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OPTIMIZATION-BASED ACTUATOR MANAGEMENT FOR HYBRID CONTROL ALLOCATION

Abstract

In all Space systems in which more than one actuator combination is available for producing an equivalent effect, a logic is required to decide with which actuators and how a commanded control action will be executed. This problem, known as actuator management, is classically addressed without exploiting available degree(s) of freedom or by using sub-optimal solutions like precomputed lookup tables or pseudoinverse. These approaches lead to multiple modes, actuator constraints issues potentially deriving in actuator errors, and necessity of back-up solutions for FDIR.

This paper presents a generic solution, the Virtual Actuator, that simultaneously and autonomously copes with all these challenges in a single convex optimization-based setting. The approach is not limited to the classical control allocation problem but also enables to enhance the actuator management to perform secondary tasks while minimizing the overall cost of the command execution.

The Virtual Actuator presented in this paper is designed for the specific task of actuation management in a spacecraft with redundant and/or different types of actuators. Specifically, reaction wheels, thrusters, and magnetic torquers are considered in an optimal control problem in which commands are allocated within available actuators while minimizing power and propellant consumption by the kernel exploitation. The algorithm embeds actuator constraints and presents robust functionalities in terms of possibilities of minimizing error against unfeasible commands. Furthermore, it allows working in degraded scenarios, i.e., when one or more actuators are not available, by just simple onboard preconditioning. The generic formulation is presented and then tailored for the ALTIUS missions, demonstrating flexibility to address different scenarios, specifically, adding autonomous reaction wheels zero crossing minimization, continuous wheels desaturation by use of magnetic torquers, and use of actuators working at different frequencies. The optimization problem is designed with a convex formulation and solved with the Sener Optimization Toolbox (SOTB).

The Virtual Actuator is implemented in a realistic simulator of the ALTIUS mission to demonstrate the performance and autonomy provided in different tasks without requiring any change of modes. Results of integrated and unitary tests are presented to demonstrate the potential of the technology. Furthermore, the algorithm is autocoded and tested in space-graded hardware to demonstrate real-time capabilities, convergence guarantees, and number of maximum iterations bounded, validating the Virtual Actuator for embedded online implementations.