DESIGN AND FABRICATION OF UAV FOR DEFENCE APPLICATIONS

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Abstract

In the present day with growing technology the Unmanned Aerial Vehicle (UAV) designed have limitless applications. These days UAVs are widely used in military operations, surveillance purposes and in Industries because of their reliability, size, cost effectiveness and multi-functionality. The number of automobiles is increasing by leaps and bounds. This is creating traffic congestion and increased pollution levels. UAVs are being developed keeping in mind all these aspects. An UAV can move from one place to another effortlessly. It can cover more distance in less time than conventional modes. This paper discusses on the Design and Assembling of an UAV for Defence Applications. UAVs can be used for reconnaissance and collecting data. UAVs can be controlled manually or automatically with encryption of the map-coordinates for added security. Features like Obstacle avoiding, GPS and Pick and Drop finds application in UAVs.

Keywords: Flight Controller, Arduino, Electronic speed controller, BLDC Motors, Servo Motor.

I. Introduction

Quadcopter is a classification of UAV which has 4 rotors. It is also referred as Drone. The drone is abbreviated as Dynamic Remote Operated Navigation Equipment. These play a vital role in surveying sites, signs of illegal trapping. These vehicles are the first successful heavier than air vertical take-off and landing (VTOL) vehicles. These UAVs use an electronic control system and sensors to stabilize the UAV. It is used for country border protection [I-II].

The drone has 2 sets of identical angled propellers: one pair of clockwise (CW) and another in counter clockwise (CCW). This clockwise and counter clockwise rotation is used to prevent the UAV from rotating itself. The movement of the drone can be measured by thrust and torque. The rate of change of rotor discs is used to control drone thrust and torque load characteristics. The propellers are attached to BLDC Motors to create thrust and help the UAV to lift up. The movement of the drone is
calculated by the given input values (x, y, z, θ, ϕ, ψ) [VI]. The motion of the drone is controlled by three properties. These properties are classified below and the schematic representing roll, yaw and pitch mechanisms are shown in Fig.1.

![Fig.1.Roll, yaw and pitch in drone](image)

**A. YAW ROTATION:**

Yaw refers to the rotation around the vertical axis and lies perpendicular to the propellers of a UAV and lies in the centre line. Yaw changes the direction of the UAV; it is controlled by a rudder stick in the transmitter. The angle is examined by rising-up/down counter-clockwise RPM while reducing/rising CW rotor speed [IV].

**B. PITCH ROTATION:**

Pitch is used for the UAV movement in backward/forward directions. It is leading the aileron stick in the transmitter. Moving the stick in the transmitter decides the movement of a UAV. It is the rotation of the vehicle fixed on the side axis or the lateral axis. If the pitch is positive then this would raise the front end and lower the tail end and cause movement respectively and vice versa.

**C. ROLL ROTATION:**

Roll is defined as the rotation of a vehicle on the front and back axis or the longitudinal axis. The port or proper action of the rudder rod of the drone. Roll is guided by the transmitter when the stick claims the directions. This parameter makes the UAV stable and helps the UAV to move in the proper direction.

**I. BLOCK DIAGRAM OF THE PROPOSED UAV**

The developed UAV’s Block Diagram or Schematic is as shown in Fig.2.
Table 1: Weights of components in UAV

| S.NO | EQUIPMENT                  | QUANTITY | WEIGHT (IN GM) |
|------|---------------------------|----------|----------------|
| 1    | ArduinoMega               | 1        | 40             |
| 2    | Gyroscope                 | 1        | 20             |
| 3    | ESC                       | 4        | 40             |
| 4    | Motor                     | 4        | 60             |
| 5    | Receiver & Transmitter    | 1        | 20             |
| 6    | Propellers                | 4        | 20             |
| 7    | Li-Po battery             | 1        | 200            |
| 8    | Ultrasonic sensor         | 1        | 30             |
| 9    | Servo Motor               | 1        | 30             |
| 10   | Frame                     | 1        | 360            |
| 11   | GPS                       | 1        | 100            |
|      | **Total Weight of Components in UAV** | **1214** |
Let \( W \) be the weight & \( T \) be the thrust produced

\[
W = 1.25 \text{kg (approx)} \quad (1)
\]

Each motor can produce the thrust of 0.7kg

\[
T = 4 \times 0.7 = 2.8 \text{kg} \quad (2)
\]

Therefore, thrust to weight ratio from the equations (1) & (2),

\[
\frac{T}{W} = \frac{2.8}{1.25} = 2.2:1
\]

Now, consider thrust to weight ratio 2 : 1

\[
\frac{2}{1} = \frac{2.8}{W_m} \quad (3)
\]

Where, \( W_m \) = maximum weight of the system.

