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Back-stepping based anti-disturbance flight controller with preview methodology for autonomous aerial refueling

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Abstract

This paper proposes a novel back-stepping based flight controller for the receiver in Autonomous Aerial Refueling (AAR) by the combination of active disturbance rejection control (ADRC) and preview control methodology. Firstly, the proposed flight control law design is divided into five loops by the back-stepping technique. The 6 DOF model for aircraft is written into several strict-feedback nonlinear forms through tactful transformation, considering that the path dynamics are originally non-affine nonlinear forms and are intractable for controller design. Secondly, the influences of the unknown flow perturbations on a receiver in each loop are viewed as the components of the "total disturbances" which are estimated and compensated by extended state observer (ESO). Thirdly, the preview control methodology is introduced into the position loop design as the system dynamic of the receiver is much slower than drogue. The position loop determines the proper reference path angle by using a fuzzy-logic ADRC controller in which previewing error and current tracking error are both taken into consideration. And a novel adaptive look-ahead distance scheme based on the fuzzy logic control (FLC) is proposed for the selection of the preview point. Finally, extensive simulations and comparisons on the 6 DOF receiver model are carried out to demonstrate the effectiveness of the proposed flight controller.

Keywords: autonomous aerial refueling; receiver flight control; back-stepping; active disturbance rejection control; preview control; fuzzy logic control

1. Introduction

Autonomous Aerial Refueling (AAR) [1], which refuels other aircrafts in the air, is an effective method of increasing the endurance and region of the aircrafts. It has drawn more and more significant interests from the research and development community [2-4], especially for the purpose of enabling unmanned aerial vehicles with this critical capability [5]. There are two ways of refueling [1]: flying boom method and probe-and-drogue method. In either case, it would be better if the receiver aircraft were automatically controlled for aerial refueling. In this paper, we focus on the probe-drogue refueling (PDR) [6,7], as shown in Fig.1.

In the PDR, the receiver aircraft is required to fly precisely to track the wobbly drogue rapidly and accurately [1-5]. However, considering the particularity of the environment and mission in the PDR, the following problems should not be ignored during the receiver flight controller design.

i. The strong impact of the multiple flow perturbations with varying magnitude and direction

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