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EXACT SEPARATION OF LONG- AND SHORT-PERIOD EFFECTS IN THE COMPUTATION OF MEAN ELEMENTS OF ARTIFICIAL SATELLITE THEORY

Abstract

It is well known that mean elements obtained by canonical perturbation theory only agree with the average of corresponding osculating elements up to the first order of the small parameter. While this fact does not compromise in general the accuracy of corresponding perturbation solutions, the exact separation of long- and short-period effects in the computation of mean elements of artificial satellite theory may be desirable in a variety of aerospace engineering tasks, like maneuver design or fast orbit propagation. In particular, the computation of mean frequencies that comprise all the long-period effects of the perturbed Keplerian dynamics dynamics is essential in some space geodesy applications or when high accuracy is needed in preliminary orbit and maneuver design.

Regarding artificial satellite theory, the exact separation of long- and short-period effects is customarily carried out to first order effects. However, the strict removal of short-period effects to get mean frequencies that capture the whole long-period dynamics is also relevant in the computation of second order effects of the dominant zonal harmonic of the second degree. Indeed, for Earth-like bodies these kinds of effects are comparable to those produced by the higher order harmonics of the gravitational potential. Therefore, they are routinely incorporated into operational software, yet commonly limited to the second-order terms of the mean variations.

For the main problem in artificial satellite theory, we compute the mean to osculating transformation that is pure periodic in the mean anomaly, and hence provides mean elements with the required characteristics. We also provide the inverse, osculating to mean transformation, which is crucial for the initialization of the mean frequencies of the perturbation theory in order to avoid the abnormal growth of errors in the along-track direction. Both transformations are computed in closed form of the eccentricity up to the second order of the small parameter, and can be included as additional patches to improve the performance of existing semi-analytic orbit propagators. Tests carried out on the new theory show the improvements of the computed mean elements over traditional alternatives in the literature.