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PERIODIC ORBITS IN THE RESTRICTED THREE-BODY PROBLEM WITH NON-SPHERICAL MASS DISTRIBUTION OF PRIMARIES

Abstract

Small celestial bodies such as asteroids and comet nuclei are known to possess very irregular mass distribution and gravity field. From the spacecraft dynamics point of view, this means a highly chaotic motion and high sensitivity to initial conditions: a very small deviation in the state can result in a very different dynamical outcome. This is very relevant for the case of close-proximity operations. For these reasons, the effective design of trajectories to fly a spacecraft in the proximity of an asteroid requires the accurate knowledge of the physical, inertial and dynamical properties of the target body. This motivates the use of shape-based methods to model the mass distribution of such bodies.

In the last few decades many binary asteroid systems have been discovered and it is currently estimated that many Near-Earth Asteroids (NEA) are binaries. Binary asteroids are very interesting under many points of view. They are real-life laboratories to test gravitational dynamics and also, they offer the unique opportunity to determine precisely asteroid masses and densities. For these reasons, the study of the dynamical environment near an asteroid pair is a very relevant topic for future space missions.

The paper details the method used to find periodic motion in the proximity of a binary asteroid of non-spherical mass distribution and presents a survey of periodic solutions found. The dynamical model is implemented through a Restricted Three-Body Problem (R3BP) formulation, with mass distribution of primaries modelled according to a non-spherical shape model, with gravitational attraction due to primaries computed using a polyhedron analytical model. Existing binary systems are cosidered, with reference mainly to binary asteroid 65803 Didymos.

Periodic solutions are found through variable-time differential correction, starting from initial guesses provided by periodic orbits in the Circular Restricted Three-Body Problem (CR3BP). The initial guess is corrected and continued through multiple-parameter continuation, correlated to the change in shape of the primary. As for a constant density ellipsoid, continuation is achieved by slightly changing the mass distribution from spherical to ellipsoidal, through continuation of the semi-major axes of the ellipsoid. The same idea applies to any shape: continuation is performed by gradually displacing the vertexes of the polyhedron shape model, from their actual configuration backwards, until they reach a simpler geometry (sphere or ellipsoid). Orbit families in the binary asteroid environment are eventually shown and compared with their parent families in the CR3BP.