DESIGN OF FLIGHT CONTROL FOR HYBRID VEHICLE

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Abstract— *The mission of the paper is to design of flight control for Hybrid Vehicle that is capable of flying in Fold (shorter arm length of the vehicle) and unfold mode (larger arm length of the vehicle). Fold mode is especially required to navigate through narrow passages during indoor navigation The results of eCalc calculator shows that the vehicle exhibits more agility in fold mode of the Vehicle and literature survey reveals that greater the arm length greater the stability in unfold mode..*

Keywords—*stability, agility, unfolded UAV, folded UAV, controller for retraction and extension of arms.*

1. Introduction

UAVs are increasingly being used in civil and military applications which indirectly create an importance on controller. Quadcopter is called as rotorcraft where it has four rotors with the fixed wing where the pair of rotors makes the mechanism by two are rotating in clockwise direction and other two are rotating in anticlockwise direction. They produce lift, thrust is obtained by controlling the speed of the rotors which enables the movement of the quadcopter.Hence thrust and torque can be generated. It is also called as multirotor and a Foldable aerial vehicle consist of self-deployable arms and methods to deploy the vehicle are disclosed in the literature survey. The arms have patterns which allow the arms to retract between wrapped, flat and deployed configurations automatically without user interface. Aircraft with self-deployable arms with its own patterns without any user interface [1][6][9][10][15].

Symmetrical shaped central frame secured top and bottom plates and having four corners. Corners are diagonally outwards and receiving avionics packages. Boom arms are complementary dimensions, arranged parallel in retracted position for storage and transport [2]. An unmanned Aerial vehicle (UAV) consists of a central body or frame, which has multiple arms extending from it. The purpose of the arm is to contain and support one or more propulsive units. Each arm can be configured to operate in two flight configurations namely, a flight configuration wherein the arm is extending away from the body and the other flight configuration wherein it is folded against the central body. At least one of the arms is arranged such that the rotor blade(s) of the propulsion unit rotates in the first direction when the arm is in extended configuration and rotates in the second direction when the arm is in compact configuration, wherein the first and second direction are not similar. Provisions are made for the systems .methods and assembly kits relating to the foldable multi-rotor vehicle. The unmanned aerial vehicle is ergonomic and compact and can be easily folded and carried around [3].

The portability factor of an UAV can be improved if it is transformed into a foldable one. This concept comprises of two rotor modules with atleast one rotor hinged to the vehicle by hinge shaft. The flying and folding demands are met by rotation of rotor modules. The flight path and control module will be placed inside the vehicle path or than the rotor modules so that the control reliability is improved [4][7][8].

2. Comparison of '+' and 'X' Configuration

For a '+' and 'x' configuration vehicle will feel different to the pilot with same motors and software settings. To Find Torque:

1. For '+' configuration,

T=F*D (1)

Where T= Torque, F= Force, D= Distance from the center.

2.For 'x' configuration though it has two motors that are aligned 45° to each other respect to the axis of frame,

T=F*D*cos(45°) (2)

Moment of inertia is same for the both of the configuration. In 'x' configuration it has two motors rotating opposite side to each other in the front than '+' configuration which has only one arm with motor. Therefore, there is more torque available for 'x' than '+' configuration. Since 'x' has more torque it produces 41% more angular acceleration than '+' configuration. In case of Yaw Visibility On flying the pilot can see two of the four arms of the quadcopter due to the frame shape and other accessories. For 'x' it has two marked front arm and yawing motion is easily visible. For '+' configuration it has only one marked front arm so it is difficult for pilot to recognize the yaw motion. In case of Camera View: For 'x' the camera mounted in the front without any obstruction from the propeller and arm. For '+' though it has only one arm it is difficult to get a clear view to the camera.(Sometimes this concern for a '+' configuration can be rectified by placing the camera with a stand on the top or placing at the bottom)[5][11][13][14].

