

Miniature Quad Rotor Stabilization

S. Rushendar Babu¹, Vinod Kumar thakur², C. Arun Kumar³

Vel Tech High Tech engineering college

Abstract. UAV as the name suggests is an aerial vehicle which doesn't need pilot (human) and thus is controlled wirelessly or autonomously by an onboard system for carrying out many useful applications. Such aircraft have already been implemented by the military for reconnaissance and surveillance flights. Further use of is UAVs by the military, specifically as a tool for search and rescue operations, guarantees continued development and research of UAV technology. Also it provides the advantage of no risk to any human resource. But, since there is no one around to control its flight from inside it has to be stabilized automatically while simultaneously controlling its hovering and movement capabilities. Also this falls under the category of MAV since its size is less than 12inches. So in this paper we are proposing our model, its control and stabilization method, an obstacle avoidance system to reduce the optimum damage caused

Keywords: UAV (unmanned aerial vehicle), MAV (micro aerial vehicle)

1. Introduction

The ability to pack on a payload makes quad rotors the best choice when designing an aerial robot.

Quad rotor is a UAV and MAV which consists of four rotors (propellers) to generate a lift. Control of such a craft is accomplished by varying the speeds of the four motors relative to each other. Quad-rotor basically demands a complicated control system for balanced flight. Uncontrolled flight of a quad-rotor would be nearly impossible by a single person, as the dynamics of such a system insists constant and continuous adjustment of four motors simultaneously. Even though they may be classified as helicopters but unlike standard helicopters quad rotors use fixed-pitch blades, whose rotor pitch does not vary as the blades rotate.

In the last couple of years quad rotors have become a leading platform for aerial robotics. Precision control, 6 degree of freedom, manoeuvrability, and the ability to pack on a payload make quad rotors the best choice when design an aerial robot.

2. Quad Rotor Dynamics

Each rotor produces thrust and momentum for the quad. The rotors placed opposite to each other rotates in same direction rotates in same direction(clockwise or counter clockwise) resulting in a rotational torque similarly other pair of rotor rotates in opposite direction to produce counter rotating torque. The resultant is maintained at the centre. The centre of gravity of the system is at the geometrical centre of the structure for stability.

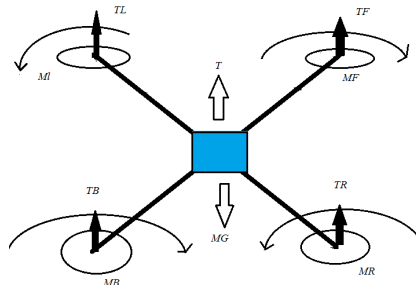


Figure 1:-Depicts the dynamics of the quadrotor, the direction of rotation of propellers, weight force, and effective thrust provided

For vertical acceleration all the forces should be equal to each other

$$f_1 = f_2 = f_3 = f_4$$

The resultant force is at the centre of the structure. Consider the following diagram

$$x = (f_3 a - f_1 a) / (f_1 + f_3)$$

$$\text{If } f_1 = f_3 = f$$

Then $x = 0$

The position of resultant force is at the center of the body (0, 0), both the resultant forces are at (0, 0) where mg is concentrated.

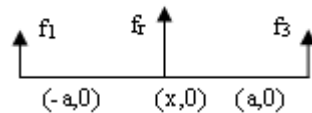


Figure 2:-Depicts the three effective forces, and the force at the center

$$F_{\gamma} >= mg + d$$

$$4f >= mg + d$$

$$Av >= g / 4 + d / m$$

Roll and pitch as per the equation of resultant force

$$x = \frac{(f_3 a - f_1 a)}{f_1 + f_3}$$

$$y = \frac{(f_2 a - f_4 a)}{f_2 + f_4}$$

For pitch and roll the values of x and y should be varied .for pitch

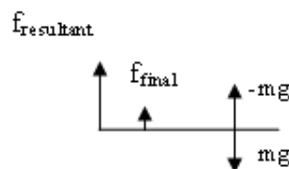


Figure 3:-This shows the resultant force due to thrust force being more than weight force

$f_1 : f_3$ is not equal to one .position of resultant force, is going to vary accordingly

Resultant should be greater than mg to generate a lift. Resolving them to get the resultant value of force

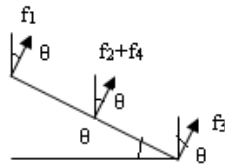


Figure 4:-Depicts the tilting of a quadrotor and change in its dynamics. The forces gets varied accordingly

As the value of θ varies the component of force can be resolved into vertical and horizontal components. The horizontal component is $f \sin \theta$ and vertical component is $f \cos \theta$.

$$F_x = 2f_2 \sin \theta + f_3 \sin \theta + f_1 \sin \theta$$

$$F_x = (2f_1 + f_4 + f_2) \sin \theta$$

$$A_x = \frac{2f_1 + f_4 + f_2}{m}$$

For the system yawing torque can be generated by decreasing the torque on the motors. For clockwise torque the motors giving an anticlockwise torque should slow down and give a clockwise torque .total rotational can be given as

$$T_\gamma = t_1 + t_3 - t_2 - t_4$$

The equation of rotational torque is given as

$$T = f \times r$$

r is constant the equation can be written as

$$tr = r(f_1 + f_2 - f_3 - f_4)$$

2.1. Design procedure

In the model we are using 2805kv brushless motor which provides rpm of 24000 approximately.

$$MotorRPM = 0.8 \times voltage \times Motor \text{ kV Rating}$$

The motor used very small in size and runs at very high rpm. The motor is used with ep-7035Rx3 tri propeller. The motor gives a maximum torque of 375g with this arrangement when tested by us. The total weight of system is estimated 500g approximately. Battery used to power the system is 11.1 v 2200 mah.

