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BOUNDED MOTIONS NEAR EQUILIBRIUM POINTS OF CONTACT BINARY ASTEROIDS BY A HAMILTONIAN STRUCTURE-PRESERVING CONTROLLER AND ITS APPLICATIONS

Abstract

Holding the key to the origin of universe, asteroids have attracted more and more interests. In order to provide ideal position for high-resolution image observations on asteroids, periodic orbits and low-energy transfer trajectories between them have been constructed. For example, Shang et al. developed a global numerical method combing grid searching and differential correction, systematically searching periodic orbits around the equilibrium points (abbr. EP) (Shang et al. 2015). Yang et al. generated two-impulse transfer orbits connecting EPs by a new three-step method (Yang et al. 2015). Feng constructed a third-order analytical solution around stable EPs by the Lindstedt-Poincaré method and introduced the linear feedback control law based on low thrust to stabilize the motion (Feng et al. 2015). However, Shang's results cannot maintain long-term body-fixed hovering, which leads to the miss of significant information on the asteroids. Apparently, Yang's results are unsuitable for some fuel-limited or long-term missions. Concentrated on stable EPs only, Feng's results cannot apply into unstable EPs, such as saddles with one-dimensional stable/unstable manifolds and two dimensional center manifolds (referred to as 1+1+2 type), or those with two-dimensional stable/unstable manifolds and zero-dimensional center manifolds (referred to as 2+2+0 type)(Jiang et al. 2014). To overcome their drawbacks, this paper proposed a Hamiltonian structure-preserving controller to stabilize the motions near the EPs of 1+1+2 and 2+2+0 types of 1996 HW1 by generating stable Lissajous orbits based on low-thrust techniques. Firstly, the asteroid 1996 HW1 is modeled as a contact binary asteroid, consisted of a sphere in physical contact with an ellipsoid, which capture the main characteristics of a 1996 HW1. Then the linearization near arbitrary EPs is derived from the equations of motion after implementing Taylor expansion. In planar cases, analytical results show that two collinear EPs are saddles of 1+1+2 type. According to Jiang, two non-collinear EPs are unstable of 2+2+0 type, and their eigenvalues are two pairs of conjuncture complex numbers. Subsequently, by implementing complex diagonal matrix decomposition upon the corresponding symplectic matrix the stable/unstable manifolds of non-collinear EPs are refined to stabilize the system with different gains. As for collinear EPs, the stable/unstable manifolds as well as center manifolds are utilized. Furthermore, it is analytically proven that the poles of the system can be arbitrarily assigned on the imaginary axis by this controller. Its sensitivity is measured by Frobenius norm. Finally, our controller is applied to low-thrust missions and the stable Lissaous orbits are yielded numerically.