Paper ID: 15935
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ASTRODYNAMICS SYMPOSIUM (C1)
Orbital Dynamics (1) (6)

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A QUATERNION BASED REGULARIZATION FOR CLOSED ORBITS

Abstract

Two-body regularization is a very powerful tool to increase accuracy and computing speed in orbital propagation in particular near attracting masses or along highly eccentric orbits. Regularization can be further improved by the variation of parameters technique, especially when dealing with the long-term study of the motion of asteroids, comets, as well as natural and artificial satellites subject to relatively small perturbation forces. The decomposition of the position vector of a point mass into the product of its magnitude and its direction and the change of the independent variable from physical time to fictitious time are preliminary steps for achieving regularization. The celebrated Kustaanheimo-Stiefel method exploits this artifice in order to transform a perturbed Keplerian system into a set of perturbed harmonic oscillators.

In 2006 Peláez proposed a new formulation for the two body-problem equations of motion, named DROMO. The idea is to track the evolution of an orbital frame moving with the particle and link a new set of generalized orbital elements to this frame. The result is an improvement in accuracy with respect to other efficient methods in orbital dynamics and a more compact and simple formulation of the equations of motion. However, full regularization can not be achieved due to the structure of the Sundman transformation employed. From a practical point of view, when the orbital motion is highly eccentric the growth of the propagation error is amplified near the apoapsis.

We present a new regularized method for propagating closed orbits under perturbations, called ELI-DROMO, which inherits the regularized framework of DROMO. The concept of projective coordinates is exploited in order to decompose the particle dynamics into a perturbed harmonic oscillation of the orbital radius and the evolution of a unit quaternion describing the orientation of the orbital plane. The independent variable is changed from physical time to eccentric anomaly through Sundman's transformation and regularization is achieved by embedding the Keplerian energy and by properly choosing the rotating reference frame. The number of dependent variables is eight: they are the physical time and seven regular elements generated by applying the variation of parameters technique. The new method is tested and compared with the most efficient regularized schemes known nowadays by considering two examples: the Tsien problem and the Stark problem. ELI-DROMO shows the best performance between the compared methods.