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SATELLITE EPHEMERIS COMPUTATION WITH IDEAL-HODOGRAPHIC ELEMENTS USING BREAKWELL AND VAGNERS' ENERGY-CALIBRATION CONTROL

Abstract

The decomposition of perturbed Keplerian motion into the slow attitude variation of the orbital plane and the fast motion of the orbiter in the orbital plane gives rise to successful numerical integration schemes. In these cases, the angular velocity of the moving frame, used in the determination of the attitude, splits into one component in the radial direction and another component in the normal direction defined by the instantaneous angular momentum. The component in the radial direction is the same in any case, but the component in the normal direction varies depending on the chosen frame, as, for instance, the nodal or the apsidal frames. Moving frames with null component in the normal direction are also possible, and, as shown by Hansen, provide additional advantages derived from the simplification they introduce in the formulation of the variation equations. Most notably, the angular motion in the orbital plane turns into a simple Keplerian rotation. Still, the inherent Lyapunov-type instability of Keplerian motion makes that, soon or later, observable in-track errors unavoidably arise. Time-regularization approaches notably improve the geometric description of the orbit. However, since the time-regularization technique does not change the perturbed Keplerian dynamics, the Lyapunov-type instability is not removed when using this approach, but just confined into the differential equation related to the integration of the physical time as a function of the fictitious time used in the regularization. Because the shift introduced by time errors mainly translates into in-track errors, time-regularization strategies do not help in practice to improving accuracy when the aim is ephemeris computation.

On the other hand, it is known that the performance of numerical integration schemes may be notably enhanced with an energy-scaling process whose aim is to keep the integrated orbit as close as possible to the energy manifold of the true orbit. We demonstrate that this is also the case of special perturbation methods based on Hansen's ideal frame concept, whose accuracy is notably improved with a very simple calibration scheme due to Breakwell and Vagners that only affects the hodographic velocities and negligibly increases the computational burden. With this technique, the performance of the classical, physical-time integration of the set of hodographic ideal elements is improved to a comparable accuracy level to that of the fictitious-time alternative in the geometric description of the orbit, while avoiding the event detection processes needed by the latter in the computation of satellite ephemeris.