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A DOWNGRADED TRAJECTORY OPTIMIZATION METHOD COMBINING DEEP NEURAL NETWORKS AND LOSSLESS CONVEX OPTIMIZATION FOR THE THRUST DESCENT FAILURE

Abstract

In order to enable the rocket to use the remaining fuel as much as possible to inject the optimal degraded orbit in the event of thrust descent failure which prevents the rocket from completing its original mission, this paper proposes a decision-making process that includes three orbit degradation strategies. The corresponding terminal orbits for these three strategies are (1) A circular orbits with maximum energy; (2) An elliptical orbit with maximum energy constrained by perigee and apogee heights; (3) An Elliptical orbit with minimum eccentricity. A pseudo-spectral sequence convex optimization method is adopted to solve the optimal control problem corresponding to these three strategies. In order to ensure the convergence of the algorithm, non-convex terminal constraints and objective functions are convexified by lossless convexity instead of simple linearization, including equivalent transformation and relaxation of constraints based on flight dynamics, as well as introducing the additional coasting phase. But the above operation will introduce new variables to be optimized, including the perigee angle and the coasting time, which will generate additional non-convex terms. A two-layer solution strategy was adopted for this difficulty: using a sequential second-order cone programming method to solve the optimization problem under fixed perigee angles in the first layer and using the Newton's method to solve the optimization problem of perigee angle in the second layer. In order to further ensure the convergence of the algorithm and improve computational efficiency, a deep neural network is trained to generate initial conjectured values of the perigee angle and the coasting time online. This indirect application of artificial intelligence can significantly reduce the application risk while improving the performance of traditional optimization algorithms. Numerical simulations are conducted to compare the proposed algorithm and existing linearization based sequential convex optimization algorithms in different fault scenarios, which show that the proposed method has stronger convergence and higher engineering value.