



Design and Development of Automated Aero-Terrestrial Systems for Persistent Surveillance Missions

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Abstract: Overhead unmanned aerial surveillance is currently being performed by fixed wing aircrafts. These vehicles require a constant flow of air over the wings and as such cannot perform stationary aerial surveillance of an area of land. Multi-Rotor Aerial Vehicles are used for by hovering at a fixed point in air. Since this vehicle uses multiple rotary motors to achieve the hovering condition, the endurance of the vehicle is inadvertently very low. Low endurance leads to short duration surveillance mission. Typical endurance of surveillance for a quad-rotor system varies from 15mins to 20mins. In this paper Design and Development of automated Aero-terrestrial system for persistent surveillance mission, deals with improving the endurance of the Multi-rotor aerial vehicle by autonomously recharging the batteries.

Keywords: Quadcopter, docking station

I. INTRODUCTION

Over the past decade, the use of unmanned aerial vehicles (UAVs) in reconnaissance and search and rescue has greatly increased throughout the world. Remotely piloted unmanned aircraft provide tactical aid to the military in real-time. These vehicles have proved to be efficient first responders in a number of hostile mission scenarios. Teams of multiple such vehicles can also be used for persistence missions in hazardous or unknown environments reducing the risk to their human counterparts. However, the most significant constraint on the any aerial vehicle for such persistent missions is the depletion of its on-board power resource - electrical or fossil fuel. Several structure and configurations have been developed to execute aerial surveillance. Overhead unmanned aerial surveillance is currently being performed by fixed wing aircrafts. These vehicles require a constant flow of air over the wing, and as such cannot perform stationary aerial surveillance of an area of land. It can be solved by the design and development of a Multi-Rotor Aerial Vehicle which can perform surveillance by hovering at a fixed point in air. Since this vehicle uses multiple rotary wings to achieve the hovering condition, the endurance of the vehicle is inadvertently very low.

II. DESIGN METHODOLOGY

Development of a stable platform for aerial surveillance, involves designing and developing any Multi-Rotor Aerial Vehicle. For the convenience of design Quadcopter is chosen as the Multi-Rotor aerial vehicle. Here aim is to achieve the surveillance without the intervention of humans. There is a requirement of autonomous navigation i.e. Waypoint Navigation and Auto Landing onto a docking station. The docking station used for recharging of the Li-Po batteries should center and position the quadcopter for recharging its internal batteries. The docking station is built-in with embedded system involving Li-Po recharging circuit to recharge the batteries.

It involves three main subsystems

1. Developing Multi Rotor Aerial Vehicle
2. Waypoint Navigation and Docking Station
3. Autonomous recharging of batteries

The development of Quadcopter involves the study of the kinematics and dynamics helps to understand the physics of the platform and its behavior. Together with the modelling, the determination of the control algorithm structure is very important to achieve a better stabilization. Is tested on Matlab.

III. SIMULATION

Simulation of the control algorithm of the Quadcopter using Simulink and Matlab. Simulation of the Quadcopter for attitude performance i.e., Roll, Pitch and Yaw performance was conducted by considering the follow control design specifications [25].

- i. Overshoot: 5 %
- ii. Settling time: 500 ms

iii. Rise time: 120 ms

iv. Steady State Error: 2%

Using the technique of Root Locus, the values of K_p , K_i and K_d were found.

