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SPACECRAFT TRAJECTORY DESIGN USING DATA-DRIVEN MODEL PREDICTIVE CONTROL

Abstract

The spacecraft trajectory is influenced by multiple celestial gravitational forces and exhibits the highly nonlinear dynamics. Moreover, low-thrust trajectories are often considered because of the limitations of thruster level. To design such trajectories, it is general to compute the optimal trajectory by the direct methods to reduce the sensitivity of the initial guess. On the other hand, the indirect approach can provide the optimal solution by resorting to the calculus of variation. Although the dimension of the problem is less than the direct approach, the solution procedure is extremely hard due to the small convergence radius.

This paper focuses on an indirect approach for the optimal trajectory design with the aid of powerful data-driven approach, which can address the global nonlinear dynamics. The extended dynamic mode decomposition (EDMD) algorithm is originally developed in fluid mechanics in the era of big data and is nowadays becoming a popular tool for data-driven analysis of nonlinear dynamics. The EDMD constructs an approximation of the Koopman operator, which transforms nonlinear dynamics into an infinite-dimensional space where its evolution is linear. In previous studies, the definition of the Koopman operator was extended for relatively simple nonlinear dynamical systems including control forces, and the data-driven model predictive control (MPC) was proposed to achieve global stability. In this study, we apply an approximation of the Koopman operator obtained by the EDMD to a complicated orbital design problem because its nonlinearity dramatically changes depending on positions. In the process, the data-driven MPC is used to find the optimal transfer trajectory by leveraging the benefits of the data-driven approach and MPC.

This paper deals with the Earth-Moon circular restricted three-body problem (CRTBP) as an example and the optimal cis-lunar transfer trajectory is investigated. The optimal trajectory design in the CRTBP is considered to find the low-thrust trajectory. We show that the linear representation of the nonlinear dynamics obtained by the EDMD can remarkably reduce the complexity of the problem and overcome the numerical difficulties arising from the sensitivity of the initial guess. The results of transfers with various thruster levels are demonstrated to highlight the effectiveness of the data-driven MPC.