Disturbance Rejection of a Single-Axis of a Quadcopter using Lead compensation

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ABSTRACT

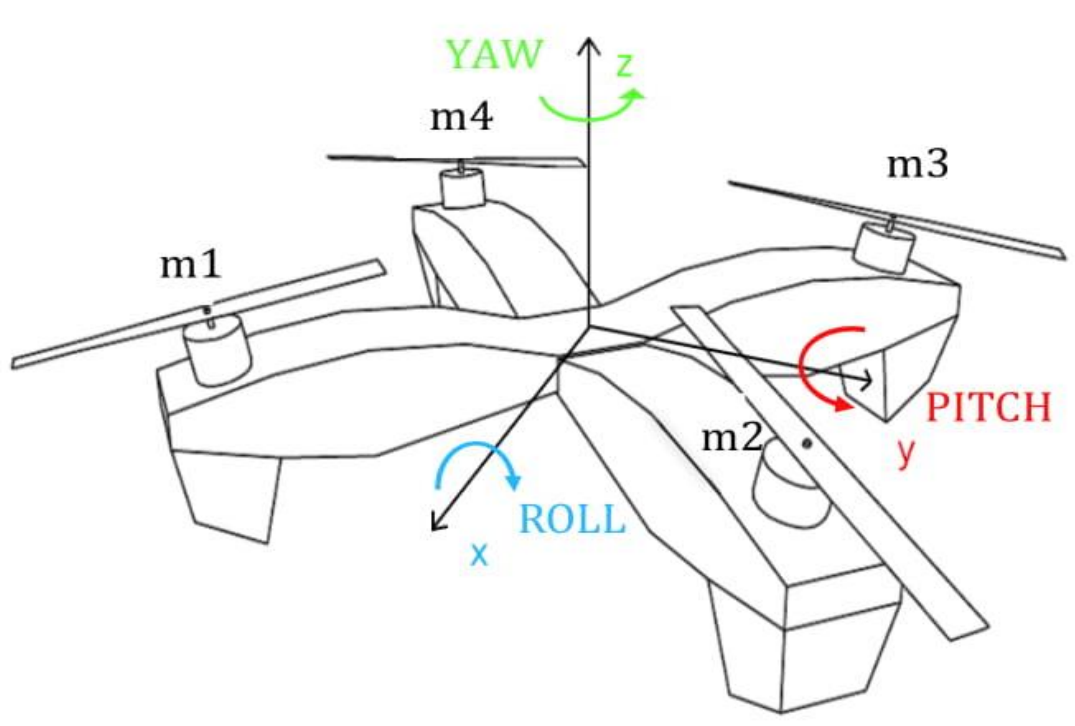
This poster presents a simplified approach for modelling a single axis of a Quadcopter and designing a low-cost Quadcopter flight controller for its proper stabilization. It also involved creating a test-setup for the application of black-box estimation and control algorithm. The work was carried out in 4 stages: 1) Data acquisition via serial communication 2) Data-driven modelling using System Identification 3) Controller design to achieve the desired transient specifications and 4) Validation of the control scheme. It also included comprehending the associated control challenges and in the process learning how to implement classical control design on a real-world problem. At the end of the study, it was observed that the Lead controller designed using the classical control design effectively reduces the settling time of the Roll-Axis when a step change in disturbance is given to the system.

