Design And Fabrication of Quadcopter For Surveillance

Karan Kumar Shaw
Dept of Aerospace Engineering
SRM Institute Of Science & Technology, Kattankulathur, Chengalpattu District, Tamil Nadu-603203, India

Abstract- *Drone surveillance is the surveillance that involves the use of Unmanned Aerial Vehicles (UAV) to capture the still images and video in order to gather information about specific targets, which might be individuals, groups or environments. Drones can be equipped with various types of surveillance equipment that can collect high definition video and still images, the speed of operation will be faster with the drones as it can continues to fly for a particular time at a desired altitude .This method saves time, money and minimizes the risk to the personnel involved in surveillance. This project aims at developing one such vehicle using Quadcopter configuration consisting of 4 Brushless Direct Current motor (BLDC) combined with suitable propeller that produces thrust of 4.8 Kg (at 100% RPM) using lithium Polymer (Li-Po) battery of current capacity of 5200 mAh and 11.1 V to meet the required current and voltage requirements. A HD First Person View (FPV) camera along with its transmitter is placed on the drone for surveillance. These UAVs can also contribute to the reduction of risks for security staff. The system provides real-time access to aerial data without jeopardizing guards safety.*

Keywords- Surveillance, Camera, Drone, Flight Controller, Image, main frame.

I. INTRODUCTION

Surveillance drones are the ideal solution to the problems faced by traditional security and surveillance methods as it allows for faster, more cost-effective and more efficient data collection. It offers coverage of areas with less blind spots. They also give the ability to access distant locations and monitor the area while seeing real-time action. This is useful in cases where security staff is limited, and large areas need to be monitored. Risk is reduced, ensuring the security and safety of facilities, assets and most importantly personnel executing security and surveillance operations. This project describes how an aerial surveillance system can be built using an unmanned aerial vehicle or a drone. We start by studying the features of our aerial surveillance system and then discuss some of the techniques that we have used in building it. After that we mention how we have incorporated those techniques into a drone and have made them work together harmoniously in order to achieve our desired aerial surveillance system. This system will be a convenient and efficient alternative to current Surveillance Systems. The drone provides fast and efficient surveillance at an affordable rate so that it can be used widely at private, institutional and by the government.

II. LITERATURE SURVEY

One of the most important things while writing any research paper is through and detailed study of various journal concerned to my work which is foremost preliminary step for proceeding with any research work writing. Herewith mentioned of the some of the surveyed papers:

Eluwande et al. (2016) [1] proposed a possible solution to monitoring the vast pipeline network across Nigeria using quadcopter It is also designed to catch any crude oil theft of pipelines by sending alert message directly to the control centre. Their pipeline monitoring system consists of microcontrollers, sensors and a GPS module with message consists of attack.

Adarsh. A et al. (2018) [2] have published a Research paper in International Journal of Trend in Scientific Research and Development on surveillance of fruit farm using drones. The drone is designed in such a way that it identifies the water, pesticide and fertilizer requirement of plant and the drone also collects the data of condition of fruits in the trees using Image processing Technique. The drone was also used to avoid bird feasting in the plantation area.

Prof. B. Balaji *et al.*(2018) [3] developed an hexacopter UAV with the purpose of spraying pesticides as well as crop and environment monitoring using Raspberry Pi that run on python language. Their UAV also contains multiple sensors like DH11, LDR, Water Level Monitoring sensors. From this experiment, they finally concluded that with proper implementation of UAVs in the agricultural field almost 20%-90% savings in terms of water, chemical maltreatments and labor can be expected.

Péter Miksa et al. (2019) [4] published a research paper on Drone Systems for Factory Security and Surveillance, which describes technical implementation in modern drones are assisted by various sensor systems (lidar, ultrasound, camera) that they are equipped with and the application of task-specific drones in industrial areas. The drone sensor system assists in the safe execution of tasks both indoors and outdoors.

Rahul Desale *et al.* (2019) [5] described an architecture based on UAV that could be employed for agricultural applications. Their UAV was designed not only for spraying but also for monitoring agricultural fields with the use of cameras and GPS. Their design was optimized for cost and weight. They used a microcontroller kk 2.1.5 which has inbuilt firmware.

