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Mars Exploration – missions current and future (3A)

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JET TRANSPORT-BASED MARS ENTRY PREDICTION-CORRECTION GUIDANCE

Abstract

To accomplish future Mars exploration missions, including sampling return and manned exploration, the Mars entry, descent and landing (EDL) technologies are developing rapidly, which require high landing accuracy. Because of uncertainties of Mars atmospheric density, spacecraft aerodynamic parameters and initial entry conditions, entry trajectories are usually dispersed and have large landing errors. At present, many uncertainty quantification methods are used to solve the problem that high-accuracy Mars entry under uncertainties, including Monte Carlo (MC) simulation, local linearization theory (LLT) and generalized polynomial chaos (GPC). However, these methods have certain shortcomings. The MC requires a tremendously expensive computational overhead and LLT is difficult to achieve a satisfactory accuracy. For highly nonlinear stochastic problems with long-term integration or discontinuity, GPC usually diverges.

Therefore, this paper presents a numerical prediction-correction guidance method based on Jet Transport, which aims at uncertainties of initial point states, atmospheric environment and aerodynamic parameters during Mars entry. The Jet Transport allows to propagate full neighborhoods of initial states instead of a single initial state by means of usual numerical integrators, so the problem that multi-parameters uncertainty propagation and quantification can be effectively solved by combining it with process of Mars entry guidance. The proposed method steps are as follows: Firstly, uncertainty parameters are introduced by the Jet Transport in the integral process of prediction-correction guidance and uncertainty propagation and magnitude are quantitatively in each guidance cycle so that multi-point uncertainties analysis is accomplished. Thus, the position of the parachute opening point is obtained. Secondly, lateral guidance parameters of numerical prediction-correction guidance are adaptively feedback adjusted to improve the accuracy and adaptability of it.

This paper conducts comparative experiments on uncertainties analysis of Mars entry based on Monte Carlo and Jet Transport numerical prediction-correction guidance. Simulation results indicate that the proposed method has higher computational efficiency, shorter computational time and stronger robustness compared with traditional Monte Carlo simulation, when solving Mars entry problems under uncertain conditions. Furthermore, compared with initial point and single-point uncertainties, the multi-point uncertainties analysis of the proposed method is more practical and conducive to deal with emergencies during the whole Mars entry process.