New challenges in automatic control for AOCS – CNES vision
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For the past decade, CNES funded several industrial and academic studies to improve AOCS software and make it benefit from the new advances in automatic control. Through Research and Technology studies, training periods, PhD and postdoctoral studies, the AOCS department experimented new techniques within two research axes : robust linear control for linear time-invariant systems, and nonlinear control mainly linked to actuator saturations.

The first axis includes analysis and design methods such as H_∞ control, mixed H_2/H_∞ design (several benchmarks), µ-analysis and synthesis (electromagnetic control of MIM experiment, SPOT5 flexible modes control), but also numerical aspects with LMI formulation of the problems and SDP solvers (development of engineering tools). Some results of these studies have been successfully applied by CNES, such as the mixed H_2/H_∞ control with pole placement in LMI region for the normal mode of the microsatellite DEMETER. The use of these techniques can still be improved (multi-objectives and multivariable design for 6 ddl control).

The second axis includes some work on flatness (attitude guidance of maneuvering satellites, nonlinear magnetic control of IASI type mirror), linear parameter variant (LPV) control (CMG cluster guidance), and actuators nonlinearities (limit cycle optimisation of thrusters modulator, linear control of saturating actuators). Unfortunately, very few of these results have been applied until now, mainly because the complexity is too high and most of them are incomplete.

Whereas for today missions existing tools and methods are satisfactory and perform reliable and accurate enough AOCS, they will probably be limited for future missions. CNES vision of AOCS software improvement needs is twofold : higher accuracy, in particular for formation flying missions, and cheaper design for generic platforms.

For higher performance, the first requirement is to get more accurate sensors, actuators and computers. But automatic control will also contribute to it. One way to perform a more accurate control is to better know the system to control : thus one can achieve a sometimes less robust but more accurate design. In this scope, adaptive methods and online identification and optimisation can be useful (for example, on-board forward/backward estimation filters for agile Earth observation missions). In the same optics, the use of nonlinear design techniques may lead to a better performance ; some are of interest for our systems : periodic control for planetary missions, decentralised control (can also be linear) and control through a network for formation flying, antiwindup techniques to optimise the use of fine propulsion systems (also valid for formation flying).

Cheaper design through generic platforms is another axis of AOCS improvement to which automatic control can contribute. The control challenge here is to improve the design robustness within an acceptable performance envelope. Several research axes can be studied : methods such as gain scheduling, fuzzy control, adaptive control, etc. allowing AOCS architecture simplification, but also validation process improvement (use of worst case analysis, robustness margins computation improvement, automatic code generation (PRISMA example)) and on-board autonomy (autonomous orbit control on DEMETER, robust FDIR), reducing operating cost.

Finally, the numerical issue can not be forgotten, for the design tools first (Matlab/Simulink alternative), but also for the validation tools (Monte Carlo techniques) and the on-board implementation.