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ANALYSIS AND EXPERIMENTS FOR DELAY COMPENSATION IN ATTITUDE CONTROL OF FLEXIBLE SPACECRAFT

Abstract

On-off actuators are quite common in space activities, both for translational and rotational dynamics. In order to command this kind of actuators, a modulation of the classic continuous control signals must be performed. In this way, an input that varies according to just three values (i.e. zero, maximum positive and maximum negative) is obtained. There are several known techniques for the modulation of continuous signal, from the classic Bang-Bang technique, to the Pulse Width Modulation and the Pulse Width Pulse Frequency Modulation (PWPFM). However, the application of these techniques to real spacecraft always presents challenges, ranging from the selection of their characteristic parameters to the optimization of the behavior in specific maneuvers. This paper focuses on the implementation of these discrete control laws for the attitude of a flexible platform. The topic is preliminarily faced from a numerical point of view, developing different models for the study of different aspects of the problem. For assessing the flexible characteristics of the platform, a structural model of its main parts (central bus and solar wings) is developed first. Then, the systems' overall flexible behavior is studied following a multibody approach. For control purposes, a Matlab/Simulink model is used, including sensors noise, actuators inaccuracies and processing delays. For a greater accuracy, an ultimate model is implemented, embedding the multibody structural model in the control oriented program. The co-simulation enables to investigate in depth the interaction between control modulation and flexible dynamics. The mathematical model provides the modulation and control parameters that are applied to an experimental testbed, a free floating 2D platform, with inertial navigation sensors and on-off thrusters. This platform can be equipped with very light and flexible aluminum panels, as a mock up of spacecraft solar wings. The experimental testbed shows that in most cases the torques applied by the thrusters to the platform bus are transmitted to the panels, exciting the elastic dynamics and leading to complete instability. Several strategies are tested in order to improve the performance, as modifying the modulation parameters (in particular in the PWPF case), changing the control parameters (decreasing for example the derivative gains) or varying the command with the input shaping techniques. The performance of these strategies will be commented with a particular care to the actual implementation problems. The analysis clearly proves that the discrete modulation, especially when applied to flexible spacecraft, needs to be carefully tailored to the specific application.