III. DESIGN AND WORKING OF QUADCOPTER

Any aerial vehicle works on the simple principle that when the thrust exceeds its weight, it lifts off. In order to design a Quadcopter, we need to estimate our payload, then with respect to the weight of the motor, propeller, ESC, FPV camera and video transmitter has to be selected. Battery is also selected accordingly by knowing the current and voltage requirement of the electronic components. Then the thrust required has to be formulated and finally the frame of the drone is designed depending upon the required arm length and application of payload.

A. Payload Estimation

The main payload for the surveillance drone is the FPV camera and video transmitter. Therefore, payload is estimated from the values obtained from manufacturer's manual.

Table 1- Payload Data

PARTS	WEIGHT (grams)
Camera	12
transmitter	58
Total	70

B. Construction

This project elaborated the design and fabrication of quadcopter for surveillance, where the prefix quad-copter implies ("quad" = four), the drone having four arms. Two hollow square tubes of length 441mm are joined together to form the main frame of the drone. Every arm-end of the copter consists of motor which will be the fixed along small landing frame at its bottom and its respective propeller which is mechanically coupled to the motor. The same configuration is followed on every arm of the quadcopter. For each motor, the output of the Electronic Speed Controller (ESC) will be connected and input side of the ESC will be connected to the flight controller. The other input of the ESC will be connected to the power distribution board where Li-Po battery supplies the power. In the similar way, all other ESCs, motors and propellers are connected. A receiver receives the signal from the transmitter is connected to the flight controller. An FPV camera along with its transmitter is also connected to the flight controller.

C. Working

The Transmitter transmits the signal which is being received by the Receiver on the drone. The signal from the receiver goes into the Flight controller where it is processed by the accelerometer and gyroscope sensors. The processed signal is sent to the ESC which controls the amount of current drawn by the motor depending upon the signal it receives. The propellers are mechanically coupled to the motor which rotates about its axis and produces thrust. The FPV camera takes current supply from the flight controller and it records the video, the video signals will be processed by the transmitter and it will be received by the receiver on the ground.

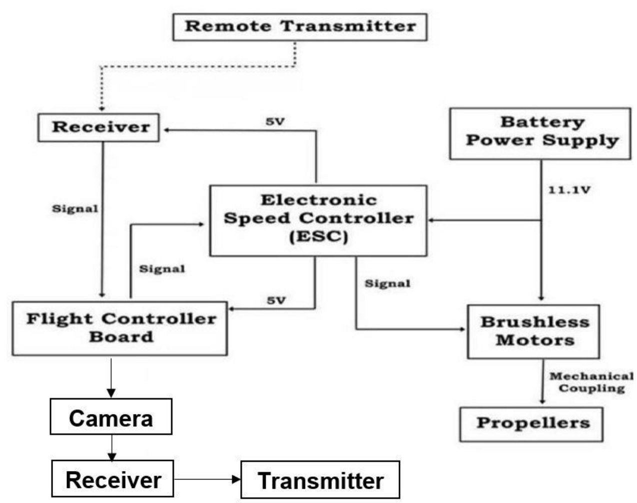

Figure 1-Block Diagram for Working Process

IV. ELECTRONIC COMPONENTS

A. Motor

The selection of motor involves comparing the data sheet of various models and selecting the one which produces higher thrust with lesser current intake. The motor which we have used here is BLDC outer runner A2212/6T having 2200 KV rating that produces maximum output of 24,420 RPM.

Figure 2-Selected A2212/6T Motor

B.Propeller

The selected motor operates with 10 x 4.5 inches propellers. APC propellers which are made up of long glass fibers or long carbon fibers with a Nylon matrix is most suitable for this design owing to its high strength to weight ration.

Figure 3-10 x 4.5 inches Propeller

C.ESC

It is abbreviated as Electronic Speed Controller and is used for controlling and regulating the speed of an electric motor. Based on Motor manufacturer’s manual, a 30A rated ESC best sits with selected motor and battery. It provides cut-off voltage of about 3.3 V.

