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Author: Dr. Feng Zhang
China Academy of Launch Vehicle Technology(CALT), China, jimmyzf2004@126.com

Mr. Chen haipeng
China Academy of Launch Vehicle Technology (CALT), China, hitchenhp@163.com
Dr. Changzhu Wei
School of Astronautics, Harbin Institute of Technology, China, weichangzhu@hit.edu.cn

AN ONLINE TRAJECTORY PLANNING SCHEME FOR A CLASS OF LONG-RANGE AEROSPACE TRANSPORTATION VEHICLE

Abstract

Global long-range rapid transportation has gradually become a new technological requirement for aerospace transportation systems, and has given rise to diverse technical solutions. As a promising choice, the lifting-body horizontal-landing propulsion-free flight vehicle (LHPFV) can fully utilize aerodynamic effects to achieve long-range rapid flight with comfort and low overload, and meanwhile effectively save propellant consumption, thereby becoming a focus in this field. However, the long-range flight results in much more complex and longer-duration atmospheric effect acting on such type of vehicles, and also brings larger errors especially in multi-stage handover points. In this light, it is hard for the LHPFV to ensure high-precision and reliable landing based on the traditional pre-determined trajectory tracking philosophy. Online trajectory planning would be a feasible solution, but has to face the new challenge of much narrow flight corridor of such type of vehicles, since the combined effects of lifting-body shape, high dynamic pressure and large characteristic area with no doubt lead to various severe nonlinear constraints, involving overload, heat flux density and others, can easily contradict the admissible boundary of the flight corridor of the LHPFV. This forms the background of the present work.

To deal with this issue, this study proposes a feasible online trajectory planning scheme for such type of vehicles. On the one hand, the re-entry propulsion-free flight stage adopts an online convex optimization method to achieve high-precision fast planning for the flight trajectory with handover-point constraints. To do so, 1) an equivalent online convex optimization model for re-entry is firstly constructed by stage/control variable expansion, constraint relaxation and convexification; 2) an adaptive grid-updating based high-precision discretization method is proposed to improve solving accuracy; and 3) an efficient solution method with adaptive trust-region and updating step-size is given to ensure reliable online solution convergence of the flight trajectory. On the other hand, the terminal descent and landing stage utilizes receding-horizon prediction and correction planning technique to achieve energy management and precise landing with remarkable aerodynamic effects. By doing so, 1) a finite-parameter based mathematic model for energy management phase is firstly formulated; 2) a fast trajectory computation method is proposed enabling accurate prediction of terminal state from current control inputs; and 3) the dependency of terminal states on control inputs is further recognized such that the control variables can be adjusted in advance to reduce terminal landing errors. At last, the effectiveness and feasibility of the proposed scheme are verified through numerical simulations.