Paper ID: 71783
oral
student

IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation & Control (3) (5)

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ONBOARD TRAJECTORY OPTIMIZATION FOR ASTEROID LANDING BASED ON GENERAL KOOPMAN OPERATOR

Abstract

In the past few years, various asteroid exploration missions have been implemented via flyby, rendezvous or landing approaches, among which asteroid landing is the precondition for sampling return. Considering the complex gravitation environment near the asteroid and the large communication delay, onboard trajectory optimization is usually required, which is the basis for the autonomous control of the space vehicle. Typically, onboard trajectory optimization can be divided into two categories, the model-based and the data-based methods. The model-based approaches rely on the known dynamic models, which may not be ready for most situations. In the data-based ones, the learning models can be established through the training of the sample data, and then numerical optimization algorithms will be utilized to solve the problem. At present, there are two main types of data-based trajectory optimization methods, identified by the data learning approaches. The first one utilizes the deep learning, the learning models of which are set up under high-dimensional and strong nonlinear space. The main disadvantages are that the learning process usually relies on the high-performance computers and large training time, which is unrealistic for the space vehicle with limited computational resource. Besides, it is also a great challenging to solve the corresponding trajectory optimization problems, which are described by the deep neural network. The second one takes the Koopman operator to obtain the learning models, under high-dimensional linear space. The main advantages are that the training burdens can be significantly reduced, and the optimal solution can be easily found based on the linear optimization algorithms. However, due to the large loss of accuracy after linearization, the Koopman approach is usually valid for the situations with weak nonlinearity, such as the simple periodic orbit motions or short-range orbit maneuvers, and for the simple control problems, such as the linear quadratic regulator and model predictive control. In this paper, a new data-based onboard trajectory optimization method for asteroid landing problem, based on the general Koopman operator, is proposed. By utilizing the general Koopman operator, the learning models can be established under high-dimensional and weak nonlinear space. Thus its accuracy can be greatly enhanced, comparing to the traditional Koopman approach. Then, the optimal control models can be formulated based on the Pontryagin's minimum principle, which will be much easier to be solved due to its nature of weak nonlinearity. Numerical demonstrations are also provided, to validate the effectiveness and efficiency of the proposed method.