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A GENERAL CONTROL/STRUCTURE CO-DESIGN FRAMEWORK TO OPTIMIZE ATTITUDE/FLEXIBLE DYNAMICS OF EARTH OBSERVATION (EO) SATELLITES

Abstract

Modern space missions for Earth Observation (EO) purposes often rely on satellites equipped with very large flexible appendages, as antennas and solar panels, which are demanded to perform fast (i.e. agile) slew manoeuvres. In most cases, the elasticity of such systems cannot be neglected in the design of the attitude controller, as excessive elastic displacements of the structural elements may compromise their stability and pointing performance. Therefore, the integration of GNC laws in flexible space systems still represents an open challenging task, whose best solution often depends on the specific type of application.

In this scenario, the most widely adopted techniques in control design are the classical but yet labour intensive tuned feedback controllers, generally integrated with low-pass/notch filters to suppress the resonant peaks of the spacecraft flexible modes. Alternatively, in the early phases of spacecraft design, structure and control disciplines perform separate and time consuming iterative sequences to avoid interactions between the flexible and rigid dynamics. In this context, as opposed to the latter approach, this paper aims at proposing an automated nested optimization framework to simultaneously optimize spacecraft structural and control dynamics, to be applicable to a wide range of flexible spacecraft. The objective of such a co-design architecture is to modify tunable parameters, at both structural and control levels, to minimize the mass of the spacecraft while maximizing its agility and satisfying imposed requirements in terms of pointing and maximum displacement in some structural key points.

Moreover, as robust multivariable techniques have become more and more applied to ensure satisfactory robust performance margins, this paper's goal is to pose a multi-channel structured Hinf control architecture in the co-design problem. To guarantee the generality of implementation, a structural design tool (MSC Nastran) is interfaced with a coding environment (Matlab/Simulink) to set-up an autonomous exchange of information between structural and control domains. Starting from an initial definition of the spacecraft material, geometry and control requirements (in terms of loop-shaping transfer functions), relevant parameters are extracted from the structural tool and a linearized dynamic model assembled. Then, a controller is synthetized based on the provided requirements, followed by a VV phase on an in-orbit nonlinear plant of the satellite. The procedure is repeated until the stop criteria (based on tolerance and max iterations) is satisfied. Finally, the output of the proposed architecture is obtained as an optimized structural model and robust controller tailored for the in-orbit dynamics of the satellite.