BACKGROUND

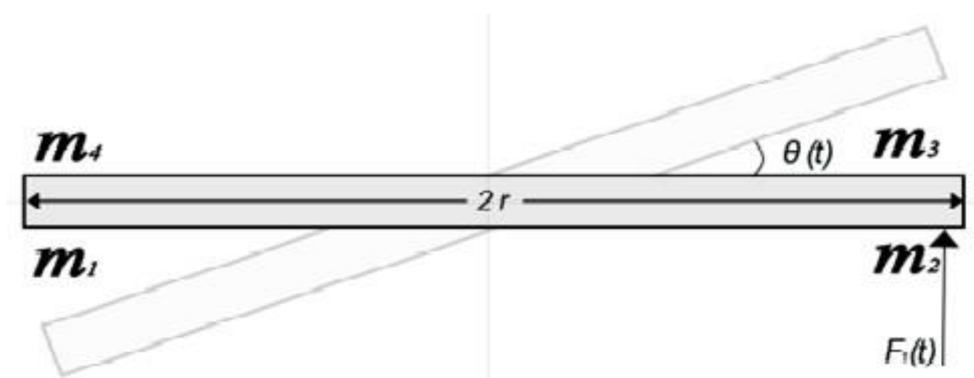
A quad-rotor, also called a quadcopter helicopter or quad-copter, is a multi-rotor helicopter that is lifted and propelled by four rotors. These machines use independent variation of the speed of each rotor to achieve control. Varying the rotor speeds of all four rotors, thereby changing the lift forces, generates the motion of a quadcopter. The Quadcopter tilts towards the direction of a slow spinning rotor, which enables acceleration along that direction. A good controller should properly arrange the rotor speeds such that only the desired states will be changed. The wide acceptance of the quadcopter has led to huge R&D in the field. Unmanned Aerial Vehicles (UAV's) started as a platform for hobbyists and enthusiasts but rapidly caught the attention of researchers and are currently projected to be a billion–dollar industry. Their mechanical simplicity allows for diverse and versatile applications, some examples are augmented ball cooperative construction, rope-bridges, pole balancing.

METHODOLOGY

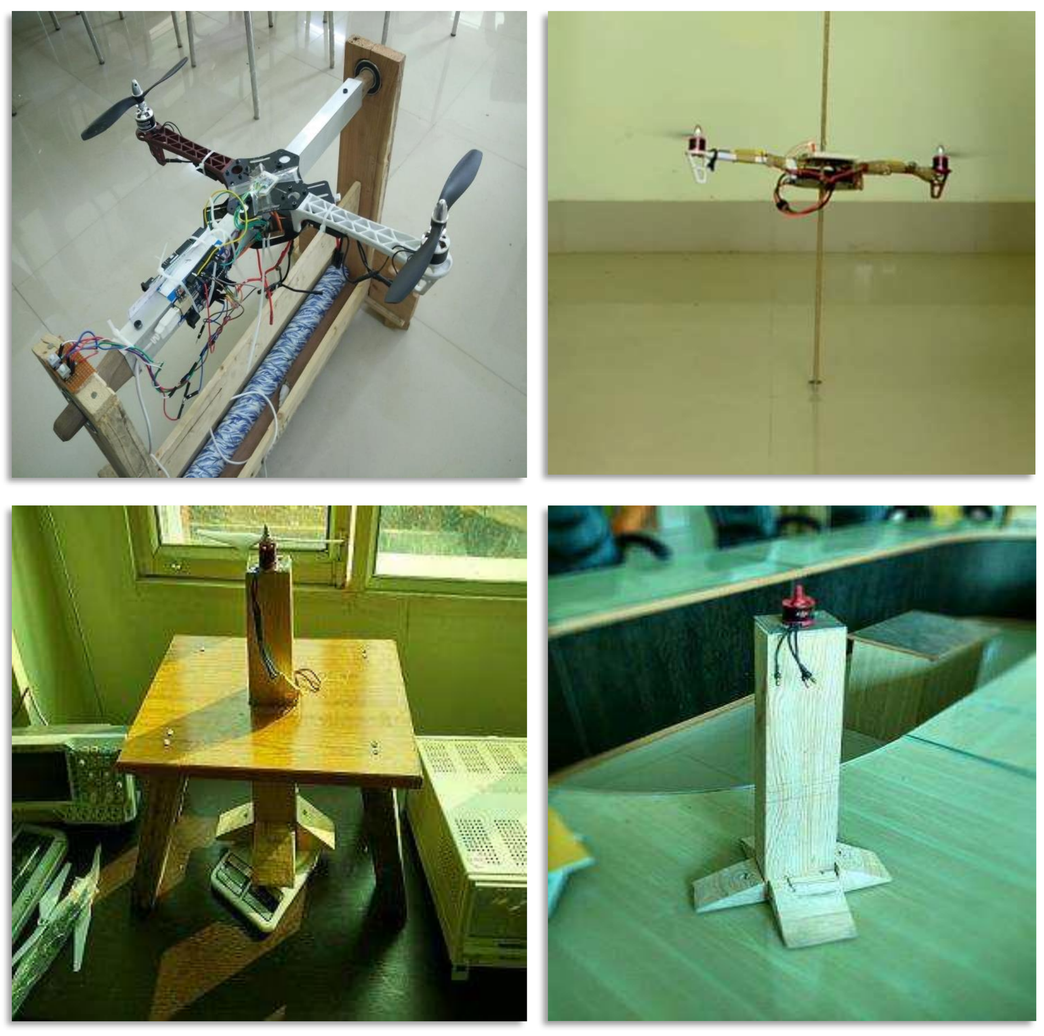
- We assembled the Quadcopter in the X-configuration as shown in figure. The four motors are labelled as m_1, m_2, m_3, and m_4. In the X-configuration, the two motor lie on either side of the X-axis and Y-axis.



