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# DATA-DRIVEN ONLINE OPTIMIZATION FOR SPACECRAFT FUEL SLOSH

**Abstract**

This paper presents a data-driven approach to address 6-Degrees-of-Freedom spacecraft guidance control problem in the presence of dynamic uncertainties. One of the key challenges of automated space missions is the accurate representation of spacecraft dynamics that covers the entire performance envelope, which is highly nonlinear, and rendering them is impractical for control systems. Particularly, the developed approach focuses on the fuel or propellant sloshing problem but also applicable to the uncertainties caused by large flexible space structures which deteriorates the accuracy of translational and rotational motion control for future space servicing missions such as capture of space debris that requires agile, autonomous, and precise manoeuvres.

Today, model-based approaches dominate the space industry; however, the closed-loop trajectory generation and feedback controller is constrained by the systems' operating frequency and computational capabilities of the onboard platforms. Although high-fidelity simulations can be advanced with the most accurate models, in-orbit implementations require an applicable trade-off between the model accuracy and complexity due to onboard implementation concerns. The proposed approach employs behavioural systems theory to capture complex fuel sloshing dynamics without prior knowledge of the fluid dynamics. This is achieved by parametrizing all possible trajectories by using the simulation and in-orbit data. Next, constrained optimization problem is formulated to address safety and performance constraints while minimizing the fuel use. Furthermore, it is well known that data driven, and optimization-based algorithms have the bottle neck of high computation power demand. On that note, the second objective is to employ industrial grade simulation models that can be adapted to real-time simulation environments and use space-based radiation hardened processors such as LEON3 to enable more realistic simulation practice. The performance of the algorithm is presented in the scope of a potential future mission and of the available equipment for rendezvous and docking operations towards space servicing missions. A benchmark comparison study is also conducted to highlight the clear advantages of the data driven formulation. The Processor in the Loop experiments demonstrate that the proposed strategy is a promising candidate for future space servicing missions because 1) the data-driven algorithm shows additional robustness to uncertainties like fuel slosh, 2) the algorithm is real-time implementable on low power space processors as convex programming offers deterministic convergence properties and guarantees finite time solutions, 3) physical constraints can be addressed in the safety critical systems, and 4) does not require intensive modelling and trade-off study for onboard implementation.