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NEAR-EARTH ASTEROID CAPTURE MISSION DESIGN METHOD BASED ON THE ORBITAL DYNAMICS IN THE PLANAR-CIRCULAR RESTRICTED THREE-BODY PROBLEM

Abstract

Asteroid exploration missions are very important for science, engineering, future resources, and also planetary defense field. To deal with the high cost of spaceflight that is usually included in the missions, this study focuses on a method to put a Near-Earth Asteroid (NEA) into an orbit that is captured by Earth's gravity field (capture orbit). The velocity vector of an NEA is changed by the kinetic impactor (KI) and the NEA is put into the capture orbit. In this study, the orbital motion of the NEA in the vicinity of Earth is formulated in the planar-circular restricted three-body problem and the change in the NEA's velocity vector caused by KI is replaced with the change in a scalar value named as the Jacobi integral of the NEA. Since the value of the Jacobi integral can be uniquely converted to the components of the velocity vector, introducing the Jacobi integral is useful to investigate the orbit of the deflected NEA in the vicinity of Earth. In addition, to prevent NEA from escaping from Earth's gravity field or even colliding with Earth, the deflected orbit should not behave chaotic. To investigate whether the capture orbit behaves chaotic or not, we introduced the Small Alignment Index (SALI). SALI can be obtained by numerically integrating the equations of motion after adding small deviations to the initial state of the capture orbit. If the value of SALI remains 1 after sufficient integration time, the orbit does not behave chaotic. By combining the Jacobi integral-based orbit analysis and SALI, an appropriate capture point that yields putting an NEA into a regular capture orbit with the smallest delta-V is found. When an NEA approaches Earth, the value of SALI is calculated on the path of the NEA for a given value of the Jacobi integral. If we find points where the SALI remains 1, the required delta-V to achieve the change in the Jacobi integral is also calculated for each point. By selecting the point that yields SALI 1 with the smallest delta-V, an appropriate capture point can be found. The proposed method was numerically performed for capturing fictional asteroids that were created from actual NEA orbital data. As a result, several capture points that put NEAs into regular orbits with the smallest delta-V were found. Also, some fictional NEAs can be put into stable periodic orbits and the capture duration was more than 500 years.