International Journal of Scientific Research & Engineering Trends
Volume 5, Issue 2, Mar-Apr-2019, ISSN (Online): 2395-566X

Design and Implementation of Quad copter

Gaurav Gadge **Ankita Ledey** **Sourabh Pawer** **Gulshan Balpande**
Department of Electronic & Communication
Shri balaji Institute of Technology & management
Betul, MP, India
ggadge19@gmail.com

***Abstract*- This paper presents the design and implementation of an aerial surveillance quad copter for search and rescue application. The aim of this research is to develop a real-time, compact and cost effective drone that will be capable of search and rescue operation and the class is intended to provide the student with both theoretical and practical knowledge in the areas of electronic engineering and design, system integration hardware programming, and control system design and implementation. The frame of the quad copter was made up of very light glass fiber to ensure stability while flying and also to reduce weight of the overall material. The entire design generated a compact and low cost surveillance quad copter with weight of approximately 1.50 kg; which can take photographs from environments with the aid of the onboard mounted camera. Live streaming was done with the help of laptop during fight.**

***Keywords* - Quad copter, real-time, rotor-craft, surveillance, reconnaissance, wireless communication.**

I. INTRODUCTION

The quad rotors are a very popular type of unmanned aerial vehicles because of their mechanic simplicity in comparison with other flying robots. The construction shown on Fig. 1 is very simple. It is formed by four beams which are orthogonal to each other. At the end of each beam, there is a BLDC (Brushless DC) engine with a propeller. Common helicopters have very similar flight characteristics as quad rotors, but quad rotors have different methods of flight control.

The paper deals with the modeling and realization of quad rotor. This robot is used for many purposes. It can be used in civil or military applications. This type of robot allows for very fast takeoff and its operation is very low-cost. It can carry many devices, e.g. chemical sensors for inspection of air pollution during fire. This work is divided into several parts. First of all, necessary electronics are described.

This section is followed by the description of the mathematical model of the robot. This model describes a relation between forces and torques affecting the quad rotor body. Following parts deal with the design of the state space controller. The next chapter explains software solution and implementation of the microcontroller. A computer vision system for automated landing is described at the end of the paper.

Fig. 1 quad copter.

II. REVIEW OF LITERATURE

Described the model of a flying robot with gripper mechanism for surveillance purpose. The authors used aluminum frame to reduce the weight of the flying robot. The flight was able to lift more payloads due to the use of 1800KVA runner motor. However, the flying robot has the challenge of less flight time. Design a miniature wireless quad copter that has the capability of flying about and hovering like a helicopter with the aid of extra added motors.

The software and hardware were carefully integrated to ensure a miniature technology but could not carry much payload. Proposed and designed the system and algorithms necessary to allow a quad copter to autonomous locate and land on a station target. The quad copter was able to hover in place but could not carry much payload. It was also meant for data

© 2019 IJSRET

collection or surveillance systems that only cope with moderately short battery life. In their design engaged an android operating system embedded in a smart phone to operate the quad copter through graphical User Interface (GUI) and user's commands on the phone. The authors developed a small size UAV capable of taking photographs from environment though they did not consider issues of stability and carriage of higher payload other than the mounted camera. Developed a successful ISR quad copter using cheap components.

The author developed system platform that could be used as a low cost substitute to perform explosive detonation of army targets at high level of precision. The quad copter however, could not resist much vibration and lacked stability. Thus, amidst all the challenges listed above, this research is intended to design and implement a compact aerial surveillance quad copter for search and rescue applications. The quad copter would be capable of autonomous flight and will be able to achieve a nominal flight altitude of about 7ft. The total mass of the UAV will be below 2kg and the battery life will endure for at least 15 minutes. In all, the quad copter will be capable of carrying moderate payload such as camera, and would be able to compensate for the external disturbances.

III. METHODOLOGY

The concept of how quad copters operate is fairly simple, but implementing each subsystem requires quite a bit of attention to detail in order for the aircraft to function properly. This section highlights the design methodology that was followed for the implementation of the quad copter and details of how each subsystem works. The first phase of the project considered the design of the quad copter while the second phase involved system implementation and simulation. The components used for the quad copter design were duly tested and checked to ensure maximum safety and also to reduce cost.

1. Design Specification - The specifications for the design were listed in table 1 below and these determine the choice of suitable components.

Table1 The specification for the quad copter design.