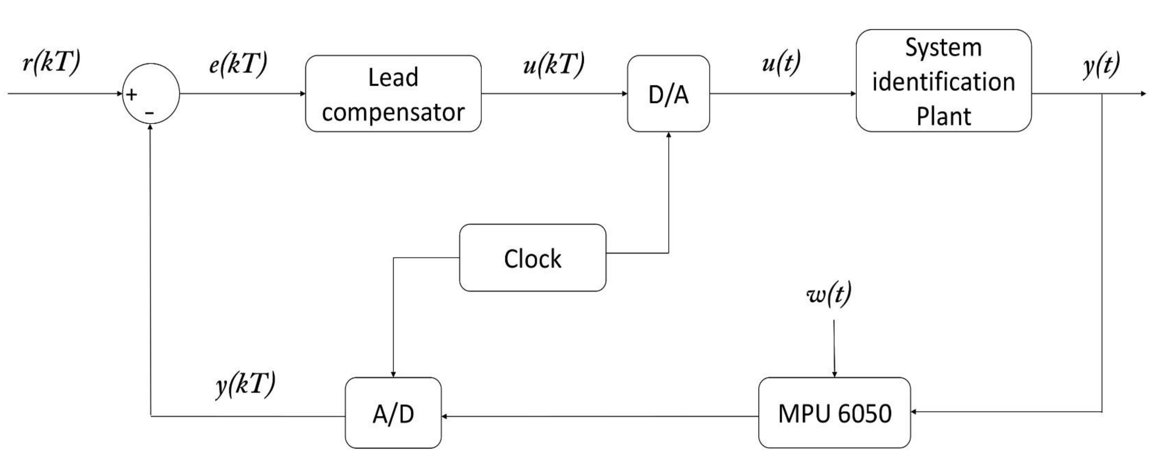
- The input quantities are Pulse Width Modulated signals to the two ESC's which are reflected as the thrust forces F_1 and F_2 generated by the motors and the output is taken as the angle (θ). As the motor-propeller system rotates, torques are generated that affect the output angle (θ).



- For black-box system identification, a constrained 1 DOF test setup was manually built to obtain the single axis dynamics of the system.