From the above equation (3),

Therefore, mission pod (\( M \)) is

\[
M = W_m - W = 1.4 - 1.25 = 0.15 \text{kg} \quad (4)
\]

Based on the above equations, the weights of the components are calculated.

**II. Components of UAV**

The UAV is controlled by the Arduino and acts as the Flight Controller. The UAV originally consists of several electronic parts including sensors like the ultrasonic sensor and Gyroscope. The UAV is elaborated to perform a real-time operating system. This UAV uses the 6 Channel Transmitter receiver connected to the flight controller board to control the movement of the drone. The equipment consists of an Arduino (Open Source), ESCs, Transmitter & Receiver, Telemetry, Gyroscope, Servo Motor, Ultrasonic Sensor, GPS module, Propellers, LiPo Battery, Frame.

**A. UAV FRAME**

There is no particular design for designing Drone. With the developing research, new designs are created. Carbon fibre plates and arms are used for strength, lightweight and durability of the frame. The arms are made of robust polyamide nylon with a particular design to increase the strength while keeping the weight at bay and has screws attached to main glass fibre PDB to hold the frame. The frame has a Power Distribution Board built into it. The battery is set on the bottom side of the drone to set the Centre of Gravity low which consequently increases adherence to ground and aids in stability. The rotors are set equidistant from the centre on the four sides. The
distance between the motors is set so that there is no aerodynamic interplay between the propellers. The frame used for the UAV is as shown in Fig 4.

Fig.4. F450 UAV frame

The most commonly used structure measurements for a drone are 180 mm, 250 mm, 350 mm, 450 mm, 500 mm, etc [III]. We have taken the structure size of 450mm. We have used glass fibre + polyamide-nylon which has built-in PDB as a frame material. This Frame has higher flexibility. It is easy to mount various components like Arduino, Battery, GPS module, etc. It has an excellent lightweight properties and strong landing gear made of carbon fibre and Printed-power Distribution Board (PDB) for neat and easy wiring. The frame we used is built up of glass fibre and the branches are made of ultra-durable polyamide nylon. This combination makes a pretty flexible and strong multirotor structure UAV.

B. ARDUINO MEGA:

The Arduino Mega is chosen due to the greater number of pins. There are 54 digital (I/O) pins & 16 AI Pins. This has a 16 MHZ crystal oscillator. It operates on 5V DC. The input can be supplied with input DC voltage of 7–12V(recommended). It has a memory of 256KB of which 8 KB is used by the bootloader. Its brain is an ATmega2560 microcontroller which controls all the functions of the Board. We can reset the Arduino by pressing the reset button which erases everything stored on the board. It can be connected to the computer by USB cable. A power port is available on the board for DC input from a DC Supply. Arduino can be easily programmed, and various functions can be performed. Depending on the application Arduino models can be chosen to suffice the requirements, size constraints and weight constraints.

C. ELECTRONIC SPEED CONTROL

Esc is an electronic circuit that is used to maintain the acceleration of the rotor rotation. An electric motor rotates due to the attractive forces that are designed with the stator coil windings and permanent magnetite’s which are rotor. ESC has three output terminals which are connected to the terminals of the 3 Phase BLDC motor of the UAV. The battery of the UAV is directly connected to the Esc. The maximum
current flow through the ESCs used is 30 Amps. It converts the PWM signal received from the Arduino and then gives proportional output and drives the BLDC motor by providing required high electric power. The electronic speed controller is fabricated on the 32-bit microcontroller architecture and has an array of MOSFET to drive the BLDC motors. It has a signal wire and two output supply wires which supply components on-board at a constant 6.6V DC. The signal to the ESC is given from the Arduino.