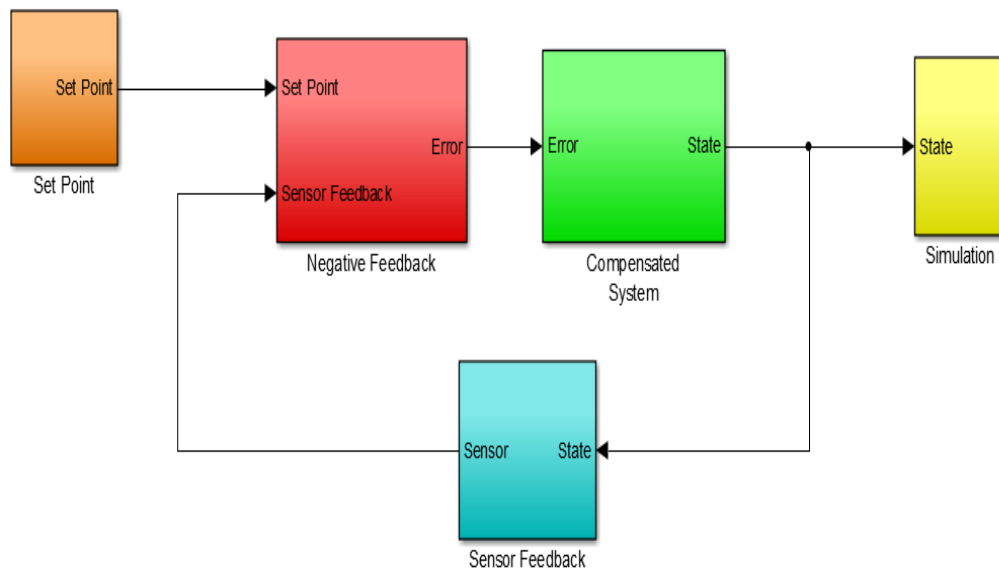


Figure 1. Simulink model of Quadcopter

The sensor feedback block adds the sensor covariance after filtering the sensor values through Kalman filter [24]. The simulation block, plots the attitude and shows the 3D animation of the quadcopter. The PID controller's design constants K_p , K_i and K_d obtained from Root Locus design. The controller was followed by the Inverse Kinematics for the Servo to obtain the desired PWM. The input to the Controller is Error and its output is corresponding PWM. Simulink model of PID controller with the motor control (Inverse Kinematics) is shown in Figure 2.

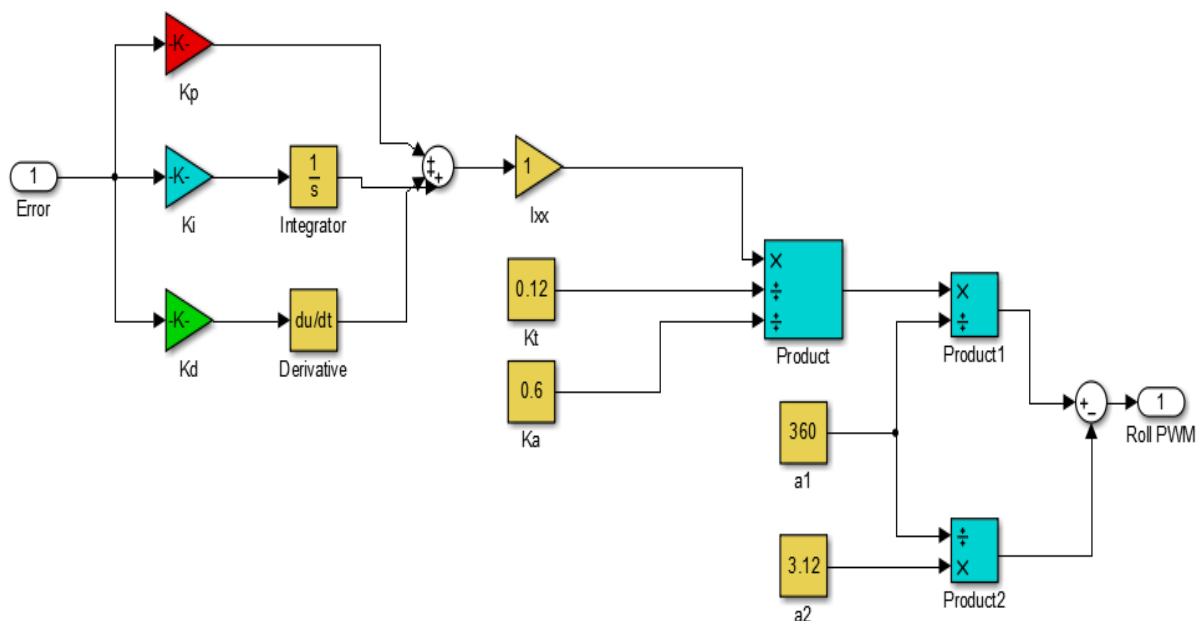


Figure 2. Design of PID Controller

The PID constants i.e. K_p , K_i and K_d obtained by simulation need to be tested with the actual quadcopter model.

IV. TESTING

Testing of the PID controller the values of K_p , K_i and K_d were used to obtain the corresponding Z-transform and it was implemented on APM controller. The desired angles for the Stabilized platform were maintained

constant at 0 degrees [13] & [14]. The performance of the PID is measured in terms of overshoot and settling time. In Figure 3 we see set point at 0 degrees meaning the roll axis has to be maintained at zero degree.

