Abstract: Needs & Application of Advanced Control Techniques in Space

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Space is a domain best suited for the application of Automatic Control techniques.

Space industry is a relatively recent field for the application of automatic control. Its special needs and special environment has seen the development of a culture of mathematical modelling, and exhaustive analysis and validation on models, more and more accurate, for the on-ground validation of Space systems. Such an approach makes it a natural candidate to transfer ambitious work on mathematical proofs and theoretical demonstration of properties. The development of “Worst Case Analysis” is exemplary in this respect. The presentation of this development, conducted by ONERA and Astrium between 1997 and 2001 illustrates the interest of this new technology to further the mastering of complex parametric sensitivity and behaviours.

By focusing on the mathematical proof on complex models, the Space domain permits a fast “time-to-market” of the most recent advances in automatic control design, as long as it proves suited to well-formulated needs or shortcomings in the traditional approaches. The Hinfinity synthesis has seen such a fast transfer. Based on a clear indentification on key new challenges in the domain of Space applications – coming from drag-free missions, as well as demanding performances in the growing Satcoms platforms – research was initiated as soon as 1991 to support methodological developments in the application of the recent academic breakthroughs. 1994 has seen the first industrial applications on the Eurostar 2000+ new generation Satcoms. Since that time the Hinfinity synthesis has been deployed largely to support the most demanding control needs, in terms of performances expressed in the frequency domains.

The current dynamism in this field of engineering proves that this general trend is a sustained one and should even extend in the coming years. The major drivers for this extension are two-folds. First new architectures set new challenges in automatic control. It is the case for rendezvous systems or formation flying, complex space transportations missions, or the emergence of composite exploration needs. All of them call for a renewed effort in automatic control, for supporting distributed architectures, non linear systems, or in the analysis field, for supporting the safety and dependability demonstrations. A second driver is in support to the industry need for cost and complexity reduction in the on-board solutions, to accelerate the time-to-product and block the exponential growth in validation complexity.

In support of these new needs, a strong and diversified research effort has been launched: from the exploratory studies on MPC for rendezvous, to the application of Hinfinity filtering to robust FDIR, to the development of LPV and generally speaking LFT-parameterised controllers for addressing many architecture needs, in the fields of both synthesis and analysis. Many space control problems can be cast as LPV control problems. LPV design appears promising both as a control technique to tackle new problems and as a methodology framework to improve the whole development cycle. Astrium is currently leading an ESA study on LPV design methodology. In this first study, Astrium is supported by ONERA and CNRS: ONERA will develop an industrial tool for frozen parameter systems and CNRS will develop a tool (more a prototype) for LPV synthesis and will focus on the methodology for using

LPV synthesis. Astrium will give benchmark and study cases for validating tools as well as methodology and will also develop the complete benchmark. The presentation will detail the study.

In the analysis domain, beyond the LTI context, LPV is a promising context with associated analysis technique allowing to analyze the robustness in nonlinear systems and uncertainties: the L_2 gain analysis which is a mathematical generalization of the well known H_∞ norm. It allows to analyze robustness properties. However its foundation for performance analysis is not well established as it does not ensure basic qualitative properties (such as a constant input produces a constant output). In contrast, the incremental gain analysis is another generalization of the H_∞ norm and is a complete one.