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AN OVERVIEW OF AUTONOMOUS OPTICAL NAVIGATION FOR DEEP-SPACE CUBESATS

Abstract

A new era of space exploitation is fast approaching. CubeSats have performed a revolution in the way satellites are deployed into interplanetary missions. The exploitation of standardized dimensions and Commercial-Off-The-Shelf (COTS) components have boosted their utilization by reducing mission costs and development time. The cutting down on the space entry-price grants the democratization of interplanetary exploration, opening access to space also to small companies and universities.

The downside of this flourishing growth resides in the saturation of the ground networks. As state-of-the-art, ground-based radiometric tracking is employed for deep-space navigation. Despite the high reliability, its adoption will become more and more unsustainable with the massive wave of nanosats to be controlled in space, which will hamper also new launch possibilities. Miniaturized probes that can operate in complete autonomy from the ground represent the solution of this issue. Moreover, the adoption of a self-driving spacecraft may also cut the cost related to human employment, which has not experienced degrowth with the introduction of miniaturization.

In this work, an Extended Kalman Filter (EKF) featuring line-of-sight acquisitions of planets is developed to estimate the probe state onboard, which simulates a stand-alone navigation accomplished by an interplanetary CubeSat. The research objective involves indeed developing an autonomous optical navigation algorithm for interplanetary nano-spacecraft applications. An improvement of the solution accuracy is performed by correcting the planetary light-time and aberration effects and by exploiting the optimal beacons selection strategy to acquire the external observations. Moreover, the numerical precision of the estimator is improved through the implementation of factorization techniques and non-dimensionalization strategies. The navigation algorithm is then tested on a platform comparable to a CubeSat onboard computer to verify its sustainability and performances.

This work will present the results obtained for a deep-space CubeSat on an Earth-Mars transfer and will discuss possible improvements in view of a future hardware-in-the-loop simulation. The present work is framed within the EXTREMA project, awarded an ERC Consolidator Grant in 2019.