Figure 4-30A rated ESC

D.Battery

In case of drones, a rechargeable battery of lithium-ion technology using a polymer electrolyte is commonly used. Depending upon the overall weight, the battery that can be used is ORANGE 5200/3S-40 weighing 360 g having current capacity of 5200 mAh with Voltage of 11.1 V (3x3.7=11.1v).

Figure 5-5200 mAh Battery

E.Flight Controller

The flight controller is programmed with various flight operations and is proffered with Auto level function. It consists of sensors like accelerometer and gyroscope that receives the signal from the receiver and forwards it to the ESC. The KK 2.1.5 Multi-Rotor LCD Flight Controller is most suitable depending upon the mission requirements as well as owing to its inbuilt firmware.

Figure 6-KK 2.1.5 Flight Controller

The sensors used in the Flight Controller are:

1)Accelerometer-Accelerometers provide information about drone acceleration/acceleration forces in X, Y and Z axis. When drone stays perfectly still, it will report only one acceleration: 1g of Earth’s gravity pulling it down to the ground. When drone is banked left 90 degrees, Z axis would report 0g, but Y would report 1g. Accelerometer data is used to determine where is up, where is down and what is current attitude.

2)Gyroscope- Gyroscope is the sensor that drone needs for stable flight. It gives information to the flight controller on how fast aircraft is rotating around its own axis: roll, pitch and yaw. A gyroscope is used in an aircraft to help in indicating the rate of rotation around the aircraft roll axis.

F.Radio Transmitter and Receiver

The most commonly used transmitter and receiver that matches the given flight controller and coordinates with selected electronic components are FlySky CT6B 2.4Ghz 6CH and FS-R6B respectively. This configuration provides upto 6 channel options and range of about 1000 meters.

Figure 7-Transmitter & Receiver

G.FPV Camera and Transmitter

The most important part about designing a surveillance drone is the selection of the camera. Being the most sensitive part in the drone, it is important to decide the correct location of camera so as avoid any damage during crash landing. The cam which can be used here is HD FPV camera with following specifications like Horizontal resolution: 1200 TVL, lens:2.5 mm, image sensor: 1/4 CMOS SUPER HAD II / 1/3 CMOS SUPER HAD I, Day/Night: Auto/Color/B&W with current consumption of 320 mA.

Figure 8-FPV Camera

Figure 9-Video Transmitter

5.8G UVC receiver is used to receive the video signals. It can be connected to the android mobile which has installed the GO FPV application in it.

Figure 10-5.8G UVC receiver

V. THRUST CALCULATION

Based on the specifications of the selected electronic components, the weight build-up is made for the drone.

Table 2- Weight Build-Up

PARTS	WEIGHT (grams)
Main Frame	244
Landing frame	300
Battery	360
Motor (4)	232
ESC (4) + power distributor	128
Propeller (4)	34
Flight controller	20
TOTAL	1318

The overall weight of the drone is calculated by adding the total weight of components and the weight of payload.

Overall weight = payload + weight of components
= 70 + 1318
= 1388 grams (approx.)

Thrust produced by one propeller with one motor= 1200 grams
Total thrust produced = 4x1200 =4800 grams
Thrust to weight Ratio= Thrust produced / total weight of drone
= 4800/1388
= 3.45 : 1

VI. BATTERY DRAINAGE TIME

The motor used in the drone is A2212/6T 2200kv motor and the propeller used is a 10 x 4.5 propeller. This combination produces 1200 grams of thrust at max RPM with 3s battery that is validated practically using motor testing jig. It consists of movable plate where motor is attached and fixed plate that holds the spring balance which records the thrust horizontally.

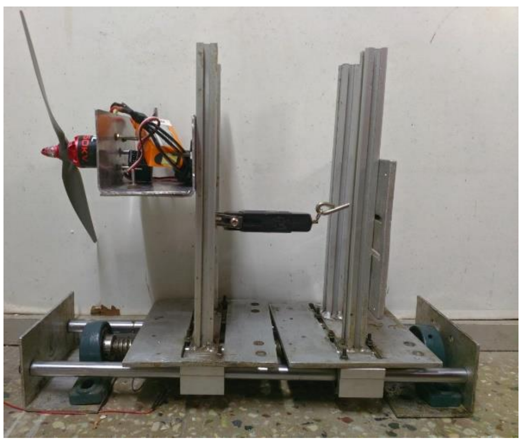

Figure 11-Motor Testing Jig

Accordingly, Table 3 lists out the amount of current drawn from various electronic components.

