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Design of an Autopilot for an Autonomous Unmanned Aerial Vehicle

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ABSTRACT

Unmanned aerial vehicle (UAV) has many applications such as military defense and surveillance, weather forecast, terrain surveying, and civilian search and rescue. In this paper, the autopilot of an autonomous UAV is designed using PID control algorithms. First, the dynamic model of the aircraft is implemented using six degree-of-freedom (6-DOF) rigid body equations of motions coupled with an aerodynamic model, thrust model, atmospheric model, and gravity model. Then, the autopilot is designed using heading, altitude and speed as desired inputs for autonomous mission. The control surface deflections and throttle setting are determined using PID control algorithms. The performance of the autopilot is evaluated using full nonlinear simulation. The response for typical input signals in altitude, airspeed and heading was investigated.

1. INTRODUCTION

Unmanned Aerial Vehicles (UAVs) have many important uses including civilian search and rescue, border patrol, environmental and traffic monitoring, disaster relief, military applications and forest fire surveillance. The versatility and low cost of UAVs provide a potential for a dramatic increase in their use in the public and private sectors. Control of small UAV is difficult due to the small mass, low Reynolds number, and light wing loading. Autopilot design and dynamic simulation of UAV's are discussed in many publications [1-7]. The purpose of this paper is to design an autopilot for small UAVs. First, 6-DOF dynamic model of the airplane is developed in section 2. It is divided into five modules: equations of motion, aerodynamic model, thrust model, atmospheric model, and gravity model. The autopilot development is explained in section 3. The performance of the autopilot integrated with the dynamic model is demonstrated in section 4. Finally, the conclusions and future work are discussed in section 5.

2. UAV DYNAMIC MODEL

In this section, the dynamic model of the UAV is described using the equations of motion, aerodynamic model and thrust model. The atmospheric model is the standard atmosphere and the gravity model is based on constant acceleration of gravity.

2.1 Equations of Motion

The UAV dynamics is represented by a nonlinear six-degrees-of-freedom model in body-axis system located at the center of gravity as shown in Fig. 1. The equations are written in terms of translational velocity (u,v,w), angular velocity (p,q,r), mass property parameters (m, c_1,..., c_9), external forces (F_x, F_y, F_z) and moments (M_x, M_y, M_z) [1]. The total force $\mathbf{F}$ is composed of gravitational force ($\mathbf{F_G}$), aerodynamic forces ($\mathbf{F_A}$), thrust force ($\mathbf{F_T}$). The total moment $\mathbf{M}$ is composed of aerodynamic moments ($\mathbf{M_A}$) and thrust moment ($\mathbf{M_T}$). Finally, the equations of motion can be expressed as