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A WEAKLY MODEL DEPENDENT CONTROL SCHEME FOR A CLASS OF LARGE-SCALE LONG-RANGE AEROSPACE TRANSPORTATION VEHICLE

Abstract

Global long-range transportation has become an increasing research focus in current aerospace transportation community. As a viable choice, the lifting-body horizontal-landing vehicle with large wings can fully use aerodynamic effects to achieve long-range flight with comfort and low overload, and effectively save propellant, thereby gradually drawing a wide attentions. However, compared with traditional lifting-bodyvehicles, suchtransportation vehicles often have large wings and possess to be larger-scale, which brings many control challenges, including: 1) the thin-walled large wingspans easily lead to significant aeroelastic effects, and mix rigid and elastic low-frequency characteristics; 2) the propellantmotion results in significantly time-varying vibration frequencies; and 3) the cross-domain aerodynamicmechanism has not been fully recognized, and the aerodynamic disturbances at the junctionsbetween vehicle segments are complex, leading to distributed steering effects along different segments especially in case that the flight environment is greatly changing.

This article tackles the high-precision and reliable flight control problem and proposes a weakly model-dependent robust control scheme, composed of three parts. Firstly, an autonomous prediction and correction method is developed to onlineobtain accurate aerodynamic parameters. To do so, 1) an unsupervised layer-by-layer pre-training model is constructed as the basic model for aerodynamic identificationby fully utilizing wind tunnel and historical flight data; 2) an aerodynamic parameter network for online sample-correction by using online measurement data; and 3) the aerodynamic identification network is incrementally modified by using stochastic gradient descent incremental learning method, to improve accuracy and adaptability.Secondly, a low- and dense-frequency elastic vibration suppression technology is proposed to online identify the vibration frequency, and enable high-quality elastic vibration control. By doing so, 1) a particle swarm optimization algorithm is introduced to give anoptimizedfilter design by using offline elastic vibration test results; and 2) The empirical mode decomposition method is online utilized to identify the central frequency of elastic vibration, which helpsto update the filter trap center to filter out the elastic vibration signals.Finally, a high-gain prescribed-time control and online optimal allocation method are given to attenuate strong disturbances and address actuator saturation. To this end, 1) a predetermined-time disturbance observer is designed to improve both the disturbance rejection quality and control accuracy; 2) a prescribed-time sliding-mode control law with explicit time indicators is developed to quantitatively regulate the convergence time; and 3) an online control allocation method is proposed to achieve a power-law improvement in allocation efficiency while avoiding actuator saturation.