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GENERATION AND STABILITY ANALYSIS OF BOUNDED RELATIVE ORBITS USING LAGRANGIAN COHERENT STRUCTURES

Abstract

Recently studies around the searching of bounded relative orbits for formation-flying missions keep constantly emerging because this type of orbits can guarantee the spacecraft remain naturally bounded in relative distance under the perturbations without the need for external orbit maintenance. Much of the available research in bounded relative motion problem focuses on the identification of bounded relative orbits from the perspective of various analytical and numerical initialization methods, such as low-order approximations to the bounded condition, and Poincaré/stroboscopic mapping combined with iteration algorithms (Schaub and Alfriend,*CMDA*,2001; Lara and Gurfil,*CMDA*,2012; Xu et al.,*CMDA*,2012; Baresi and Scheeres,*CMDA/JGCD*,2017). Nevertheless, the problems of stability analysis of bounded relative orbits and the corresponding orbit generation are yet to be dealt with in the astrodynamics community.

Within the framework of dynamical systems theory, the perturbed relative motion in the along-track direction between the chief and deputy exhibits the weakly hyperbolic property with degenerated eigenvalues by the decomposition of state-transition matrix. Therefore, the aim of this work is to develop a novel approach for the design and nonlinear stability analysis of such bounded relative motion via the computation of Lagrangian coherent structures (LCS) defined as ridges of finite-time Lyapunov exponent (FTLE) fields. Specifically, the FTLE fields are the first to be calculated in the Poincaré section of the perturbed relative motion, which is imposed by the bounded constraints that both the chief and deputy share the equal values of nodal period and drift of the right ascension of ascending node over one nodal period. Due to the weakly hyperbolic feature of relative motion, the LCS would not serve as a clear boundary of the phase flow on the map. To remedy this, the bisection method is introduced to extract the LCS, followed by its refinement of imposing the bounded constraints. In this way, the LCS and its refinements (corresponding to the families of periodic orbits and quasi-periodic orbits) are utilized to assign the spacecraft to generate the bounded relative motion. With the help of LCS, the FTLE map can be divided into the stable, unstable and critical regions to perform stability analysis, allowing for the initialization of spacecraft to achieve the long-term bounded relative orbits.

As the illustrative example, the bounded relative motion of large amplitude and long duration can be achieved by our proposed approach, which is compatible with that obtained by the traditional purely numerical ones (Xu et al.,*CMDA*,2012; Baresi and Scheeres,*CMDA/JGCD*,2017).