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MARS ENTRY GUIDANCE DESIGN USING A NOVEL RECEDING HORIZON SUBOPTIMAL CONTROLLER

Abstract

One of the demands for future Mars exploration is pin-point landing, in which the landing precision should be less than one hundred meters and that is two orders of magnitude higher than the current level. In the process of the high-speed vehicle entering a rarefied atmosphere with highly uncertainties as the Mars atmosphere, the trajectory deviation caused by entry guidance can be the major part of the total landing errors. Due to modeling errors such as the atmospheric modeling error and the vehicle's aerodynamic model inaccuracy, the more the guidance law depends on the models, the greater the trajectory dispersion can be. To reduce the impact of model errors on guidance performance, a guidance law based on receding horizon control is developed for reference trajectory tracking.

Firstly, a nominal entry trajectory is obtained by Gauss pseudospectral optimization method offline, and the formulation uses the nonlinear vehicle dynamics with a spherical and rotating Mars, path and control constrains. Then, the guidance strategy presented in this paper tracks the nominal trajectory by generating the necessary angle of bank that the vehicle should simultaneously execute. At each guidance cycle, the prescribed trajectory as well as the commanded bank angle in the finite horizon is obtained by an indirect optimization method, in which the cost function has several components with associated weighting factors accounting for tracking accuracy and control constrains. The indirect optimization approach is based on Pontryagin's minimum principle, which results in a set of algebraic and ordinary differential equations with their boundary conditions, called boundary value problem (BVP). In this paper, the BVP is transformed into a system of nonlinear algebraic equations by using the differential transformation method to reduce the computational burden caused by differential operation. Moreover, the system of algebraic equations is solved by a trust region Newton's method. Furthermore, the closed-loop guidance law is tested by the simulation of 500 entry cases with modeling errors. Numerical simulations show that the proposed guidance scheme is feasible and effective in tracking the nominal trajectory, thus has the potential to be applied to online guidance.