3. Design and Testing of Hybrid Vehicle

Fig 1: Design of Unfolded frame of Hybrid Vehicle (0degree)

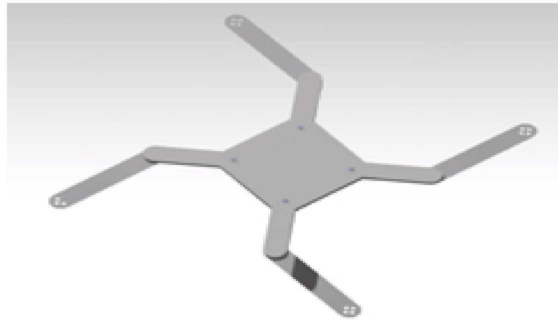


Fig 2: Design of Folded frame of Hybrid Vehicle (45degree)

Fig 3: Design of Folded frame of Hybrid Vehicle (90degree)

The diagram output of Hybrid Vehicle using CATIA software is designed and based on the foldable arm quad frame. This design has perfect constraints and materials applied. The dimension of the frame is designed based on the other parameters such as motor configuration, electronic speed controller and other components. It is also about the design of foldable arm. The materials applied are aluminium and carbon fiber. Aluminium has been used for the plates. Carbon fiber is been used for the foldable arms.

The design procedure starts with the basic diagram of the foldable arm quad frame along with the dimensions (length of unfold arm is 16cm, length of folded arm only is 11cm, arm width is 2cm). Then entering into CATIA V5 >MECHANICAL SKETCH. Selecting yzaxiz and click sketch icon. Entering into the sketch, start drawing the diagram. Using the given dimensions the diagram is drawn. First the frame is drawn for the given dimension and 4 holes are made at the corners for fixing the foldable arms. Then the nuts and bolts for the given dimensions for the hole existing in the plate is been drawn in a separate file. After the completion of sketch the file has been moved to the extrude portion where it is being excluded for the given dimension. Then for the plate bolts and nuts the material is been applied the material applied is aluminium.

After the completion of applying materials the file is being saved in a separate folder. Then the foldable arms of the given dimension is been drawn. After the sketches been completed the extrude portion comes in the extrude portion for the given dimension the foldable is been extruded.After extruding the foldable arm the application of material comes the Carbon Fiber material is being applied for foldable arms. After the application of material the file has been saved in the folder. Both the files are being saved as .catpart.Then both the files are being drawn into the product folder in the catia.After entering into the catia the sketches are being fixed at a particular location. Then foldable arms are being separately place at particular location where holes are there and Tighten by bolts and nuts. After all the fourth foldable arms are being fixed then the angle is been turned to zero degree 45 degree and 90 degree. After the completion of angles the rendering portion comes where the object has been placed in a reality image and the rendering starts. It is shown figure 1, 2, 3.

The foldable arms have been drawn in catia and material has been applied and it has been rendered in reality. Ultrasonic sensor (HC-SR04) converts ultrasound waves to electrical signals which is used for the measurement of height of the Hybrid Vehicle from the ground. It is also used to fold the arms 45 degree by using distance from sensor and output of Arduino Uno is connected to servos, the arms folded automatically based on the output of servos from Arduino Uno(atmega328p controller) .APM 2.8 flight controller gives stabilization and control to Hybrid Vehicle.

The Electronics control system used for the folding of servo mechanisms are Servo Motors, Altimeter sensors and Receivers. After the model has been designed, fabricated and assembled, the work was focused on flight testing of the model. Altimeter sensors were placed on the frame, which senses its altitude and fold the arms during the autonomous mode of operation. When the model is placed on the ground, the model extends its arms and when it reaches to preset altitude, the altimeter sensors sense that specific altitude and transmit signals to the servos, then the servos rotate, there by folding the arms successfully to the set angle. Overall weight and thrust of each motor calibrated by the equipment show in figure 4(a) &(b).

Fig 4(a)&(b): weight and thrust calculation using Turnigy, brushless motor thrust stand equipment

3.1. Laboratory Test

Laboratory setup was build with the following specification, to check the retraction of the arms of quadcopter the setup shown in figure 5 & figure 6.

Thrust Produced at each motor: 3.9226N
Overall thrust : 15.6906 N
Weight of the Hybrid Vehicle Quadcopter : 1000gm = 9.8066 N
Thrust that can be utilized for flying: 5.8839 N

It is also observed that the thrust remains constant when flying in both conditions.