D. BRUSH LESS DC MOTOR

Brushless DC motor is an electronically commutated motor. These are simultaneous rotors and are powered by a 3 Phase Supply. An Electronic Speed Controller Unit is used to produce an alternating signal to start the rotor. Each brushless motor has three copper windings evenly separated by the fixed part of the motor, known as the stator. Permanent magnets are fixed on the rotating part of the motor which is called the rotor. These rotors are where the propellers are attached and are built with a perpetual attraction rotor and wire-wound stator poles. The rotor will begin to rotate when two of the three windings are supplied with a potential difference, creating a magnetic field. Electrical power is transformed into mechanical power by the magnetic forces acting in the motor and the wound stator poles. A 3-phase star connection is used in BLDC motor. A rotor by the connection is made by stimulating 2 Phases at a time. The motor is rotated clockwise 60 degrees from one point to another point alignment by changing the flow of current from one terminal to another terminal. In real-time supreme torque is produced when the perpetual attraction rotor is aligned 90 degrees apart of the stator attractive field. No brushes are used for commutation in these motors. Both are commutated electronically and the chief plus-points of those devices are N vs Torque characteristics. High performance with Noise free movement and attain extremely high-speeds and more prolonged service life. We need an ESC to control this type of motors. There is no sparking and no considerable electrical noise is produced. These are rated in KVs like 850 KV, 1000KV, 1200 KV, 1400 KV, and 1800 KV. We have used a 1000KV motor for this project. The BLDC motor rated 1000KV spins 1000 times per volt with the application of the 1Volt potential difference. Four BLDC motors are used in the UAV. These motors will produce the required torque and lift.

Considering the weight of the UAV, 30A ESC and 10*4.5 or 9*4.7 propellers are used.

- Max Efficiency: 80%
- Max Current: 12A
- No Load Current (10V): 5A
- Max Watts: 150w
- Max Efficiency Current: 4-10A (>75%)
- ESC Recommended: 18A (Minimum)
E. ULTRASONIC SENSOR

This sensor is used extensively to gauge the gap to an object by beaming ultrasonic resonance which are inaudible to the human ear. It computes gap by beaming a pitch at a defined wavelength and receives this sound loop after bouncing/reflecting of an object whose distance is to be measured. The flow chart for the functioning of the ultrasonic sensor is as shown in Fig 5. The time of sound wave produced also the sound wave reaching behind is recorded as the time elapsed, the distance between sensor and the object can be calculated.

\[
\text{Distance} = \frac{\text{Sound Speed} \times \text{time taken}}{2}
\]

We used HC-SR04 sensor for ranging the distance. It has a range of 0.02m to 4m of analysis functionality with has mastery of about ±3mm.

There are four pins that you need to connect in HC-SR04: VCC (power), Trig(Trigger), Echo(Receive) & GND(Ground).

- Operating Voltage: 5V DC
- Operating Current: 15 mA
- Measure Angle: 15°

![Fig.5. Flowchart of Functioning](image)

F. SERVO MOTOR

This device is used to incorporate self-regulation technology. Servo is a self-sustaining electronic device that turn with great precision and control [V]. The angle of the motor is based on the shaft movement. The shaft rotates to about 180° angle.
The shaft movement is regulated by a speed controller for tremendous torque and precise positioning. These are available in power rating from a part of a watt to 100 watts[VI]. The range of signal controls makes the rotor to revolve in CW or CCW direction, at varying velocity, depending on the control signal. It is utilized in the UAV for pick and place application[VII]. The servo motor is controlled by the Arduino Mega on-board. When a signal is sent to the Arduino from the Transmitter, the Arduino sends a proportional output Signal to the Servo motor and controls the required output.

G. TRANSMITTER AND RECEIVER

Radio control can be defined as controlling a device remotely by employing radio waves as propagation medium. Radio transmitter transmits radio signal at 20 Decibels to remotely control UAV wirelessly via the receiver. The signals transmitted by transmitter are received by the receiver on the UAV and sends corresponding signal to the Arduino. The hand-held radio transmitter has two sticks to control the motion of the UAV and other buttons to control the extra functionalities. Military, Industrial and scientific research organizations use RF controlled drones. The number of channels in transmitter defines the number of operations the UAV can perform or that can be controlled by the operator. The stick handle of the radio transmitter is called as gimbal. The RC System uses a 2.4GHz radio frequency. Other details of the two different modes are elaborated in the PID tuning section. Receiver is connected to the Arduino for the decoding the signal that is send from the transmitter. The transmitter is powered by the battery (3.8-7.8V). The energy in a high-speed reversing current radiates off as electromagnetic waves (RF) from the antenna. The transmitter stores information of the signal, to the radio frequency current which are to be carried by the RF waves. The four channels are used by the Arduino to control the motors. Rest of the pins are used for the special function like Pick and Place via a servo motor etc. The Fig 6 gives the block diagram of the RC System.
The details of the transmitter used for fabricating UAV:

- Support up to 6 channels at 2.4 GHz
- Range up to 305 meters (1000 feet)
- Support DSM2
- Easy to interface

H. BATTERY

To fly the UAV, a high-power, lightweight, reusable, high discharge power supply which is enough to fly the drone is required. Rechargeable batteries are used due to its reusability. We used a LiPo battery to power the drone because it is the battery with high power density and has all the required characteristics to be selected for the purpose of providing power supply for a considerable flying time. It is the best type available now for the purpose.

