Paper ID: 66884
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IAF SPACE SYSTEMS SYMPOSIUM (D1)
Technologies to Enable Space Systems (3)

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DESIGN TO THE EDGE: PERSPECTIVES OF AI AND ESTIMATION TECHNIQUES IN AUTONOMOUS SPACECRAFT

Abstract

Artificial Intelligence (AI), in its different categories, is expected to remarkably affect space technology. This is already visible in the ground segment, especially in observation scheduling and data processing (images), but significant applications are envisaged also at the platform level, i.e. in the space segment.

First, the field of failure identification and detection greatly benefits from these increased capabilities combining expertise and computation. Not only diagnosis, but also the more demanding prognosis step can be carried out continuously all over the bus functionalities. The outcome will be an effective onboard autonomous failure management, defined as the adoption of the best solution to work in presence of non-nominal behaviour, without ground controllers' intervention, outages nor delays.

Even more remarkable, a breakthrough improvement can be allowed by the autonomous adaptation of the onboard systems to optimally perform in nominal, i. e. not plagued by failures, operations. The combination of effective Bayesian estimation techniques (built on the basis of multiple filter algorithms) with learning capabilities of AI opens the possibility of an educated, continuous knowledge of the state of satellite subsystems together with its (estimated, yet highly credible and accurate) evolution in time. Subsequent operations can be therefore defined onboard neglecting conservative safety allowances. Likewise the relaxed stability concept introduced in fly-by-wire aircraft, new operations envelopes can be approached. This is a "design to the edge", always maximising the performance on the basis of an up-to-date evaluation of the critical conditions. So, not anymore nominal conditions and pre-designed behavior, yet the best exploitation of available resources everytime. Notice that similar approaches are currently attempted in state-of-the art technological ventures as racing cars and high performance sailing.

The paper aims to investigate these topics by discussing some suitable applications and providing, by means of simulations, a quantitative view of the expected benefits. A first significant example of the capabilities of AI/estimation combination is given in the attitude control domain by the reaction wheels' desaturation manoeuvers, where the requirements to avoid dangerous pointings, to ensure power generation, to handle agile payloads often end up to limit controllers' authority leading to suboptimal solutions. Similar approaches can be outlined (i) for the structural subsystem, smartly managing elastic deformations induced by re-orientation maneuvers in very large platforms, (ii) in thermal control subsystem, by a wise cross-correlation with power subsystem behaviour to ensure satisfying temperature ranges onboard, and (iii) in navigation/orbit determination, always including in-flight experience about concerned hardware.