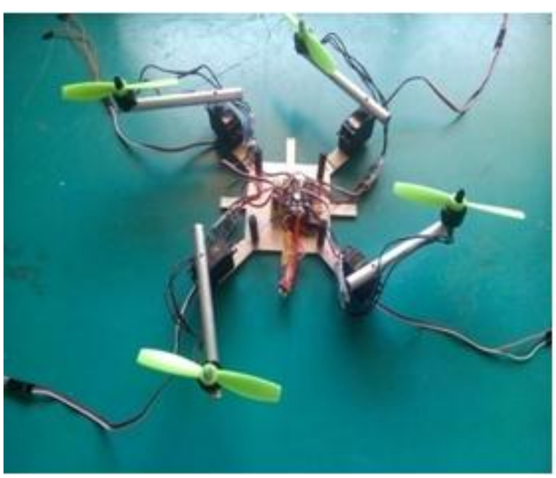


Fig 5: 45 degree retraction arms in Fold mode

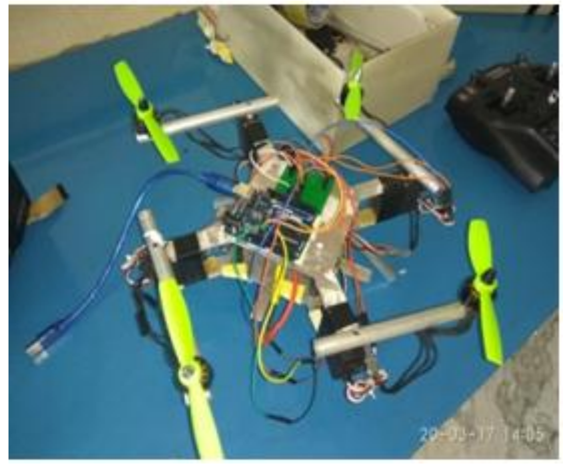


Fig 6: 90 degree retraction of arms in fold mode

The retraction and extension of the arms in the manual mode was successfully tested in this setup. The servo motor (S3003) used for folding and unfolding mode (retraction and extension of arms)

The Avionic c1806 2300kv motors are a unique design made from the highest quality magnets, casing and bearings to allow the maximum cooling of the motor. Specification of constant velocity (Kv (rpm/v)) of this motor is 850 which uses a power rating of 250 W with Idle current 0.6A and Resistance of 272 mΩ. It is specifically made of weight of 52g with 14 wire winds. It also uses cells Li-PO: 2-4.The advantage of this motor is high power to weight ratio, high speed and effective electronic control.

In this research, Servo motors (S3003) are used in radio-controlled quadcopters to fold and unfold the arms in the frame from 0 degree to 90 degree (especially 45& 90 degree) .It has three wire connection (power, ground, control) the function of the S3003 servo is to receive a pulse width control signal 1520 **μ**sec that represents a desired output position of the servo shaft, apply operating voltage range from 4.8-6.0v (Direction: Counter Clockwise/Pulse Traveling 1520-1900**μ**sec) with 7.2mA/idle Neutral Current Drain for a voltage of 4.8V and also 8mA/idle wave current drain for voltage of 6.0V to its DC motor until its shaft turns to that position.

Arms of the frame are attached to the shaft therefore arms folded and unfolded automatically based on the shaft turns.

The operating speed of this motor for 4.8 v is 0.23sec/60.another important of the specification of this motor degree at no load Potentiometer Drive: Indirect Drive. After folding the arms of this Hybrid Vehicle, It also helps to improve easy transportation from one place to another.

