Modeling and Adaptive Tracking Control of a Quadrotor UAV

Mostafa Mohammadi, Department of Electrical Engineering, Iran University, Tehran, Iran

Alireza Mohammad Shahri, Department of Electrical Engineering, Iran University of Science and Technology, Tehran, Iran

Zahra Boroujeni, Department of Electrical Engineering, Iran University, Tehran, Iran

ABSTRACT

The dynamics of UAV's have special features that can complicate the process of designing a trajectory tracking controller. In this paper, after modelling the quadrotor as a VTOL UAV, a nonlinear adaptive controller is designed to solve trajectory tracking problem in the presence of parametric and nonparametric uncertainties. This controller doesn't need knowing any physical parameters of the quadrotor, and there isn't need to retune the controller for various payloads. In this approach, the control of a quadrotor is performed by using decentralized adaptive controllers in the inner (attitude control) and outer (translational movement control) loops. The outer loop generates the instantaneous desired angles for inner loop. The inner loop stabilizes the orientation of the vehicle. Inverse kinematic of robot is used to convert outputs of the outer loop to inputs of the inner loop. The controller needs some unknown physical parameter to generate control signals. A robust parameter identifier estimates the required parameters for the outer control loops. Simulations are carried out to illustrate the robustness and tracking performance of the controllers.

Keywords: *Adaptive Control, Dynamic Model, Quadrotor, Trajectory Tracking, Unmanned Aerial Vehicle (UAV)*

INTRODUCTION

Unmanned aerial vehicles (UAV's) have received great attention in both military and civilian domains in recent decades. These kinds of vehicles are used in many applications such as search and rescue operations, surveillance and photography. Quadrotor is one of new drones, which has four independent rotors. Controlling a quadrotor is performed by proper velocity control of each rotor. High maneuverability is one of the most interesting features of the quadrotor.

It is essential to model UAV in order to control it. The dynamics of UAV's have special features that complicate the process of designing a tracking controller. Unknown nonlinearities, strong coupling between subsystems, unknown physical parameters, nonparametric uncertainties in inputs and external disturbances such

DOI: 10.4018/ijimr.2012100105

as wind gust are some of the basic difficulties associated with the control of such systems. Therefore, an advanced control strategy is required to achieve good performance of the controller. Many researchers have solved the trajectory tracking problem for UAV's in different ways.

Das, Lewis, and Subbaro (2009) used backstepping approach for controlling a UAV. In this study aerodynamic forces and moments are estimated by neural networks as a method for handling unknown nonlinearities. A nonlinear adaptive controller for the quadrotor was proposed in Madani and Benallegue (2008). This controller which is based on backstepping technique is combined with neural networks. Huang, Xian, Diao, Yang, and Feng (2010) presented a backstepping based techniques to design a nonlinear adaptive controller which can compensate for the mass uncertainty of the vehicle. Michini and How (2009) developed an L1 adaptive output feedback control design process. This controller has robustness to time delay and actuators failure. However, only linear methods are applied in this paper. In Dierks and Jagannathan (2010), output feedback control of a quadrotor UAV using neural networks is performed. Nicol, Macnab, and Ramirez-Serrano (2011) proposed a new adaptive neural network control to stabilize a quadrotor helicopter against modeling error and considerable wind disturbance. The new method is compared to both dead zone and e-modification adaptive techniques. Roberts and Tayebi (2011) presented an adaptive position-tracking control scheme is proposed for a UAV for a set of bounded external disturbances.

Raffo, Ortega, and Rubio (2010) used an integral predictive and nonlinear robust control strategy to solve the path following problem for a quadrotor. Aerodynamic disturbances and parametric uncertainties are considered in this paper. In Mhammed and Hicham (2009) a high gain observer and sliding mode controller is designed which allows on-line estimation of the roll and pitch angles as well as all the linear and angular velocities of the vehicle. Under the restriction that only the inertial coordinates and yaw angle are available for measurement. Das, Lewis, and Subbaro (2009) apply dynamic inversion to the inner loops, which yields internal dynamics that are not necessarily stable. Instead of redesigning the output control variables to guarantee stability of the internal dynamics, a robust control approach is used to stabilize the internal dynamics. In Lee, Kim, and Sastry (2009) two types of nonlinear controllers for an autonomous Quadrotor helicopter are presented. A feedback linearization controller, which involves high-order derivative terms, and the second type involves a new approach to an adaptive sliding mode controller using input augmentation. In Benallegue, Mokhtari, and Fridman (2008) a feedback linearization based controller with a high-order sliding mode observer running parallel is applied to a VTOL unmanned aerial vehicle. Zhang, Quan, and Cai (2011) discussed the attitude control of a quadrotor aircraft subject to a time varying and non-vanished disturbances and stabilized using a feedback controller with a sliding mode term. Efe (2011) presented different control architectures; a robust control scheme that can alleviate disturbances. A Proportional Integral and Derivative (PID) type controller with noninteger order derivative and integration is proposed as a remedy. A neural network is used to train to provide the coefficients.

Zemalache and Maaref (2009) applied a fuzzy controller based on on-line optimization of a zero order Takagi–Sugeno fuzzy inference system, which is tuned by a back propagation-like algorithm, for a drone. It is used to minimize a cost that prevents an excessive growth of parameters. In this paper some uncertainties are considered. Orsag, Poropat, and Bogdan (2010) used an innovative method to solve the quadrotor control problem, which is based on a discrete automaton. This automaton combines classical PID and more sophisticated LQ controllers to create a hybrid control system. Fahimi and Saffarian (2011) presented an innovative

Related Content

Wheelchair Secure Navigation with RF Signal Triangulation and Genetic Algorithm Optimization

Leonimer Flávio de Melo, Evandro Junior Rodrigues and João Maurício Rosário (2015). *Handbook of Research on Advancements in Robotics and Mechatronics (pp. 750-792).*
www.igi-global.com/chapter/wheelchair-secure-navigation-with-rf-signal-triangulation-and-genetic-algorithm-optimization/126033?camid=4v1a