Parameter	Value
Lifting thrust	7.50N.
Weight	Max. Component weight: 1.5kg
Battery	a. Type of cells – LiPoly cells (3S). b. Estimated flight time – 15mins.
Visibility	Suitable in clear weather only
Range of radio frequency coverage	1km
Frequency of video feed transmission	5.8GHz
Frequency of control signals	900MHz

2. Hardware Design - The following factors were put into consideration during design of the quad copter.

2.1 The Quad copter Body- The frame of the quad copter was made of very light glass fiber. Many other materials such as aluminum and wood were considered. Aluminum was not used because of its inability to absorb vibration from the motors whereas wood could easily be destroyed by insects and weather conditions. The body of the quad copter is divided into three parts. body frame, landing gear, and gimbals. The body frame enclosed all the needed components. The body frame was made slim with holes drilled to it to maintain stability while flying and to reduce the weight of the overall material. The width of the frame was 450mm and the height was 55mm. The gimbal was used to hold the camera in place and the landing gear was made to have a lower center of gravity for stability when landing the quad copter.

2.2 Motors (brushless) and Electronic Speed Controllers (ESCs) - Before choosing a motor for the design, the total weight which the UAV was meant to take was determined, and then the thrust required to lift the quad copter was worked out. This was necessary because if the thrust provided by the motors were too little, the quad copter will not respond well to control and will even have difficulties taking off, and if the thrust was too much, it might become too agile and hard to control. A rule of thumb required for thrust is given as:-Thrust w eight * 2 4 = ÷ ( ) (For 2:1 thrust / weight ratio) …… (1)

Where: weight = estimated weight of loaded vehicle which is obtained by adding the individual weights of all motors, propellers, ESCs, camera etc.

(Assuming all other minor components weigh not more than 373g so that the overall weight can be approximated to 1500g). For the quad copter to hover, it has to beat gravity. Since the overall weight of the system is 1500g (Including the weight of the minor components), its four (4) motors and propellers have to produce at least 1500g of thrust in order to beat gravity. As we have 4 motors, each one has to produce 1500 ÷ 4= 375gof thrust (with assumptions that all motors/propellers produce equal thrust).

Since it is general rule to have a 2:1 thrust/weight ratio for a standard quad copter, the standard thrust therefore required for each motor is: 375g x 2 = 750g. From the above estimate for the thrust, Turnery D2836/8 1100KV Brushless Out runner Motor with the following specifications was chosen. Table 3 below gives the specifications for a 1100KV brushless out runner motor.

Given the equation for static thrust: T pi r rho P = 2 * * 2 * * 2 0.3333 …… (2)

© 2019 IJSRET

Where: T = thrust, r = propeller radius (in meters), rho= air density = 1.22kg/m3 P shaft power voltage x current motor efficiency = = = * 15 * 18 * 75% 202.5 y in watts W … (3)

The following assumptions were made: eta = 0.7, Motor efficiency = 50% (the maximum efficiency for a brushless motor is around 75% and happens around 90% of the motors maximum speed), Propeller radius = 1/2 the length of the propeller (given a 10 x 4.7 propeller) = 5 inches or 0.127m, current and voltage (for shaft power) = maximum current and voltage of the motor whose products gives the maximum power = 300W. The estimated thrust for one motor therefore becomes:-

T = 17.18N (4)

This value of thrust obtained by calculation based on estimation can be said to be close to the value of the thrust (max. pull) of 1130g as specified by the manufacturers. Therefore the choice of motor is justified. In choosing ESCs for the motors, the amperage of the motors is put into consideration. For example, the selected motor draws a maximum of 20A current. So it is necessary to go for a speed controller with amperage higher than 20A. A 30A speed controller with battery eliminated circuit (BEC) output of 5V/2A is chosen.

This means that 5V output from the ESC can power up the microcontroller and the servomotor (for camera gimbals). With this, the ESC can comfortably handle the most amperage that the motor will ever draw; and together with the suitable battery pack, the motors will always be able to pull all the energy it needs and so will be able to realize its full potential. In combination with the above motors and speed controllers, a 10 x 4.5 propeller is chosen as well.

2.3 On-Board Power Supply- The entire system is battery powered. The battery is a LiPoly 3S pack which has an output voltage of 11.1V and a capacity of 3000mAh. It is connected to the ESCs through the PCB in the frame. The electronic speed controllers (ESCs) which feature a built in battery eliminator circuit (BEC) of output 5V/2A then supplies the 5V which is required to power the microcontroller. The battery is also used to power the camera and the Sky zone transmitter.

