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DATA-DRIVEN MODELLING OF ORBITAL ENVIRONMENT AROUND PHOBOS

Abstract

Since its discovery, Martian Moon Phobos has become increasingly interesting astronomical objects to investigate. From a scientific perspective, understanding the origin of Phobos provides insights into the evolution of Mars. Nowadays a series of Mars and Phobos exploration missions have been carried out or in process, e.g., Mars Express, Mars Exploration Rover, Mars Reconnaissance Orbiter. Particularly, Japan Aerospace Exploration Agency (JAXA) has proposed its first sample return mission from Phobos in Martian Moons eXploration (MMX). One of the challenges in MMX mission is the signal delay due to long Earth-Mars distance, which is about 12-20 minutes for Mars spacecraft. Error sources in orbital mechanics mostly consist of the unmodelled components involved in the dynamical model and the navigation errors including those from instruments and coordinate systems, leading to high demand on orbital control technique on the compensation in unavoidable signal delay. The unmodelled components involved in the real dynamical environment are the main source of the orbital uncertainty. In particular, a spacecraft orbiting Phobos moves in the gravity field of Mars and Phobos. The potential perturbations that this spacecraft suffers from are Sun's gravity, solar radiation pressure, Mars irregular shape, Jupiter gravity, etc. Most of the disturbances aforementioned are implemented upon the spacecraft in various period. The summary of these forces can be approximated by a series of sine function $\Sigma \mathbf{A}\mathrm{i}\ \sin(it)$, where the amplitude vector $\mathbf{A}$i and the number of the series are to be real-time computed based on the previously obtained data. In Phobos orbiting phase, the spacecraft is supposed to encircle around Phobos for 2-3 days, long enough to capture and estimate the real model by data-driven technique. The dynamical environment is not changing dramatically compared with Mars escaping phase or planet gravity assisting phase. In this investigation, the navigation error is described as Gaussian type. Gaussian assumptions on navigation uncertainties are usually adopted in orbital uncertainty propagation problems. The Gaussian error hyper-ellipsoid magnifies and rotates with the increasing of propagation time, and gradually becomes non-Gaussian due to the nonlinear nature of dynamics. Another technical challenge in this investigation is to find proper value set of $\mathbf{A}$i optimizing the distance between the probability density of the calculated and the observation results. To solve this problem, the genetic programming is introduced to optimize both the $\mathbf{A}$i and N, the number of series used in the modelling.