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NEW CONCEPTS OF AUTOMATED ANOMALY DETECTION IN SPACE OPERATIONS THROUGH ML-BASED TECHNIQUES

Abstract

The introduction of ML-based technology for spacecraft health monitoring is being under investigation in several research and development projects in the last decade. One of the main goals is to significantly increase early anomaly detection and prediction capabilities by providing great benefits to space systems deployment as well as to space operations, increasing overall mission efficiency and autonomy, decreasing operation costs and facilitating ground decision activity, especially in scenarios with very large fleets of satellites. In this process, the analysis of user needs together with the definition of prerequisites and design drivers related to automated anomaly detection strategies are a key point, taking into account the computational framework in both on-board and on-ground applications and operational deployment. Particularly, for the on-board use case, special attention is necessary to the appropriate architecture and design of methods / algorithms to meet the performances and constraints of space-qualified hardware platforms. Indeed, the implementation constraints imposed by low resources of space qualified devices will require adaptations to lower memory usage and processing resources need.

Within this framework, we propose and analyze methods to detect anomalies in the time series provided by system telemetry. Anomaly detection is pre-pended by a multi-scale analysis stage coping with the potential multi-cycle-stationarity of the signals and exploits statistical analysis and unsupervised machine learning to identify the signature of normal operations whose absence implies the occurrence of an

anomaly. More specifically, three approaches are envisioned: outlier analysis (in which statistical distribution of normal telemetry is identified and used in a classical statistical test), detection by compression or by prediction (in which one learns how to effectively compress/predict normal telemetry and uses compression/prediction effectiveness as a score to reveal anomalous behaviors). Experiments show that these methods are able to blindly identify unusual telemetry trends, let them be anomalies or change of operation modes thus being promising candidates for deployment in real world applications. Methods to possibly implement these techniques on resource-limited, space-compliant hardware are also analyzed in the perspective of increasing on-board spacecraft autonomy.