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AN ALGORITHM TO ENGINEER AUTONOMOUS BALLISTIC CAPTURE AT MARS

Abstract

The space sector is experiencing flourishing growth and evidence is mounting that the near future will be characterized by a large amount of deep-space missions. In the last decade, CubeSats have granted affordable access to space due to their reduced manufacturing costs compared to traditional missions. At the present-day, most miniaturized spacecraft have thus far been deployed into near-Earth orbits, but soon a multitude of interplanetary CubeSats will be employed for deep-space missions as well. However, the current paradigm for deep-space missions strongly relies on ground-based operations. Although reliable, this approach will rapidly cause saturation of ground slots, hampering the current momentum in space exploration.

EXTREMA, a project awarded an ERC Consolidator Grant in 2019, enables self-driving spacecraft, challenging the current paradigm under which spacecraft are piloted in interplanetary space. Deep-space guidance, navigation, and control applied in a complex scenario is the subject of EXTREMA, which aims, among others, at autonomously engineering ballistic capture (BC), a mechanism suited for limited-control platforms. EXTREMA is erected on three pillars. Pillar 1 is on autonomous navigation. Pillar 2 is about autonomous guidance and control. Pillar 3 deals with autonomous BC.

In this work, an autonomous BC algorithm suitable for spacecraft with limited control authority and onboard resources is proposed. The algorithm is applied to target BC corridors at Mars, which are time-varying manifolds supporting capture that can be targeted far away from the planet. Mars is chosen without loss of generality due to its relevance in long-term exploration. The algorithm envisaged a novel methodology to generate new BC corridors correcting an initial set of BC orbits provided that the latter is enough regular. BC orbits at the desired epoch are obtained solving a well-posed three-point boundary value problem exhibiting eight boundary constraints. The constraints are linearized, and the problem is solved for a finite set of variables with the multiple shooting technique. The resulting linear system is solved to correct an initial guess into a new BC orbit. The computationally demanding problem of finding BC orbits through stable sets manipulation is unburdened by just solving a linear system, making the algorithm compatible with CubeSats onboard resources. An overview of the autonomous BC algorithm and the details of the correction procedure are provided. In addition, the algorithm performance is assessed and limitations of the correction methodology are discussed.