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ACCURATE ORBIT PROPAGATION OF PLANET-ENCOUNTERING BODIES

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ABSTRACT

We tackle the problem of accurately propagating the motion of those small bodies that undergo close approaches with a planet. The literature is lacking on this topic and the reliability of the numerical results is not sufficiently discussed. The chaotic motion of the close-encountering bodies makes their propagation particularly challenging both from the point of view of the dynamical stability of the formulation and the numerical stability of the integrator because of the high-frequency components of the perturbation.

In this work the accuracy achievable in the orbit computation of a planet-encountering body is assessed by comparing different formulations of the perturbed two-body problem combined with a fixed step-size (and fixed order) multistep method. In the proposed strategy the primary body of attraction is changed when the propagated object is sufficiently close to a celestial body. Moreover, the formulation and the step-size can be changed whenever the primary is changed. The crucial aspects related to the restart of the multistep method and the critiria adopted to switch the primary are described in detail.

Different combinations of the following formulations are tested: the non-linear Newtonian equations integrated with respect to either the physical or a fictitious time, the Burdet-Ferrandiz and the Kustaanheimo-Stiefel regularizations, and several sets of orbital elements.

We choose as a test-case the asteroid 99942 Apophis which represents a challenging example: as a consequence of the huge amplification of the orbit uncertainty after the 2029 Earth encounter we need to predict its position at the meter-level accuracy in the 2069 close approach.

Our goal is to show that the proposed approach improves the performance of both the propagator implemented in the OrbFit software package (which is currently exploited by the NEODys service) and of the propagator represented by a variable step-size and order multistep method combined with Cowell formulation (i.e. direct integration of position and velocity with respect to either the physical time or a fictitious time).