

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Special Issue 6, May 2015

Wireless Control Quadcopter with Self-Balancing System

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ABSTRACT: The military uses unmanned aerial vehicles (UAVs) in dangerous locations by keeping the human operators at a safe distance. The larger UAVs always provide a reliable long duration, cost effective platform for inspection. They have grown to become an essential tool for the military. Through this paper we modelled a small UAV for commercial/industrial applications. We postulated that smaller UAVs can serve more tactical operations such as searching a village or a building for enemy positions. Smaller UAVs, on the order of a couple feet to a meter in size, should be able to handle military tactical operations as well as the emerging commercial and industrial applications and our project is attempting to validate this assumption. To validate this assumption, our team considered many different UAV designs before we settled on creating a Quadcopter. We work on the Quadcopter to improve performance and controllability. The most significant problems to date have been an ambitious development schedule coupled with very limited funds. These constraints have forced compromise in components selected and methods used for prototype development. Our team's Quadcopter prototype is a very limited version of what could be created in a production facility using more advanced technology. Currently our Quadcopter has achieved stable unfettered flight as well as autonomous altitude hold. We are continuing to work on our software so that we can achieve better controllable unfettered flight.

KEYWORDS: Unmanned aerial vehicles (UAVs), Performance and Controllability, operations, Quadcopter

I. INTRODUCTION

The quad-copter was intended to be a UAV (Unmanned Aerial Vehicle) with autonomous subsystems. The plan was to equip it with a video transmitting Subsystem so its purpose could be for surveillance; however, due to cost and other priorities, the video system was not implemented. It does, however, have a small payload capacity that could be applied to the emergency delivery of low Weight supplies to remote locations. Perhaps the most significant purpose of the Quad-copter, however, is simply the exercise in engineering design that it was intended to be. Quadcopter has received considerable attention from researchers as the complex phenomena of the Quadcopter have generated several areas of interest. The basic dynamical model of the Quadcopter is the starting point for all of the studies but more complex aerodynamic properties has been introduced as well. A defined control method has been researched, including PID controllers, back- stepping control, nonlinear control, LQR controllers, and nonlinear controllers with nested saturations. Control methods require accurate information from the position and altitude measurements performed with a gyroscope, an accelerometer. The motivations to choose the quad-copter as a senior design project are varied among the group members. At some point a consensus arose to build a robot, then a robot with sensors and autonomous capabilities, and finally the consensus shifted from a mobile ground robot to a flyer. At first, there were concerns about the technical difficulties involved in designing and building a flyer however, the idea of a flyer generated enough excitement that ultimately the challenge was accepted. The initial motivation of this project was to create a flyer for surveillance purposes.

The main goal of this project was to create lightweight flyer that can maintain a steady altitude in flight, fly in accordance to a pre-set flight path, has a simple interface for controlling, and has the capability to carry a payload. The Quadcopter is to be used by any user capable of responsibly using the flyer. Therefore, a design and

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controller based on a beginner-level pilot's skills is essential to the project. The first goal was software implementation and testing. The two processors will implement a high-level language to process commands and for fast debugging. The computer interface would be a GUI, or graphical user interface, developed on a high-level language. A means of controlling the signal in small steps would be used for tilt measurements. A means of error-correction would be made to compensate for tilting for forward, reverse, and turning by measuring accelerometer and gyroscope measurements. The software would take into consideration the sampling rate of all analog inputs from their respected ADCs to confirm the given data. The second goal was to setup a remote communications device to communicate with the controller. The communications would be done using a customized system of ZigBee, 6LowPan protocols, and point-to-point communications between each transceiver. These protocols would be communicated from a microwave antenna, to a dedicated processor, to be sent via UART to the main processor. The main processor would then interpret the command to determine user-instructed commands to determine whether the command was either a non-autonomous, real-time flight controlled by the user; or an autonomous command preset by the computer for a demonstration or surveillance flight. The third goal involved getting the quad-copter in the air in stable flight. This was defined as being able to lift from the ground to a steady-state position with almost no lateral drift and no spinning. The final goal was to create a light weight, wireless-controlled quad copter with self stabilization.