3.2.Switching Algorithm for Flying Mode Foldable Quad copter

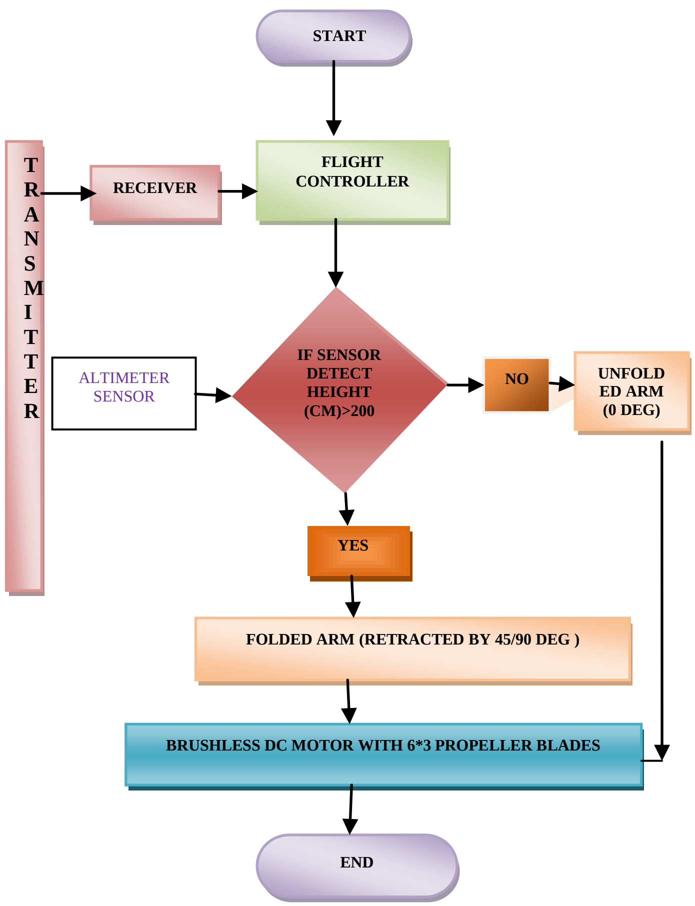


Fig 7: Flow chart of Hybrid Vehicle developed

4. Results and Discussion

4.1. Simulation Results

Simulation was carried out using by eCalc software [12].eCalc is the most reliable RC calculator on the web. It is based on common physics and a mathematical model that is able to simulate the resulting flight characteristics of a quadcopter based on the inputs like motorspecification,controller/esc,propeller,battery, motor to motor distance(60cms for unfold mode,55cms for 45 degree fold mode) etc,all the input is done hit the calculate button. eCalc Results are shown in figure 8 & 9.

The simulation results shows that maximum achievable speed in the unfold condition is 45 km/hr and it is 49.9 km/hr in the folded condition (An increase of about 4.9Km/hr speed is achieved in the folded mode).Simulation output is given in the following table.

For Unfolded condition

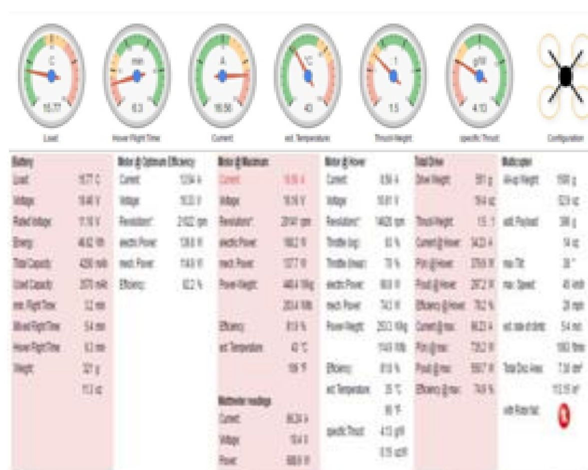


Fig 8: eCalc output of Hybrid Vehicle (unfolded mode)

For Folded condition

Fig 9: eCalc output of Hybrid Vehicle (folded mode)

Table 1: Simulation output by eCalc

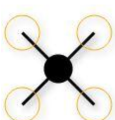
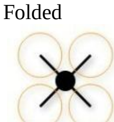
Condition	Motor To Motor Distance	Angle of the arm	Thrust produced	Speed
Unfolded 	60cms	0^0	5.8849 N	Approx. 28mph for a 3s setup with 1806 motors
Folded 	56cms	45^0	5.8849 N	Approx. 31mph for a 3s setup with 1806 motors

Fig 10: Hybrid Vehicle flying in indoor

5. Conclusion

This paper has successfully implemented the dual controllable Hybrid Vehicle, not only to improve portability in ground for easy of transportation but also provides the control for flying the Hybrid Vehicle in two different modes where each mode has its own advantages during flying. It is observed during the simulation and real time tests that improved agility in folded condition and improved stability during unfolded conditions of Hybrid Vehicle. The Hybrid Vehicle is equipped with foldable arms that can be folded autonomously by using ultrasonic sensor which is attached to the bottom of the frame was demonstrated in the indoor application. Wherever more stability is required like aerial photography, the vehicle can be flown in unfolded mode and in case of more agility requirement or to navigate through a narrow space, it can be flown in folded mode. Based on the simulation results and real time results it is found that the overall performance of Hybrid Vehicle to be satisfactory in both the modes of operation.

Future Scope

A separate FCS board could be developed to make the foldable frame autonomous and also improve stability in foldable flying condition.

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