Table 3- Current Requirement Table

COMPONENT	CURRENT REQUIRED (Amp)
Motor	48
Receiver	0.1
Flight Controller	0.1
ESC (4)	0.8
Camera	0.32
FPV Transmitter	0.31
TOTAL	49.63

Current output from battery= 5200 mAh
Total current consumption of all components =49.63A
Battery endurance = current output from battery/ Total current consumption of all components
= 5200 mAh /49.63A
= 5.2Ah /49.63A
= 5.2*60A min/49.63 A
= 312 Ampmin /49.63Amp
= 6.28 Minutes. (AT 100% THROTTLE)

Since thrust to weight ratio is 3.45 : 1, the drone starts flying at 30% of throttle and if the maximum throttle is controlled within 60% then the current consumption of motors will differ so the battery drain time at 60% will also differ. At 60% of throttle the current consumption of the motor is around 7.2A for each motor, so total current consumption of all 4 motors at 60% of throttle is 28.

VII. STRCTURAL DESCRIPTION

There are no such specific frames which is considered to be best among all the frames, however its selection is guided by number of factors like multi-rotor configurations, stability and rotating moment, component implementation, material, weight etc. Based on the size and dimensions of selected electronic components, the base plate is figured into 10 x 10 cm in shape of a square. All other dimensions are elaborately mentioned in the figure 12.

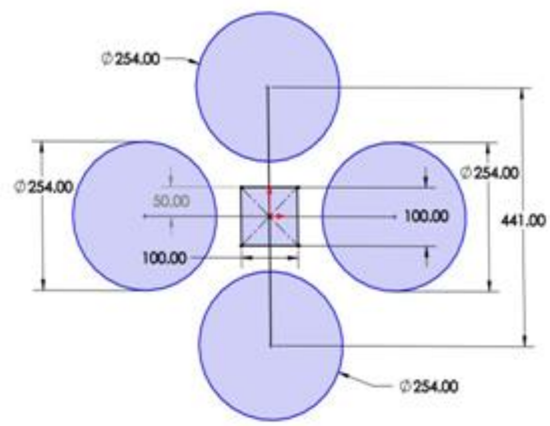

Figure 12- 2D Drawing

In this design, the arm length is determined considering the diameter of propellers and maintaining a gap of atleast 5 cm between them. Other factors that are kept in mind, while calculating arm length is maximizing the thrust, reducing weight of the frame and providing required rotating moment.

The main frame consists of four straight arms of hollow square cross-section. These hollow sections have excellent static properties, not only with regard to buckling and torsion, but also in the overall design of members. The material used to make the drone frame directly affects its stability and performance. Therefore, aluminium square tube of 2 mm thickness is used to fabricate the main frame due to its light weight and high yield strength. Two square tubes of length 441 mm are joined together using lap joint at the centre.

TIG welding is done at the point of contact of both tubes. At the arm end, suitable holes were made for the attachment of landing frame and motor. Figure 13 shows the prototype model made for this project.

Figure 13- Image of Prototype Model

VIII. STRUCTURAL ANALYSIS

While designing structures, it is very important to perform analysis as it helps to point out flaws and weaknesses inn the design. It also checks whether the specific structural design will be able to withstand external and internal stresses and forces.The main frame of the drone is analyzed in two methods.

1)Theoretical Calculation:

Considering the arm as cantilever beam, its deflection value is calculated under basic loading conditions of Load at 100% thrust that is 1200 grams at each free end The formula implied over her is: Deflection (D) = $WL^3/3EI$, where W=load acting on the frame, L=Arm length, E= Young's modulus,I=Moment of inertia. is taken into consideration.