II. COMPONENTS OF THE QUADCOPTER

Frame

Frame is the major mechanical work in the Quadcopter. We designed it with considering the aerodynamics. We used Aluminum material for making the frame. There are many configurations available for the frame. We implemented X configuration is shown in figure 1. It has more stability than other configurations. We also designed our frame for getting more self-stability. The specifications of the X Frame are tabulated in table 1.



FIG. 1. FABRICATING OF X – FRAME, FIG. 2. MACHINING OF THE ALUMINIUM FRAME

TABLE 1: SPECIFICATIONS OF FRAME

Material	Aluminium
Dimension	360mm x360mm x 80mm
X Frame	500mm
Drill	3mm
Fasteners	3mm
Slot	10mm x 5mm

Motor

We use brushless DC motors in our Quadcopter. This motor features a 3.17mm hardened steel shaft, dual ball bearings, and has 3.5mm gold spring male connectors already soldered, and also includes 3 female connectors for speed control. The motor is shown in figure 3.

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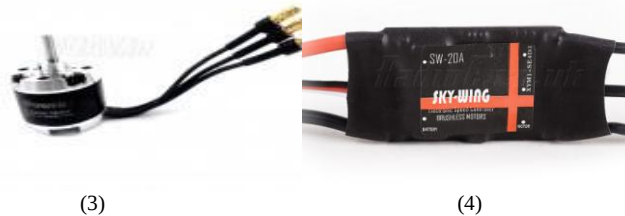


Fig. 3.DC Motor, Fig. 4. Electronic Speed Controller (ESC)

Electronic Speed Controller (ESC)

The electronic speed controllers are used as per the recommendations for the motors. We used 20A ESC for our Quadcopter. Because the minimum recommended ESC is 18A. The image of the ESC which we used is shown in figure 4.

Propeller

The propellers are the major part of a Quadcopter. They produce thrust by propelling in higher speeds. They are the main responsible for lifting of the Quadcopter. By controlling them, we can achieve forward, reverse, leftward, rightward, lifting and landing motions. We used 10 x 4.5 propellers for our Quadcopter which is shown in figure 5.

Propeller Adapter

The propeller adapters are used to mount and hold the propellers. If they were not used, we cannot achieve flying of our Quadcopter. The pictures of them are shown in figure 6.



Fig. 5. Propeller, Fig. 6. Propeller Adapter

Servo Extension

They are used as interface between the board, receiver and ESCs. A typical Servo extension is shown in figure 7.

Battery

The battery is used to store and discharge the power to the Quadcopter. We used a 1000mAh battery for our Quadcopter. The picture of the battery is shown in figure 8.



Fig. 7. Servo Extension, Fig. 8. Battery

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Micro Controller

Baseboard is capable of being out fitted with A&B MINI, zigbee, gyro, magnetometer, GPS, buzzer, LCD. The A&B Mini is a micro controller based on the ATmega328AU. It has 14 input/output pins (of which 6 can be used as PWM outputs), 8 analog inputs, an on-board resonator, a reset button, and holes for mounting pin headers. A six pin header can be connected to an FTDI cable. The A&B Mini is intended for semi-permanent installation in objects or exhibitions. The board comes without pre-mounted headers, allowing the use of various types of connectors or direct soldering of wires. The pin layout is compatible with the A&B Mini.

Motor Mount

The motor mounts are used to hold the motors. They are fastened to the frame so has to hold the motors in their respective positions. They are shown in figure 9.

Gyro & Accelerometer

The Base Board is equipped with a 3axis gyro scope and accelerometer (MPU6050) with DMP enabled which gives an accurate correction upto 0.1degrees. For the accelerometer 10 pins are outfitted. Through wire the sensor pins have to connect sensor contains a MEMS accelerometer and a MEMS gyro in a single chip. It is very accurate, as it contains 16 bits analog to digital conversion hardware for each channel. Therefore it captures the x, y and z channel at same time. The gyro & accelerometer is shown in figure 10. The header is on the left with the pins in this order "VCC", "GND", "SCL", "SDA", "XDA", "XCL", "AD0", "INT".



