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A NEW FORM OF OSCULATING KEPLERIAN APPROXIMATION OF N-BODY NON-KEPLERIAN MOTION FOR THE DESIGN OF GNC ALGORITHMS

Abstract

A new approximation of the non-Keplerian dynamics is presented in this work, it is based on the concept of osculating Keplerian orbits which are defined by the computation of an instantaneous virtual new primary whose position and gravitational field reproduce locally the behavior of a N-Body non-Keplerian motion with general perturbations.

Considering a general space environment, there exist different classes of non-Keplerian motion, periodic or not, such as the n-body dynamics, the restricted three body problem or the perturbations (e.g., solar radiation pressure or thrust dispersion errors). For these types of motion, which are mostly non-planar, the two-body Keplerian dynamics is not sufficient to accurately model the behaviors of moving objects even in the regions with a slower dynamic. Consequently, usually, if a satellite needs to follow a certain trajectory, it is needed a high-fidelity system representation which commonly leads to the design of non-linear Guidance, Navigation and Control schemes for artificial satellites to successfully accomplish the mission and counteract the complex non-Keplerian dynamics.

The objective of this research is to present a method which is based on osculating Keplerian orbits which brings together the non-Keplerian influence with the convenience of having simpler two-body equations model for single satellite motion or relative motion between satellites. This approach differs from the literature because the center gravitational body does not correspond to any physical gravitational attractor but it is fictitiously computed at each step of the algorithm to better approximate the real dynamics. The main idea behind is to process the current state of the satellite and a finite number of old-states to approximate the local dynamics with a two-body elliptic, circular, or hyperbolic conic around the newly computed primary location. Since the approximation is local, the algorithm changes iteratively the position and mass of the primary according to the local behavior of the satellite orbit propagation. At this point the motion of the satellite at the next step of the algorithm is predicted on the base of a Keplerian-motion.

In this work, the osculating Keplerian orbits algorithm is applied, with elliptic or circular osculating orbits, to a various range of periodic three-body Earth-Moon non-Keplerian orbits, such as Halo, Lissajous, Lyapunov, Butterfly and Distant Retrograde Orbits. Subsequently, position and velocity errors, for both single satellite and relative motion between satellites, are showed, demonstrating the feasibility of using this algorithm to predict motion and to simplify Guidance, Navigation and Control schemes.