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Adaptive compensation control of the quadrotor helicopter using quantum information technology and disturbance observer

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Abstract

In this paper, an adaptive compensation control scheme is developed via disturbance observer and quantum information technology for the four-rotor helicopter, which can handle the control problems of helicopter's attitude with the unknown actuator failures and external disturbance effectively. Both the digital simulations and the semi-physical simulations in a Quanser 3-DOF hover platform illustrate the effectiveness of the proposed compensation control scheme.

1. Introduction

Over the past few years, the control problems of four-rotor helicopters have gradually become a new study hotspot due to their novel appearance, simple structure, low cost, superior performance and unique flight control mode. However, there are still many open issues. For example, the actuators and sensors of quadrotor helicopters are very easy to fail because of the highly coupled control units. What's more, they are influenced by the external interference easily when flying in the air. To address these difficulties, researchers have employed various control techniques [1–4]. The attitude control of a quadrotor aircraft subject to a class of time varying disturbances based on an extended observer is studied by [1]. Ref. [2] deals with the fault tolerant control of a quadrotor by using a multi-observer switching strategy. In [4], a sliding mode

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approach is used to control a quadrotor in the present of external disturbance and actuator fault. In recent years, adaptive control method [5–20], for its unique advantage, is more widely employed to control systems. Compared with other designs, it has simpler controller structure, and can adjust controller's parameters adaptively to make the controlled system have good performances.

Some adaptive control researches have also been conducted for quadrotor helicopters [21–26], but most of them are aimed towards the uncertainties associated with quadrotor dynamics and outer disturbance. Direct adaptive control with parametric uncertainties and disturbances has been investigated in [21]. Ref. [22] proposes an adaptive trajectory tracking control algorithm for a quadrotor in the presence of parametric uncertainties and external disturbance. Backstepping based techniques are used to design a nonlinear adaptive controller in [23], which can compensate for the mass uncertainty of the vehicle. So far, there are very few papers study the adaptive compensation of quadrotor helicopters with actuator fault.

A lot of attention has been paid to the design of disturbance observer to approximate the external disturbance and unknown model uncertainties [27–32] recently. In [27], a robust tracking controller is designed based on the output of a disturbance observer for an uncertain nonlinear system. A general framework using disturbance observer based control (DOBC) techniques for nonlinear systems with outer disturbance is presented in [28]. Ref. [29,30] propose two fuzzy disturbance observers based on control schemes.

In this paper, we combine the adaptive control method with the disturbance observer and quantum information technology, to deal with the control problems of quadrotor helicopters with actuator faults and external disturbance. Compared with other reconfiguration control studies [36–41], the main contribution of this paper contains: (i) We combine the design of disturbance observer with the adaptive compensator. In addition to all the advantages of adaptive control method it has, the introduced disturbance observer can also greatly improve the anti-interference ability of the system and reduce the burden on the controller. Therefore, we can not only estimate the external interference faster and better, but also guarantee a better tracking performance of the system. (ii) A quantum technology is introduced in this paper, which makes a good function. (iii) As far as we known, there is almost no adaptive compensation control papers study the attitude control problems of the four-rotor helicopter with actuator failures and external disturbance. Some semi-physical simulation results are also given to illustrate the effectiveness of this proposed reconfigurable control scheme. The structure of this paper is organized as follows. System description is given in Section 2. Section 3 presents the control problems of the four-rotor helicopter. Section 4 details the design process of the reconfiguration control scheme. Both the digital simulations and the semi-physical simulations in a Quanser 3-DOF hover platform are given in Section 5, to illustrate the effectiveness of the proposed adaptive compensation control scheme followed by some conclusions in Section 6.

2. System description

The quadrotor is motivated by four motors and can lead to three attitudes, i.e. yaw, pitch, roll. The front and rear rotors rotate in a clockwise direction while the left and right rotors rotate in a counter-clockwise direction to balance the torque created by the spinning rotors. In this section, the Lagrange method is used to model the quadrotor. There are some assumptions to simplify the modeling process