Fig. 9. Motor Mount, Fig. 10. Gyro & Accelerometer

Charger

The charger is used to charge the battery. We used E3 charger for our 1000mAh battery. The image of the charger is shown in figure 11.

Transmitter and Receiver

The transmitter and receiver acts as the remote control for the Quadcopter. We used Avionic 2.4GHz 6 channel transmitter and Avionic V2.0 6 channel receiver. The pictures are shown in figure 12.



Fig. 11. Charger, Fig. 12. Transmitter & Receiver

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III. ASSEMBLY

The components were purchased separately and assembled by us. First, we prepared the frame which is the back bone of the Quadcopter. All other parts were just mounted and fitted over the frame. The pictures while assembling the Quadcopter are shown in figure 13.



(13)

Fig. 13. Assembling the Components & Final Quadcopter

IV. DESIGN VALIDATION

Lift and Flight Stabilization

To facilitate flight stability, two forces must be considered: Lift force and the Magnus effect. The most important force pertaining to flight was the lift force. Lift is based on the upward vertical component acting on an airfoil's aerodynamic center. The force which reacted to the thrust of the airfoil moves in a perpendicular to the airfoil, which was represented as a vertical and horizontal force. The horizontal vector is known as the drag force.

Lift Equation

$$L = C_d q S$$

Where, C_d is the lift coefficient, q is the dynamic pressure and S is the platform area, or the area of the blade or airfoil. For most airfoils, this was measured at the center of pressure, which is usually found at the center of the chord of the blade. This concept will hold true for most airfoils found on standard aircraft. In terms of measuring the lift for a helicopter, the propeller speed was considered rather than the thrust. This was due to the fact that the propeller, which is with few exceptions virtually vertical, was now operating on a horizontal plane. The centrifugal force used to move a propeller plane forward was now the primary lift force of the Quad-Copter. This calculation facilitated optimization of the motors in relation to the propellers at hand. Propeller design also factored in as the blade turns outward from the center. This resulted in a change of the angle of attack to its optimum angle at the tips of each propeller blade. This would be a disadvantage to users who are more experienced with flight stunts for helicopters. In terms of using the copter as a surveillance device, it would be ideal for the most static picture from an aerial perspective. The other force to consider for was the lateral forces being induced. Normally, there was no drag forces found on the helicopter in hover. This was due to the dual blade propeller moving at such high speeds. The torque generated from the motor created a rotational force, causing the entire craft to spin, hence the second blade to counteract the forces of the torque (called the anti-torque blade). For the quad-copter, the torques of the counter rotating blades cancelled each other out thus, protecting the system from drift. Another design consideration was the Magnus effect. This assumed a cylinder of

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infinite length which rotates. What was found was the air would have a tendency to induce a lift if the rotation of the cylinder was moving relatively upwards. This is meant to explain why a baseball pitcher can curve a ball. For the project, the force was considered negligible in still air at hover but, when turbulence occurred, it was possible for this force to become imbalanced and create a drift force. This drift force was also something to be considered when in motion. Initial take-off circumstances were also be taken into account. At start-up, the capability of a slow increase in the propellers' speed to avoid a fast take-off was desirable. Fast take-offs had long term stress and shearing effects on the internal bolts of the craft. Grounding effects was also a leading factor in faster take-off due to more air being pushed back into the airflow of the blades. This would lead to an initial cyclonic effect surrounding the blades, and created further stress on the frame and the propellers.

