A NOVEL SOLUTION FOR THE SPACECRAFT MIXED ACTUATORS PROBLEM BASED ON A MULTIOBJECTIVE OPTIMIZATION METHOD

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Abstract:

Actuators are devices or mechanisms capable of converting energy - typically electric current, hydraulic fluid pressure, or pneumatic pressure - into action, or motion in case of a mechanical system like the attitude and orbit control subsystem (AOCS) of a spacecraft. Several categories can be used to classify an actuator, such as power output, range and type of motion, resolution, accuracy, peak force/torque, heat dissipation, speed characteristics, frequency response, power requirements, among others. Therefore, they are critical components of every control system. Within the context of spacecraft missions, the performance and robustness of an AOCS is highly dependent on sensors and actuators. The most common spacecraft actuators are thrusters, reaction wheels, and magnetic torqrods. Those devices are designed to provide force and/or torque throughout the spacecraft's life in order to counteract orbital disturbances and to perform attitude and orbital maneuvers. Thrusters can provide forces and/or torques whereas reaction wheels and magnetic torqrods are on-board actuators used only for attitude control.

Every rendezvous in space aims to carry out safe, reliable and efficient maneuvers. To meet these requirements, new sensors, actuators and Guidance, Navigation and Control (GNC) methods have to be developed. The challenge of commanding efficiently and autonomously spacecraft actuators has motivated the investigation of new optimization techniques in order to extend the spacecraft's life and to insure the fulfillment of all mission requirements. The control problem of spacecraft using actuators with conflicting characteristics has been explored in this paper.

Over the past years, the spacecraft control problem by using mixed actuators has been the subject of extensive study in several space missions. A mixed actuators mode is a hybrid approach to control the spacecraft using a combination of actuators. A hybrid attitude control mode might be used as a contingency means for controlling a spacecraft that has lost the use of one or more of its operating reaction wheels. The first NASA Spacecraft Hybrid Attitude Workshop, held in Maryland in April of 2013, aimed to better understand the technical challenges, risks, and benefits of a potential hybrid attitude control mode operations on their science mission spacecraft. Examples of such missions include Kepler, Dawn, Mars Odyssey, Cassini, Far Ultraviolet Spectroscopic Explorer (FUSE), and Thermosphere, Ionosphere, Mesosphere Energetics and Dynamics (TIMED). This NASA's interest is driven by a number of recent reaction wheel failures on aging.

In our paper, a mixed actuators mode is a hybrid approach to control the spacecraft using a combination of actuators. In this sense, the problem of optimally and autonomously commanding a group of actuators with conflicting characteristics is explored in this paper. Thus a novel actuators command strategy based on a discrete multiobjective optimization approach has been *proposed herein. Such methodology, called Actuator Multiobjective Command Method (AMCM), is responsible for commanding the necessary torque for the actuators at every control cycle according to the torque level requested by the controller. It is assumed a spacecraft composed of the following group of actuators: a reaction control system, a set of reaction wheels, and a set of magnetic torqrods. AMCM generates a set of feasible solutions and selects, based on a decision making method, the best compromise solution optimizing simultaneously a group of objective functions. The proposed approach has been tested in a final approach rendezvous scenario. Due to the complexity of this phase, all elements of the GNC loop have been accurately implemented in a simulation framework. The results have indicated that a better attitude control performance can be achieved with the proposed method compared to the single actuators mode.*

The paper describes the developed novel actuators command strategy based on a discrete multi-objective optimization approach. Furthermore it presents simulation results based on numerical simulations as well as on hardware-in-the-loop (HIL) simulations performed on the robotic rendezvous and docking simulator, called European Proximity Operations Simulator (EPOS), at the German Aerospace Center (DLR).

Keywords: *Mixed Actuators Problem, Multiobjective Optimization, Final Approach Rendezvous.*