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CLOSED-LOOP GUIDANCE FOR INTERPLANETARY CUBESATS WITH INDIRECT METHODS

Abstract

A new era in space is approaching fast. Soon, several miniaturized probes will permeate the inner Solar System. The space sector is enthusiastically embracing a new paradigm for space exploration, carried out by interplanetary CubeSats. Nevertheless, the current modus operandi can hamper this momentum: while the system development costs scale with its size, the same is not true for flight dynamics operations, which are still expensively performed from ground. According to the state of the art, during the complex process of trajectory design algorithm non-compliance with mission constraints are taken care by the operators on ground -manually. This process can take hours, if not days, and as of now it is not affordable autonomously by CubeSats.

Self-driving spacecraft are the solution: futuristic probes shall travel in a totally autonomous fashion, inferring their position from the surrounding environment and computing their guidance trajectory onboard. If proven feasible, this technology will boost large missions as well. Yet, autonomous guidance and control is hazardous because robustness (convergence to a solution), optimality (cost function minimization), and sustainability (compatibility with available resources) must be met in trajectory re-design and correction maneuvers planning. Since the state of the art foresees these operations to be executed on ground, current techniques focus on optimality, and little attention is paid to designing robust and computationally simple algorithms. It is the case of indirect methods. These nonlinear programming algorithms compute the global optimum of an optimal control problem addressing it from the necessary conditions of optimality. However, they suffer from a small convergence region. Thus, they have been always considered to not ensure the robustness necessary for onboard computation – up to now.

In this work we present a new idea for the exploitation of indirect methods onboard in a closed-loop guidance scheme. The information on the nominal path of a spacecraft can be exploited to provide these methods an informed initial guess built to enlarge their convergence region. This information can be stored in the onboard computer, reducing the computational load required by the nonlinear programming computations to a mere memory access, and thus making these methods compatible with the reduced resources of CubeSats. If successful, this scheme will disrupt completely the state of the art of onboard guidance algorithms, and the way spacecraft are piloted towards their targets.