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Disturbance Observer Based Reliable H_∞ Fuzzy Attitude Tracking Control for Mars Entry Vehicles With Actuator Failures

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Abstract

This paper introduces a disturbance observer (DO) based reliable H_∞ fuzzy attitude tracking control design for Mars entry vehicles with actuator failures. Initially, to reduce the complexity of Takagi-Sugeno (T-S) fuzzy modeling, the two time-scale decomposition technique is used to divide the original nonlinear attitude tracking error model of Mars entry vehicles into a slow subsystem describing the attitude kinematics and a fast subsystem describing the attitude dynamics. The dynamic inversion control (DIC) method is subsequently applied to the slow subsystem to generate the angular velocity command. Then, the T-S fuzzy modeling method is employed to exactly represent the fast subsystem and a disturbance observer (DO) is constructed to estimate the modeled disturbance based on the derived tracking error fuzzy system of angular velocity. By the technique of linear matrix inequalities (LMIs), a DO based reliable H_∞ fuzzy controller of attitude tracking is developed to stabilize exponentially the angular velocity tracking error and the modeled-disturbance state estimation error with an H_∞ tracking performance both in nominal and actuator failure cases. Furthermore, it is shown that the original nonlinear tracking error system is also exponentially stable and satisfies an H_∞ tracking performance both in nominal and actuator failure cases under the proposed fuzzy control law together with the DIC law, provided that the timescale separation between the fast and slow subsystems is valid. Finally, simulation results illustrate the effectiveness of the proposed design method.

Keywords: Mars entry vehicles; attitude tracking control; disturbance observer; fuzzy control; H_∞ control; actuator failures; linear matrix inequality (LMI).

1. INTRODUCTION

Mars exploration missions play an important role in the future deep space exploration activities, which can gather more precise scientific data and improve the present knowledge of the solar system and the universe. Among the tasks in any Mars exploration missions, the most difficult ones are the entry, descent and landing phase [1]. An active guided entry trajectory can significantly reduce the position errors at parachute deployment than a ballistic entry trajectory [2]. During the Mars atmosphere entry phase, the guidance system uses the position and attitude information provided by the on-board navigation system to minimize the downrange and crossrange errors by changing the lift vector through bank angle commands [3], which is then fed into the control system as a reference attitude command to calculate the desired control torques that the reaction control system thrusters need to produce [4].

The challenges for the design of an entry attitude tracking controller can be seen in many different ways [2]. One of the most difficult challenges is the recovery or tolerance in the case of actuator failures, which are very likely to

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