2.1.1 Control scheme

The system used is a closed loop control system. The input from transmitter is feed to the control board where the signal is processed and a desired output is generated by the actuators. The various physical variations of the body are sensed by the sensors and it is given as a feedback to the system. The systems process these variations and try to maintain the body in stable position.

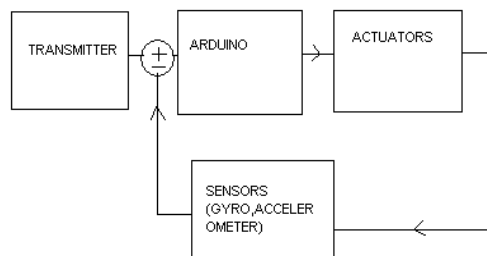


Figure 5:-Depicts the control system employed for the Quad for proper functioning and stability

Arduino

Arduinio is an open source prototyping platform. This is a small circuit (the board) that contains a whole computer on a small chip (the microcontroller). The software/hardware for the system is open source and

easy to understand. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the board is programmed using the Arduino programming language (based on Wiring) and the Arduino development environment (based on Processing). Arduino projects can be stand-alone or they can communicate with software running on a computer

2.2. Accelerometer

An accelerometer is an electronic device sensible to the changes of acceleration. Single and multi-axis models are available to detect magnitude and direction of the acceleration, and can be used to sense orientation, vibration and shock. In our case we are going to use a 2-axis model to determine the tilt of our MAV and try to stabilize it with its readings. Here the accelerometer as a tilt sensor. Whenever there is a tilt the accelerometer responds according to it and gives feedback to Arduino. In turn the board controls the motor speed and increase the speed of the motor along which the tilt has taken place. Thus the Quad gets stabilized. Since we are using two axis accelerometer any change in pitch or roll(x and y axis) will be sensed by accelerometer and will be compared with its present stable state in the board.

2.3. Gyroscope

Memec Gyroscope is a device which senses the rotational velocity. It is used to control the yawing movement. The unstability due to yawing moment is not favourable for surveillance purpose therefore the gyro is used to sense this stability. 10 bit ADC on the board is used to decode the data from the gyroscope. The output from the gyroscope varies between 0-1023. The output is fed into the following equation and the angular rate is determined

$$Angular_velocity = \frac{(5/1023)(A_reading - B_reading)}{0.0125}$$

2.5 Obstacle avoidance system

During utilization of our UAV in surveillance, reconnaissance or photography purposes there may be chance of collision with other obstacles around it. This may lead to severe damage to its costly equipment and failure of mission. So to avoid this we have installed a simple low cost self obstacle avoidance unit on QUAD.

We are using four IR sensor modules each installed at the rear end of the quad rotor i.e. underneath the motor. Each IR sensor module consists of an IR transmitter an IR receiver an OP amp working as a comparator. So each module consists of its own field of vision and any obstacle which comes within this field gets detected and the Quad moves away from the obstacle. This is done by reducing the alacrity of the opposite motor such that the whole body of the quad gets averted away from the obstacle.

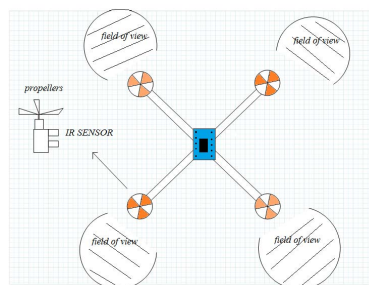


Figure 6:-Depicts the implementation of IR Sensors and its Field of operation(catchment area)

The only disadvantage of using this distance sensor module is that it can't detect black objects since the black objects absorb all the IR radiations and that doesn't reflect infrared rays back to the receiver.

Use of ultrasonic sensor is avoided in the system as the vibration in the model due to actuators induces error in the system and ultimately results in instability of the system.

2.6 Simulation results

Simulation is done using matlab. Only one part of the system i.e. pitches and roll is simulated as it is of major concern of the project. The graph for pitch and roll is same as both are similar for the quad. As the tilt varies simultaneously the force is also varied for the system. The graph shows the stability of the system during variation of the tilt and force.

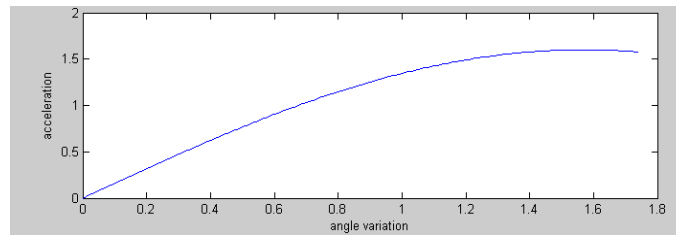


Figure 7:-Simulation using MATLAB acceleration vs tilt

Conclusions

The work done in the paper is an approach to build a platform for future implementation of various advance sensors, GPS, and camera so that it can be used for various applications mentioned in the paper earlier.

3. Acknowledgement

We are gratefully acknowledge the ideas and help provided from Mr. Vasanthraj and vel university to provide us a working space in their premises

4. References

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