weight, the size, which kind of propeller you are going to use, so everything matches up with the current consumption. When looking for the brushless motors you should notice the specifications, especially the "Kv-rating". The Kv-rating indicates how many RPMs (Revolutions per minute) the motor will do if provided with x-number of volts. The RPMs can be calculated in this way:

$$RPM=Kv*U$$

VII. 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. Propeller dynamics can be modeled by both Bernoulli's principle and Newton's third law.In general when selecting propellers you can always follow these rules:

1. The larger diameter and pitch the more thrust the propeller can generate. It also requires more power to drive it, but it will be able to lift more weight.
2. When using high RPM (Revolutions per minute) motors you should go for the smaller or mid-sized propellers. When using low RPM motors you should go for the larger propellers as you can run into troubles with the small ones not being able to lift the quad at low speed.

Figure 11: Propellers

VIII. ESC

The brushless motors are multi-phased, normally 3 phases, so direct supply of DC power will not turn the motors on. That's where the Electronic Speed Controllers (ESC) comes into play. The ESC generating three high frequency signals with different but controllable phases helps to continuously keep the motor turning. The ESC is also able to source a lot of current as the motors can draw a lot of power.

The ESC is an inexpensive motor controller board that has a battery input and a three phase output for the motor. Each ESC is controlled independently by a PPM signal (similar to PWM). The frequency of the signals also vary a lot, but for a Quadcopter it is recommended the controller should support high enough frequency signal, so the motor speeds can be adjusted quick enough for optimal stability (i.e. at least 200 Hz or even better 300 Hz PPMsignal). ESC can also be controlled through I2C but these controllers are much more expensive.

Figure 12: ESC

IX. BATTERY

LiPo battery can be found in a single cell (3.7V) to in a pack of over 10 cells connected in series (37V). A popular choice of battery for a QuadCopter is the 3SP1 batteries which means three cells connected in series as one parallel, which should give us 11.1V.A good rule of thumb is that you with four EPP1045 propellers and four Kv=1000 rated motor will get the number of minutes of full throttle flight time as the same number of amp-hours in your battery capacity. This means that if you have a 4000mAh battery, you will get around 4 minutes of full throttle flight time though with a 1KG total weight you will get around 16 minutes of hover.

Another important factor is the discharge rate which is specified by the C-value. The C-value together with the battery capacity indicates how much current can be drawn from the battery. Maximum current that can be sourced can be calculated as:

MaxCurrent= DischargeRate*Capacity

For example if there is a battery that has a discharge rate of 30C and a capacity of 2000 mAh. With this battery you will be able to source a maximum of 30Cx2000mAh = 60A. So in this case you should make sure that the total amount of current drawn by your motors won't exceed 60A.

X. IMU

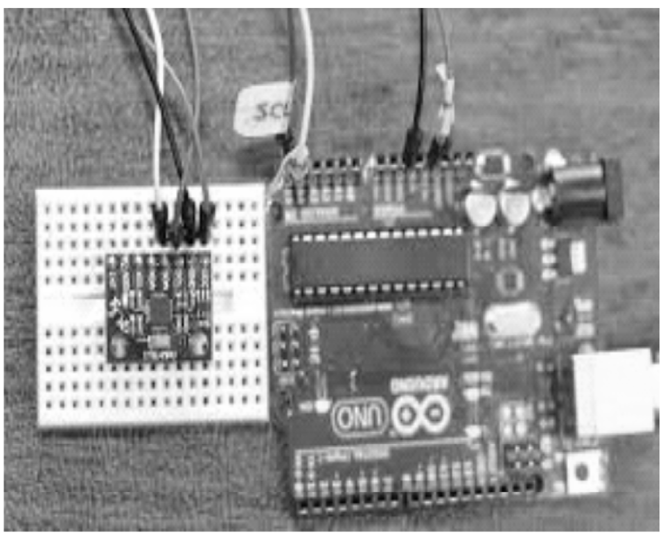

Figure 13: IMU Assembly with Arduino

The IMU is an electronic sensor device that measures the velocity, orientation and gravitational forces of the quadcopter. These measurements allow the controlling electronics to calculate the changes in the motor speeds. The IMU is a combination of the 3-axis accelerometer and 3-axis gyroscope, together they represent a 6DOF IMU.

XI. ARDUINO UNO

Arduino is a single-board microcontroller, intended to make the application of interactive objects or environments more accessible. The hardware consists of an open-source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit AtmelARM. Current models feature an USB interface, 6 analog input pins, as well as 14 digital I/O pins which allow attaching various extension boards.

XII. HARDWARE

An important aspect of the Arduino is the standard way that connectors are exposed, allowing the CPU board to be connected to a variety of interchangeable add-on modules known as shields. Some shields communicate with the Arduino board directly over various pins, but many shields are individually addressable via an I^2C serial bus, allowing many shields to be stacked and used in parallel. Official Arduinos have used the megaAVR series of chips, specifically the ATmega8, ATmega168, ATmega328, ATmega1280, andATmega2560. A handful of other processors have been used by Arduino compatibles. Most boards include a 5 volt linear regulator and a 16 MHz crystaloscillator (or ceramic resonator in some variants), although some designssuch as the LilyPad run at 8 MHz and dispense with the onboard voltage regulator due to specific form-factor restrictions. An Arduino's microcontroller is also pre-programmed with a boot loader that simplifies uploading of programs to the on-chip flash memory, compared with other devices that typically need an external programmer. This makes using an Arduino more straightforward by allowing the use of an ordinary computer as the programmer.

Figure 14: Arduino Uno

XIII. SOFTWARE

The Arduino integrated development environment (IDE) is a cross-platform application written in Java, and is derived from the IDE for the Processing programming language and the Wiring projects. It is designed to introduce programming to artists and other newcomers unfamiliar with software development. It includes a code editor with features such as syntax highlighting, brace matching, and automatic indentation, and is also capable of compiling and uploading programs to the board with a single click. A program or code written for Arduino is called a "sketch". Proper codes were developed using Arduino software that successfully implemented.

XIV. RESULT

The required semi-autonomous Quadcopter was properly designed, fabricated and tested successfully.

We have created an aerial Quadcopter with a much diversified area of application. However, the Quadcopter finds extensive application for surveillance purposes in various fields. On the other hand with few alterations in the design with respect to the intended payload and proper funding Quadcopter can serve various commercial purposes also.