Forward Motion

Forward motion was still an issue involving propellers for standard copters. Normally, blades on the main rotor can tilt in a way to create forward flight. In the quad-copter design, the propeller blades remained relatively static to the center piece. To compensate and create forward flight, the whole copter needed to be tilted by reducing the lift speed of at least one motor. Timing of this was crucial for maintaining altitude. To maintain altitude, the optimum angle the copter had to maintain, with a maximum forward thrust, was no more than 10-15 degrees. There was also the placement of the sensors for feedback to the processor. The accelerometer and the gyroscope were required to assist in this faculty. For optimal response, the accelerometer handled lateral and vertical feedback, and a gyroscope handled all rotation feedback. The orientation of each device was considered for controlling flight. Further testing in the signal processing allowed the user to observe the required statistics needed to command forward flight. As a basis for finding the optimum orientation for forward flight, the helicopter model was useful. For the typical copter, the AOA (Angle Of Attack) for each blade was assumed to be optimum for lift at 15 degrees. Since forward flight meant a change in angle of the copter, it also meant a change in the AOA, which would cause a drop in the altitude. To compensate for this, the above equation, involving the centrifugal force, was modified by setting the lift used in hovering as the forward thrust. The new lift was the vertical force upward, which had to equate to the lift in hover before forward motion to maintain altitude. The new equations generated from forward thrust were as follows.

$$L_f = L_{\text{hover}} \sin \zeta$$

Where L_{hover} was the lift in hover before forward motion, which was calculated by centrifugal force, and ζ was the tilt angle forward. For small angles (below 2 degrees) it will only appear to be a drift, and testing all angles between 5-15 degrees for any clear results was advised. The minimum value was given to distinguish from the effects of vibration and drift to the forward thrust, and the maximum is considered 15 since airfoils which are angled at more than 15 degrees begin to stall. These same considerations were also given for reverse flight, to allow for halting forward motion, as well as a reverse function for the copter. Once the copter was in a constant forward motion, the net forces were considered to be zero, and the velocity of the copter was regarded in a linear perspective.

V. APPLICATIONS

Agriculture

The aerial Quadcopter used for agricultural surveillance is an unmanned vehicle used for proper and accurate surveying of the crops and leaves reducing the human effort. The agricultural farm is surveyed by an infrared camera which will show the colour image displaying the difference between infected or diseased crop and matured crop. The innovative foldable frame design developed will allow the Quadcopter to be transported safely and with ease in a Cylindrical shaped cushioned box packing.

Commercial

Quadcopter are used commercially produced, camera-equipped, radio-controlled quad copter. It is battery-operated and includes an HD video recorder. The largest use of quad copters 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.

Media

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

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VI. CONCLUSION

The Quadcopter is now able to takeoff and reach a steady state at height, but occasionally small corrections are still needed to keep the Quadcopter in one spot. Better settings of controller, for example with using another method for finding the controller actions or use a better control method it may help for a better stabilization. Also it possible to refine the positioning in space by adding more sophisticated filters. On flight of the Quadcopter acts also the wind effect; therefore it is needed to include this effect into the overall stabilization. The remote control over a mobile application works very well. Now is implemented a basic control of the Quadcopter with possibility turn on/off controllers. Into the future can be added some advanced control functions for special maneuvers. For improvement functions of Quadcopter can be added some another sensors like a camera or altimeter. One of the many advantages of the Quadcopter is ability to fly on places, which are for human complicated to reach or so quickly as he and with the help of a camera is possible explore inaccessible locations. With added devices we can to determinate a flight path or track some objects.

REFERENCES

- [1] Aarti, J., Premalatha, B. and Krishnaveni, S. 'Combined Scheduling of GPS Signals in a GSM Based Guidance System', Aarti, J., Int. Journal of Engineering Research and Applications Vol.3, pp.465-468, 2013.
- [2] Abdallah Zaid, A., Saifallah, Q. 'Search-And-Rescue Remote Sensing Quadrotor UAV', Project Entry Documentation for National Technology Parade, pp.9-20, 2010.
- [3] Aleksandar R., Gyula M. (2011) 'The Modeling and Simulation of an Autonomous Quad-Rotor Microcopter in a Virtual Outdoor Scenario', Vol. 8, No. 4, 2011.