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ON THE ADVANTAGES OF USING A STRICT HIERARCHY TO MODEL ASTRODYNAMICAL PROBLEMS

Abstract

Space mission designers are relentlessly engaged to accomplish mission requirements and goals. Minimising fuel consumption, both with advancements in the engines technology and in the search of optimal trajectories, is of paramount importance. Although the simple Kepler dynamics yields fast and reliable results that can be easily refined in more accurate models, it lacks the capability of improving solutions because the spacecraft is forced to stump along a conic section. As a better understanding of the restricted three-body problem has been acquired and a greater qualitative portrait of its chaotic behaviour unveiled, new solutions become available. If third-body perturbation provides such benefits, one could argue that the same results could be reproduced by farther increasing the complexity of the dynamical model. What lies ahead is hence the pursue of novel trajectories, that exist only within more accurate vector fields. Unfortunately, the global picture of the restricted n-body problem is yet to be thoroughly understood. The lack of invariant structures, such as periodic orbits and fixed points, translates into the frustrating need to explore the whole extent of a six-dimensional space, hoping to stumble upon the required solution. This is where a hierarchic approach to the problem comes of great aid.

In this paper a tool is developed that combines the capabilities and advantages of several different astrodynamical models of increasing complexity. Splitting these models in a strict hierarchical order allows a clearer grasp on what is available. With the effort of developing a comprehensive model overhead, the equations for the spacecraft motion in simpler models can be readily obtained as particular cases. The proposed tool embeds the circular and elliptic restricted three-body problems, the four-body bicircular and concentric models, an averaged n-body model, and, at the top hierarchic ladder, the full ephemeris spice-based restricted n-body problem. The equations of motion are reduced to the assignment of 13 time-varying coefficients, which multiply the states and the gravitational potential to reproduce the proper vector field. This approach is very powerful because it allows, for instance, an efficient and quick way to check solutions for different dynamics and parameters. It is shown how a gradual increase of the dynamics complexity greatly improves accuracy, the chances of success and the convergence rate of a continuation algorithm, applied to low-energy transfers.