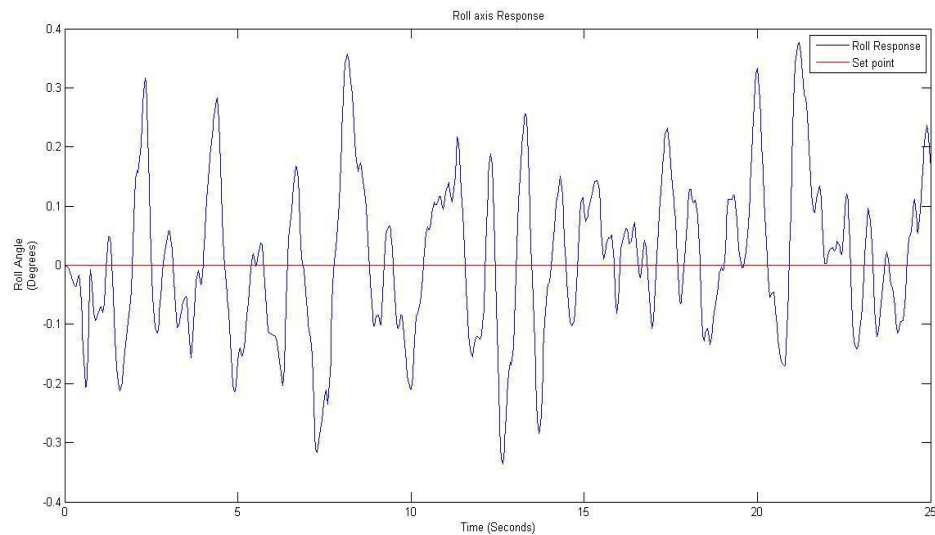


Figure 3. Roll Axis Response (Desired Angle vs Time)

This increase in overshoot and settling time for yaw is due to relative increase in moment of inertia of yaw axis.

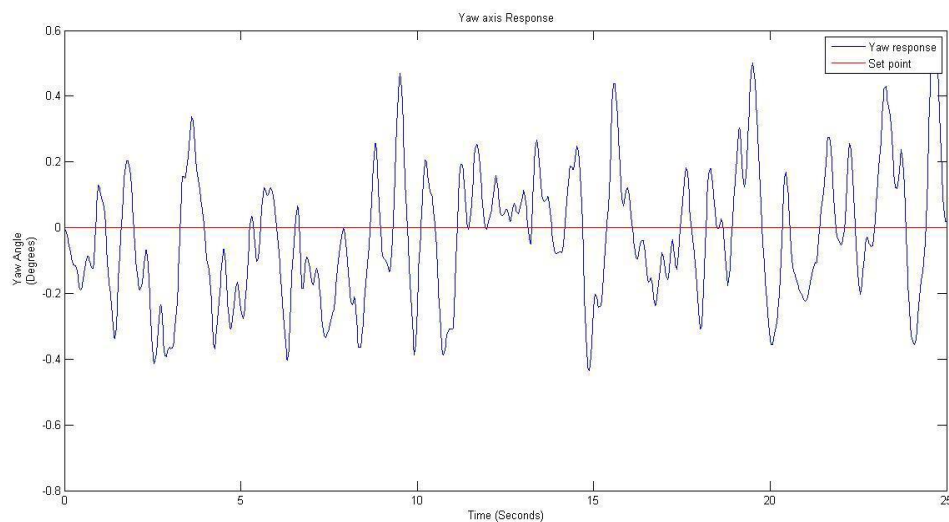


Figure 4. Yaw Axis Response (Desired Angle vs Time)

The above tested PID constant values were used for implementing the PID controller on hardware.



Figure 5: Docking Station

V. CONCLUSION

Automated persistent Quadcopter serves a system that has great potential to ensure jitter free imaging for long duration missions. Aerial surveillance being very crucial in the modern day applications, this serve enhances the capabilities of aerial surveillance by improving the endurance of the multi-rotor aerial vehicle. Autonomous intelligent aerial surveillance for longer duration is possible. Good and reliable attitude stabilization was achieved with PID controller with overshoot of 5% and settling time of 500ms. Roll response of 5.3% overshoot and settling time of 490ms, pitch response of 4.8% overshoot and settling time of 457ms and yaw response of 8% overshoot and settling time 621ms. The roll, pitch and yaw errors from the setpoint never exceeded more than a degree. Auto landing is an important feature, this was achieved with combination of GPS and Visual system which provided an accuracy of 30cms. Autonomous alignment of Quadcopter and recharging of batteries was achieved in the docking station. The recharging took 15 minutes to get the battery back to 12V.

VI. FUTURE SCOPE

Implementation of automated aerial vehicle can be improved by making it more accurate and reactive. Accuracy can be achieved by reducing motor overshoot. This can be further improved by incorporating state space control algorithm. The accuracy of the system is very limited due to the use of classical control algorithms; there is a definite scope for improvement by using advanced techniques like Fuzzy Logic Controller and Artificial neural network. Obstacle recognition and avoidance is a very important and necessary feature for this class of vehicles. The intelligence of obstacle detection and avoidance can be implemented in future.

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