LiPo batteries hold about 30% more capacity than a NiMH battery. LiPo has high discharge rate too compared to other types. LiPo batteries have a lower memory loss effect. If a cell is discharged below 3Volts its resistance increases exponentially. Due to these reasons, LiPo batteries are used for the UAV. LIPO battery should be charged with a balance charger. A 11.1V3 Cell RC LIPO battery cell reaches 12.6 volts when fully charged. This package can provide enough power to fly the drone for long at a constant current rating. A 25C3S LIPO battery is used for the UAV.

III. Propellers

A propeller is mounted to each BLDC Motor. The 4 propellers used differ in the orientation. 2 are CW and 2 are CCW. The word CW means clockwise direction & CCW means counter clockwise direction. We used a 10 x 4.5 CW and CCW propellers to meet requirements. The 10 defines the diameter of the propeller and 4.5 is the pitch of the propeller. Size of propellers varies with respect to the torque and speed characteristics of the BLDC Motor. Large sized propellers are used for carrying heavy objects like camera etc. CW and CCW propellers are attached to motors alternatively. The correct propeller is attached to the motor to match the rotation before giving the supply.

IV. Gyroscope

This is used for measuring angular velocity. This sensor can sense rotational movement and changes in adjustment and enlarge action. UAV requires a sensor to stabilize the drone during its flight. L3G4200DH is a low power sensor with a sensing component and an IC interface which has capability to provide the measured angular rate through I2C & SPI digital interface. The amount voltage varies of 2.7 to 3.6 V. The output can be taken as digital, Analog, linear. Depending on the signal from the gyroscope the Arduino gives the output to the ESCs in such a way that the UAV is in a stable position.
Model aircraft navigation systems uses 3-axis angular rate sensor (yaw, pitch & roll).
- Support both I2C and SPI for whichever method of communication for desire
- Three selectable scales: 250/500/2000 degrees/sec
- 16 bit-rate value data output.

The fabricated model of UAV is shown in the Fig. 7.

![Fig. 7. Fabricated model of UAV](image)

V. Results and Discussions

A. UAV TRACKING USING GPS

GPS means Global Positioning System. The GPS is used for the Global Navigation Satellite System (GNSS). The GPS device can salvage data from the GPS Satellites around it.
The GPS location coordinates can be obtained in all weather conditions, anywhere irrespective of the location or territory. GPS data is obtained by the GPS Module which acquires data from four or more satellites in clear sight. The detection may be less accurate due to the interference or blockage of the signals if otherwise. The Fig.8 and Fig.9 is an example for the function.

In GPS we have different types 2D & 3D. We have used 2D GPS Module which gives only latitudes and longitudes whereas 3D GPS can give height, longitude and latitude.
But GPS is limited to about 15 meters accuracy even without SA (selective availability). It can attain highest level of subtlety, accuracy and TTFF with lowest power usage in a little package.

**B. ON FLIGHT SIMULATION DATA:**

From Fig.10 and Fig.11 The Thrust vs. RPM and Current vs. RPM graphs give us the load characteristics and the power load on the UAV.

![Fig.9. Distance from Base to UAV](image_url)

![Fig.10. Motor Thrust vs. RPM](image_url)
From Fig. 12 and Fig. 13 gives the details on the data with respect to the stick position acquired during testing.
VI. Conclusion

The UAV developed can be used for military and defence purposes. This UAV can avoid obstacles, surveillance and perform pick and drop of objects. The UAV’s functionalities can be easily added or removed by changing the code (program) in the Arduino. The base code remains unchanged while other functionalities can be added to the source code. The main intention of developing this system is to bring down the rate of accidents and illegal activities to a minimum, also to reduce impact in case when the drone losses its control due to RF interference, loss of signal, failure of receiver and lack of experience of the operator. This system can be used in defence sector where the drone will be used for long range operations. We have developed this system to produce a low cost and highly effective obstacle avoiding UAV which can have other functionalities added to it due to the use of Arduino as the flight controller which can be programmed easily, and different functionalities can be run simultaneously. We hope this system can make a leap in the field of safety aspect by employing UAV which is a most discussed topic.

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