$= 1.2 \times 9.81 \times (220.5)^3 / (3 \times 70000 \times 10.86 \times 10^3)$

$= 0.0553$ mm

2) Static Structural Analysis

The 3D geometry of the frame is made in CATIA V5 software and is imported in IGES format into Static Structural Analytical System of ANSYS workbench 19.1. Static structural analysis is performed onto the frame by applying aluminium alloys as material and forces like thrust at each arm end while the weight of the frame acting vertically downwards at CG. The type of meshing used here quadratic tetrahedron with better meshing quality. On applying suitable boundary conditions, the maximum deflection obtained at each arm end is 0.082 mm as evident in the figure 14.

Figure 14- Deflection of Main Frame

IX. STABILITY AND CONTROL

The direction of rotation of propellers is opposite to each other at all four sides.Rotational moment produced by rotating the propeller at one side will be nullified by the rotational moment produced by rotating the propeller at the other opposite side. Hence the stability is achieved.

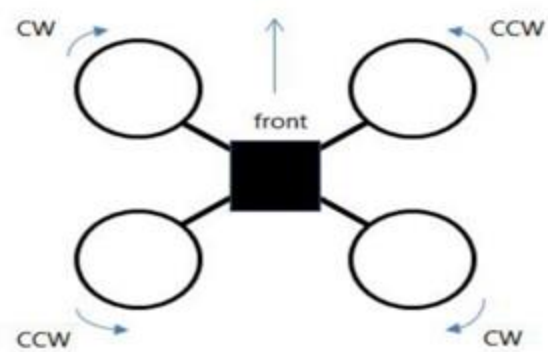

Figure 15- Rotating Moment Diagram

Direction control for quadcopter illustrates that when the throttle stick in the Transmitter is moved upward then all four motors will rotate at the same RPM with respect to the throttle level but two motors will rotate in clockwise direction and two motors will rotate in counter clockwise direction.

When the stick at right side of transmitter is moved left, the motors 1 and 4 will rotate at higher RPM than the RPM of motors 3 and 2. So that the right side of the quadcopter has more lift and hence the quadcopter moves towards left side. The same will be applicable for moving right side but only the RPM of motors at left side will be more.

Figure 16- Transmitter Controls

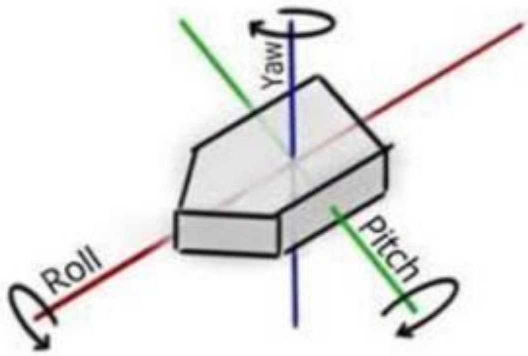

Figure 17- Basic Directional Control of Drone

X. RESULTS OBTAINED

The prototype designed based on the calculations as mentioned in this paper has undergone multiple flight tests with good results reaching the altitude of. Due to its higher thrust-to-weight, it offers extreme maneuvering with longer battery duration. The camera with its inbuilt gimble provides safety to the device. Figure 17 shows the image from the Go FPV app installed in android mobile with its first-person view.
Figure 18- Image from Go FPV App

XI. CONCLUSION

This paper elucidates design and development of the drone for Surveillance missions. Various journals and research papers were reviewed in order to determine appropriate dimensions and electronic components. The study contemplates in different aspects like thrust calculation, battery endurance, stability etc. The structural component is examined with both theoretical and Static Structural Analysis. The prototype fabricated based on these calculations shown successive flight tests with better maneuvering and stability.

The proposed design aims to maximize thrust-to-weight ratio with lesser mission execution time and higher endurance. The drones need to become smart and quick-witted in order to optimize industrial processes, maximize their utility and can be widely established in future factories. If more emphasis is laid upon these criteria's, they can be appertained in engineering, maintenance, critical infrastructure management and asset management operations. Implementation of drone system in the industry can boast new opportunities and new innovative business models. There are nearly 35 drone Start-Up companies in India and they are trying to impose these innovative technologies into their systems to make their processes safer, more reliable and more predictable. From the industrial point of view, implementation of this technology can be ideal in the automotive industry.

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