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Author: Dr. Feng Jinglang
University of Strathclyde, United Kingdom

Dr. Pierluigi Di Lizia
Politecnico di Milano, Italy
Dr. Roberto Armellin
University of Surrey, United Kingdom
Mr. Daniele Antonio Santeramo
Politecnico di Milano, Italy
Prof. Xiyun Hou
China

STABILITY INDICATOR OF ORBITAL MOTION AROUND ASTEROIDS WITH AUTOMATIC DOMAIN SPLITTING

Abstract

Most asteroids feature irregular shape and gravity field, which are usually modeled with large uncertainties due to the limited data available from ground observations. Therefore, in the frame of rendezvous missions to small bodies, the proximity motion cannot be accurately predicted before arrival to the asteroid. Conventional methods for characterizing the orbital stability either use the Lyapunov stability of the linearized dynamics or apply the pure numerical Monte Carlo simulations. However, the dynamics around asteroids tend to be highly non-linear and the use of Monte Carlo methods is often hindered by its computational effort. Consequently, this work focuses on proposing alternative methods to study the stability of orbital regimes.

Specifically, the automatic domain splitting method (ADS) is introduced as a new tool of identifying the stable and unstable regions in the phase space with gravity uncertainty. The ADS is actually based on the use of differential algebra (DA) techniques, which can approximate the flow of the dynamics with arbitrary order Taylor expansions. Even if adopted to relatively high order, pure DA tends to fail in highly nonlinear dynamical environments. The ADS was introduced to solve this issue by automatically splitting the current polynomial expansion into many polynomials whenever the truncation error reaches a predefined threshold. Therefore, ADS can deal with large initial uncertainty sets.

In this study, the asteroid Steins is taken as a test bed for the developed method and its gravity up to the 4th order and degree is considered in the dynamics. However, as the C20 and C22 harmonic terms are usually dominant over the non-spherical gravity, only their uncertainties are considered in the investigations. Given the required accuracy, the expansion order and the maximum number of splits are firstly determined, to balance efficiency. It is found that most of the splits happen in the direction of the C22 term, indicating that the orbital motion is more sensitive to its variations, compared with the C20 term. Then, the epoch of the occurrence of the first split is recorded as a measure of stability of the orbital motion. The longer the first split time is, the more stable the corresponding motion can be considered. Consequently, after the maximum allowed first split time has been determined according to mission requirements, practical stable regions can be identified.