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A NOVEL GUIDANCE SCHEME FOR BINARY ASTEROIDS-BASED GRAVITY TRACTOR MISSIONS

Abstract

The Gravity Tractor (GT) technique aims to divert the path of possible hazardous asteroids approaching Earth, exploiting a spacecraft's gravity. This challenging mission represents one of the most suitable alternatives to kinetic impactor missions like the DART. In our previous work presented at IAC 2021, we performed the feasibility analysis of such a mission applied to the asteroid binary system 162000 (1990 OS). This mission, called ARGO, aims to deflect the primary asteroid's moonlet (secondary asteroid) by increasing its semi-major axis around the primary asteroid of 100 m in less than three years. The primary outcome of that work is that the optimal GT position (the one maximizing the traction) shall be around 30 m from the moonlet's surface and in the direction of its velocity vector. In addition, the Guidance Navigation and Control (GNC) system shall perform an initial rendezvous from the previous characterization orbit to the desired GT position and grant the station keeping. To do so, we identified the low-thrust technology as the most suitable design solution. The previous GNC design was the following. Starting from the Ordinary Differential Equations (ODEs) of the three-body problem (3BP), we first derived the ODEs describing the spacecraft's motion relative to the moonlet. Then, we defined a suitable Lyapunov function to obtain the control law. Finally, collision avoidance is assured by adding an artificial repulsive potential.

Starting from this state-of-the-art, the goal of the present work is much more ambitious. Indeed, we aim to provide a new and more efficient GNC control system for the ARGO mission. In this new formulation, we start again from the 3BP and derive the dynamics equations describing the relative motion between the primary asteroid and its moonlet. These ODEs are coupled with those expressing the relative motion between the spacecraft and the moonlet. Finally, assuming that the moonlet's orbit around the primary asteroid is quasi-circular, we perform a linearization of this last dynamics in the neighborhood of the desired reference condition, obtaining a Clohessy-Wiltshire-like linear time-invariant system. At this point, a linear quadratic regulator is used to assess preliminary performance drivers. Then a model predictive control is implemented to account for thrust limitations and safety trajectory constraints. Several simulations are performed to assess the effectiveness of the new control with comparisons with the previous design. Finally, all test cases include several model uncertainties to prove the robustness of the GNC system.