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DESIGN OF SATELLITES TOURS USING PERIAPSIS POINCARÉ MAP IN MULTIBODY DYNAMICS OF JOVIAN SYSTEM

Abstract

Recently, the exploration of Galilean satellites of Jupiter has attracted a great deal of attention for solving the mystery of the origin of the solar system and exploring the possibility of life. Jupiter has many satellites, and the four largest satellites are called Galilean satellites. For the exploration of these satellites, it is essential to design reachable trajectories to the destination with less fuel consumption. However, trajectory design is difficult in the Jovian region because the dynamics around this system is highly nonlinear due to the influence of several satellites as well as Jupiter and Sun. A gravity-assist tour, a trajectory with multiple gravity assists, is one of the candidates for the optimal trajectory to Jovian moons because gravity assists aid to decrease the fuel consumption and the opportunities to observe several satellites are provided. In previous studies, the tour design of Jovian moons has been performed using the dynamical systems theory where the different invariant manifold segments are patched. However, these methods consider only specific trajectories and manifolds, and ignore other possibilities that useful transfer trajectories exist around Jupiter.

This paper proposes a new method of satellites tour design utilizing the periapsis Poincaré map effectively. In this study, the multibody dynamics around Jupiter, including the gravity of the Sun, Jupiter, and Galilean satellites, is considered. Although trajectory design is extremely difficult in this dynamical system, the periapsis Poincaré map can comprehensively find ballistic transfer trajectories by extracting periapsis from trajectories. In previous studies, the periapsis Poincaré map has been used in various trajectory design, including ballistic lunar transfers. In this study, a large set of initial guesses in the configuration space are propagated in the multibody environment to find the periapsis which can achieve ballistic capture at the satellites exploiting the gravity of multiple bodies. Several ballistic transfer families between satellites are found under the effects of multiple satellites and precise ephemeris. Furthermore, a clustering technique is introduced to analyze the transfers obtained by the periapsis Poincaré map, which enables us to automatically extract ballistic trajectory families distributed over a wide area and to efficiently perform complex tour design. By using the transfer families, we can select the most suitable transfer trajectory that satisfies the requirements of each exploration mission. In this study, we design Galilean satellites tours, but the proposed method is applicable to all planetary systems with satellites.