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QUASI-PERIODIC ORBIT DESIGN AROUND AN ASTEROID USING AN IMPULSIVE DELTA-V

Abstract

Motion around small asteroids is strongly affected by perturbation force such as solar radiation pressure due to its weak gravity. For this reason, navigation and control of a spacecraft in the proximity of asteroids is considerably difficult. It is critical for such missions to precisely identify parameters which govern the spacecraft-asteroid dynamics such as a gravitational field of asteroids and optical property of a spacecraft. One such example is the Japanese asteroid sample return mission “Hayabusa2”, which is scheduled to be launched in 2014 to explore the C-type asteroid “1999 JU3”. Although the Hayabusa2 mission will implement a hovering operation for its asteroid proximity phase, orbiting around the asteroid is also studied as an optional operation in order to shorten time for global mapping, expand observability and save fuel consumption. Orbiting around asteroids usually requires periodicity for cyclic observability. However, natural periodic orbits around small bodies exist only with limited geometry. In past studies, for example, Sun-terminator orbits and quasi-terminator orbits are proposed as periodic and stable orbits around small bodies, but orbital geometry and period of these orbits are limited irrespective of scientific requirements. In order to relax such limitation, an impulsive delta-V on an orbit per period is considered in this research. From the result of numerical analysis under the circular restricted three-body problem (CR3BP), it is proved that the solution space to satisfy periodicity is expanded significantly just by adding one delta-V per period. Detailed analyses reveal that this single impulse “quasi-periodic orbit” has high flexibility in designing orbital parameters directly involved with observability and operability such as period, inclination and altitude at periapsis. It is also important that the magnitude of the delta-V is sufficiently small and thus the quasi-periodic orbit can be realized within practical range of general spacecraft maneuverability. Moreover it is more fuel efficient than hovering. In this paper, the basic design methodology of the single impulse quasi-periodic orbits is shown in the CR3BP framework, and the structure of the entire solution space is analyzed. We show the classification of the solution in terms of orbit shapes and the stability of orbits are discussed. Then the design methodology is extended to the elliptic restricted three-body problem (ER3BP) framework and also to a full ephemerides environment. Finally, as an example of application to a practical mission, an orbiting operation of Hayabusa2 around the target asteroid 1999 JU3 is designed and its feasibility is evaluated.