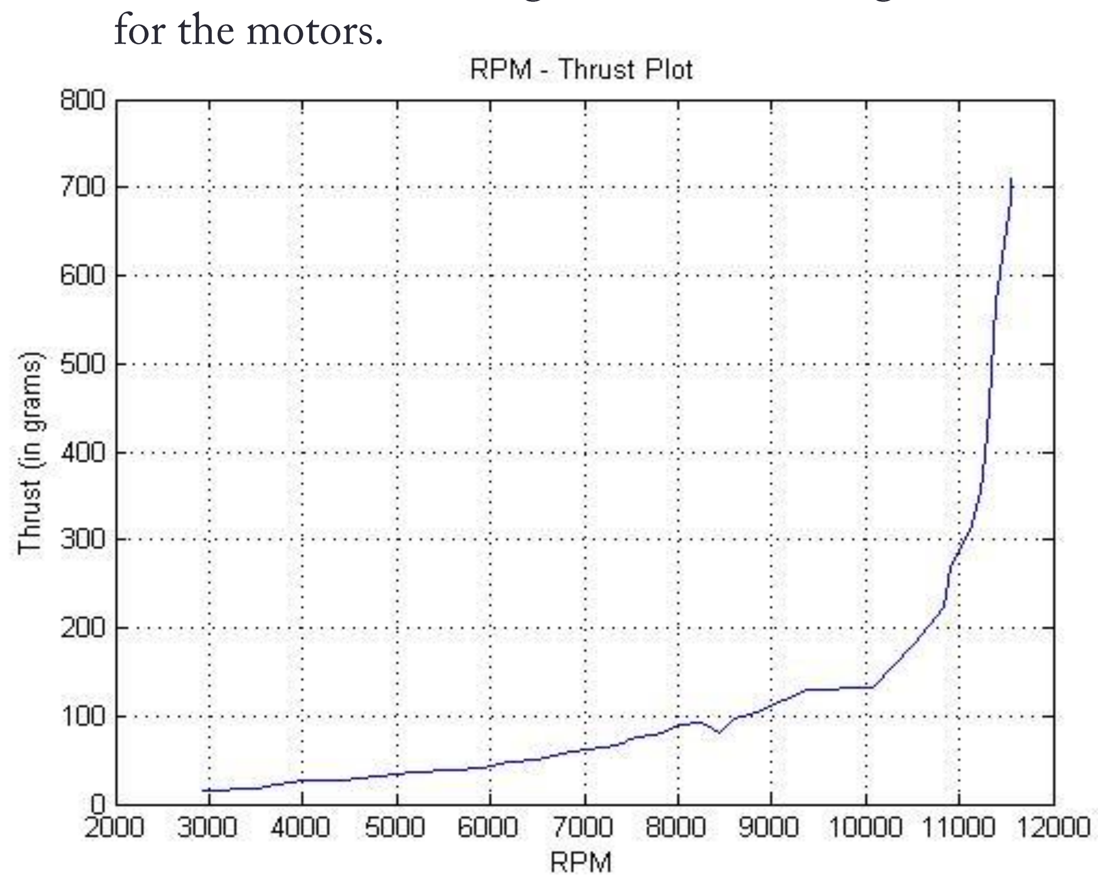


- The following block diagram shows all the necessary blocks with their associated command signals. The plant output is forced to track the reference input (which is zero degrees) despite the presence of errors in the sensor.



RESULTS

- After testing the 980 K_v motor, we investigated their thrust data plotted against the RPM values with an 8045 propeller and graph was obtained. We used these values in order get the minimum gain blocks for the motors.



- The input/output data was recorded using serial communication and the following second order transfer function was obtained:

$$G(s) = \frac{0.004182}{s^2 + 0.4182s + 1.136}$$

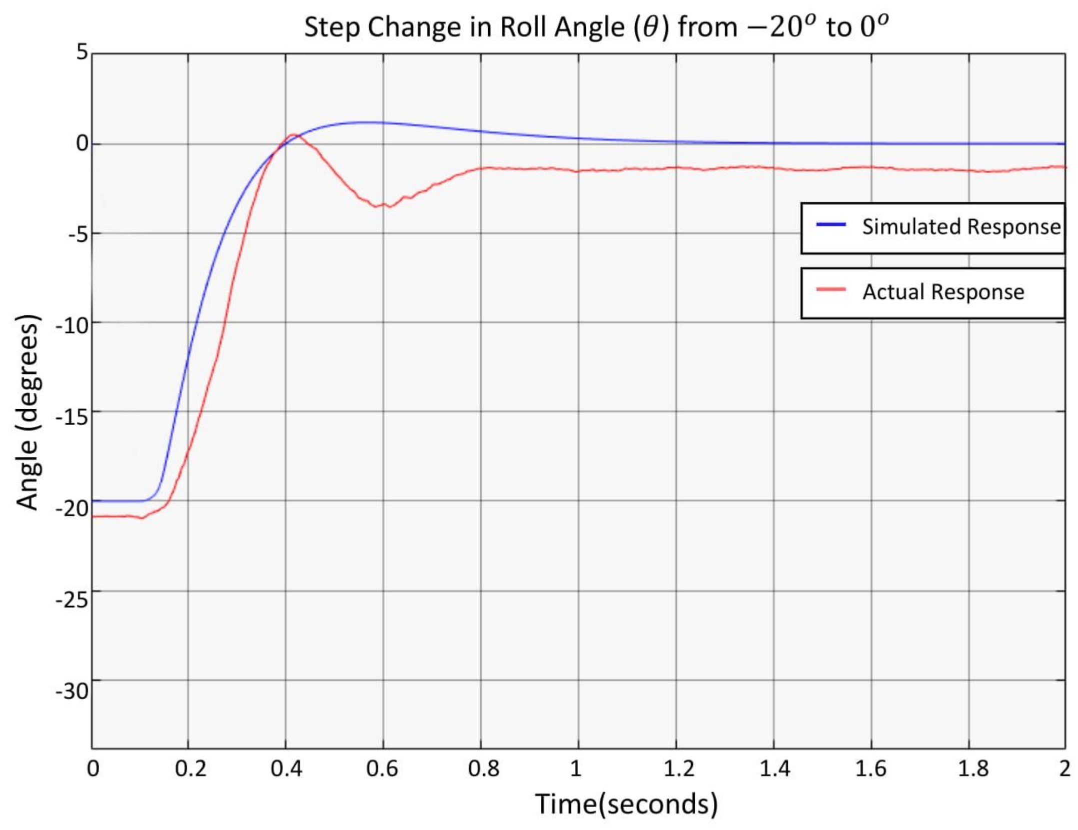
- For a settling time (T_s) < 2 seconds, %OS < 5 and steady state error < 10% the following discrete time lead controller was obtained using Euler's equation and implemented via an Arduino based microcontroller:

$$u(k) = (1 - aT)u(k-1) + (cT - b)e(k-1) + be(k)$$

where;

$$T = 0.006, a = 48.4, b = 1.818e05 \text{ and } c = 2.884.$$

- Figure shows a comparison between the time responses of the Simulated and Actual model as we force a step variation in Roll angle (θ) from -20 to 0 degrees.



CONCLUSIONS

The study presented a novel approach for Quadcopter Roll-Axis stabilization using a Lead Compensator. By subjecting the system to a step disturbance of angles, the data sets for PWM pulses and the corresponding angles so generated were stored to form an input-output data set. This data-set was then used for the System identification to yield a second order transfer function. The digital controller thus implemented performed satisfactorily with the actual model. A very low settling time of 1 sec was achieved using the controller, which was close to the design requirement. Also, as seen from the graph, the Roll angle (θ) settles quickly to its reference value without significant oscillations. Also, since the Quadcopter is generally a symmetrical machine, the results are identical for both pitch and roll axis stabilization.

Most of the flying vehicle controllers employ inbuilt PID controllers for each axis stabilization. Tuning these gains follow a trial and error approach which is not very scientific. In this work we have shown that designing a Lead Compensator based on certain design criteria performs very well especially when it comes to improving the transient performance of the system.

PS: All the tests and results obtained during the study can be seen online by scanning the following QR code via a smartphone

ACKNOWLEDGEMENT

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