In choosing a battery, it is usually ideal that the amperage of the battery pack should exceed that of the motor. This ensures that even when the motor is running at 100%, the battery will not hold it back. Therefore to have optimum power/weight combination, a battery pack just above the motors amperage should be chosen. The motor's amperage is calculated as follows: maximum power of motor = 270W, battery voltage (3s Li-Po) = 3 x 3.7V = 11.1V (Where 3.7V is the nominal voltage for each cell), maximum per motor amperage = 18A F or motors => 18A * 4 = 72A ….. (5)

A battery pack with amperage rating above 72A is therefore needed. For a 3 cell Li-Po battery pack chosen with the following specifications: Minimum Capacity: 3000mAh, Configuration: 3S1P / 11.1v / 3Cell, Constant Discharge: 40C, Peak Discharge (10sec): 50C, Pack Weight: 278g.

M ax Amperage is given as (3000 mAh *40C) ÷1000mA = 120 A …….. (6)

The amperage of the battery well exceeds that of the four motors and so is very suitable for the design. Also, there is a relationship between the vehicle weight and battery run time. With this, the estimate flight time of the quad copter can be determined. Firstly, the power required to produce the estimate thrust of 750g is determined. Since the motor's maximum power of 270W produces a thrust of 1718g, then the 750g thrust will be produced by: 750g x (270 ÷ 1718) W = 117.87W power.With the required power, the current drawn from each motor can then be calculated:

I =P ÷ U ……(7)

Where: I= motor current (A), P = motor power (W), U = battery voltage (V). Since 3s Lipoly cells with nominal voltage of 11.1V are being used, required current is 117.87 ÷ 11.1 = 10.62A (for one motor). F or 4 motors => 10.62 A * 4 = 42.48 A …… (8)

This is the current that the four motors will draw in order to hover the quad copter.

Since the battery capacity and current consumption are known, the length of time the quad copter can draw that amount of current from the battery can be calculated using equation (9) below.

T = (C ÷ I)* 60 …… (9)

Where T= time (min), C = battery capacity (Ah), I = current (A)

T = (3.0 ÷ 42.48) * 60 4.24 mins.

This time is the least flight time as the motors will not be operated at 100 percent power.

2.4 Image/Video capture device -The image capture device is the FPV camera (Mobius Wide Angle C Lens). It has a resolution of 5mega pixels and is capable of capturing HD videos. It is connected to a 5.8GHz transmitter which transmits wirelessly to a 5.8GHz receiver, and also connected to a computer for live feeds. The image/video capture device (camera) is mounted on the tabs at the bottom plate of the main frame. The mounting tab holds the camera in place and the wide view angle of the camera eliminates the need for a servo motor. This ultimately reduced the weight and power requirement of the entire system.

2.5 Motor Controllers (ESCs)-The microcontroller board's firmware monitors measurement devices

© 2019 IJSRET

(gyroscope, magnetometer and accelerometer) that make up the Inertial Measurement Units (IMU) to get the current state of the quad copter, along with the operator's input (desired state) and sends signals to the ESCs attached to each of the motors. The ESCs use these inputs received from the microcontroller to deliver the power required to control the speed of the motors. Each ESC has a processor, firmware and other electronics that manage this task by rapidly switching the power to the motor on and off. Each motor moves either in a clockwise or anticlockwise direction. Figure 1 below is used to illustrate the quad copter direction based on the variation of the speed of the motors.

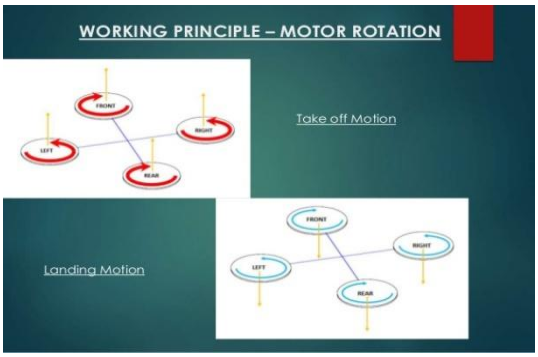

Fig.2 Basic Motion of Quad copter.

2.6 Communication System- The laptop served as the main input for control signals and the signals were transmitted to the microcontroller and vice versa through the use of the Sky zone RF modules that have been configured to communicate with one another. This is displayed in figure 2 below.

Fig.3 Communication System- the Sky zone RF Modules.

A manual transceiver was also used to override the Autopilot mode of the quad copter. Turnigy Transceiver shown in figure 3 was used. The transceiver system has a nine channel Transmitter and an eight channel receiver. It uses pulse position modulation encoding scheme at the transmitter and pulse code modulation encoding scheme at the receiver.

