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A DIFFERENTIAL ALGEBRA-BASED CONTINUATION METHOD FOR AUTOMATIC IDENTIFICATION AND PARAMETRIZATION OF FAMILIES OF PERIODIC ORBITS IN THE CR3BP

Abstract

The Earth-Moon system will be at the center of attention in the years to come, as the Lunar Gateway will soon be the main manned station. The Circular Restricted Three-Body Problem (CR3BP) is a self-evident theoretical framework to model this environment as it considers both Earth's and Moon's gravitational attraction. This system enables multiple orbit families with specific properties and applications. For instance, a Near Rectilinear Halo Orbit (NRHO) will be the nominal Gateway orbit for stability and eclipse avoidance, and Distant Retrograde Orbits (DRO) with their high long-term stability can provide graveyard orbits and support lunar exploration with Orion's first mission Artemis I. Thus, designing transfers between and within families of the CR3BP is crucial. The design of such transfers can prove computationally intensive due to the generation cost of these orbits. Therefore, methods that can offer a more efficient generation of the target orbits are of great interest.

Starting from these considerations, this work proposes an efficient method to generate and store periodic families of the CR3BP using Differential Algebra (DA). By exploiting differential correction algorithms combined with a DA-based formulation of the two-point boundary value problem, the method implements a first continuation procedure to accurately represent a whole family of periodic orbits in terms of a set of polynomial expansions expressed with respect to a selected parametrization coefficient. As a result, initial conditions of a generic orbit in the family can be computed by simple polynomial evaluation compared to costly continuation procedures. Based on this described continuation procedure, a novel 2D family description is then implemented to provide access to any point belonging to the family without further trajectory propagation. Results show this method is efficient to generate abacus and compute points of a specific family with limited resources and a given error threshold. Tests include various families, including planar Lyapunov orbits, DROs, halo orbits, and butterfly orbits, and show the method's efficiency. The described DA-based method is then used to identify bifurcation phenomena and generate new families. As opposed to usual methods, bifurcation conditions are expressed as polynomial constraints that are continuously checked while continuing a family. All bifurcation events that are identified are then stored and later processed to search for connected families and their parametrization. The work offers

different examples for the bifurcation identification, including the period-doubling bifurcation of the Halo L2 family and the bifurcations on the Planar Lyapunov family in L1.