Fig. 4 Turnigy Transmitter.

2.7 Beta flight software- Cross platform configuration tool for Beta flight control system .Allows you to configure your aircraft via a GUI. The GUI application and flight controller are both open-source.

3. Programming of component - Getting Started -To keep this guide as simple as possible I am assuming you are running this common hardware.

- Frsky RX, SBUS and Smart Port telemetry
- F3 or F4 flight controllers running Beta flight 3.2 or newer firmware
- ESC's capable of DC Shot ESC protocol before we begin; please download Beta flight Configurator first. Here are the Steps (click to jump straight to that section).
- Update Firmware
- Setup Tab
- Ports
- Configuration
- Receiver
- Modes
- Motor
- OSD

PID Tuning

Conclusion -That's all to the basic setup in Beta flight.

IV. SIMULATION RESULTS

The data used for the quad copter simulation was based on our system design as shown in Table 4 below. The individual parameters of the components that make up our quad copter were carefully calculated. Some parameters such as Torque, Thrust and time constants were carefully estimated from already measured data of a similar system. This estimation was due to the unavailability of a test bench which was required to carefully monitor and measure these parameters.

Table4. Quad copter Modeling Parameters

Parameters	Value
Gross mass, m	1.5kg
Time constant	0.076s
Minimum throttle	5%
Thrust coefficient, cq	2.925e-9 NM/RPM2
%throttle to RPM conversion constant, cr	80.584RPM/%
Mass Moment of inertial across the x-axis, Jx	0.0085136kgm2
Mass Moment of inertial across the y-axis, Jy	0.0085136kgm2
Mass Moment of inertial across the z-axis, Jz	0.016334kgm2

© 2019 IJSRET

The PID Controller gains of the various controllers were carefully tuned and appropriate gains were chosen based on the simulation results obtained. The simulation was run for 300 seconds and graphs were generated. Here, no external disturbance was added to the simulation. The Path command was such that the quad copter will move a triangular path. From the graph: P, Q and R are angular velocities about the X, Y and Z axes respectively; Phi, theta and Psi are the Roll, Pitch and Yaw angles; U, V and W are the translational velocities along the X, Y and Z axes respectively; X, Y and Z defines the position of the quad copter along the X, Y and Z axes respectively. Response against Time The graph shown above represents a stable system. At first, there is an overshoot, but with time the controller sets each of these parameters to set point.

V. CONCLUSION

This paper designed and simulated a real time aerial quad copter for search and rescue operations. A small size, less weight, intelligent, surveillance and reconnaissance quad copter which can take the photographs from environment was realized through the aid of the onboard mounted camera while live streaming was done on the laptop during flight. After implementing and testing the quad copter, the quad copter met its weight requirement. Its approximate weight was 1.50kg. The motors and ESCs were successfully calibrated; the requirement of best minimized size was met; and communication from the ground control station to the quad copter was achieved.

1. Recommendations - The motors should be firmly fastened to the arms of the chassis in order to reduce vibrations. When fixing the propellers to the motors a washer should be added to have a firm grip to prevent it from snipping off. Spare parts should be available in case of faults or need for replacement. The use of brushless motors will help not only in reducing vibrations but also consume lesser power. Also, use light materials for constructing the chassis to reduce the weight but also strong to withstand vibration from motors and propellers. The frame should be made such that there is enough clearance between each motor to make enough room for the rotation of the propellers. The frame should be aerodynamic. Assembling of the entire system should be done such that the center of mass is concentrated at the center of the system.

2. Research for Further Study - Power Improvement: Majority of the weight / mass of the system is due to the battery. This affects the total torque/ lifting power of the quad copter. Also, batteries have very limited flight time. Research on a better alternative of power such as fuel cells should therefore be carried out.

REFERENCE

[1] Dukare, H. P., Bondre, M. B., Vidhate, A. R., Tiple, R. I. and Kumar, G. (2015). Design and Implementation of Flying Robot. International Journal of advanced Research in Computer Science and Software Engineering, vol. 5, Issue 2, pp 458 - 461.

[2] Salih, A. L., Moghavvemi, MMohamed, H. A. F. and Gaeid, K. S. (2010). Flight PID controller design for a UAV quadrotor. Scientific Research and Essays Vol. 5(23), pp. 3660-3667.

[3] Owczarek, N. & Pagano, C. (2014). DRONES: A Brief History and Design Overview. Ted Ullrich, Shelby Thompson, pp 1-11

© 2019 IJSRET