52nd IAF STUDENT CONFERENCE (E2)
Student Conference - Part 2 (2)

Author: Mrs. Tatiana Fontana
The Netherlands

DESIGN, OPTIMIZATION, AND COMPARISON OF FAILURE DETECTION AND ISOLATION METHODS FOR CUBESATS GYROSCOPES

Abstract

Due to their small size, CubeSats have become increasingly popular, taking advantage of their affordability. Nevertheless, maintaining autonomy and adhering to reliability requirements is extremely difficult given the limited resources available. The need of Failure Detection and Isolation (FDI) in CubeSat mission design is crucial, as their use is being extended to deep space and lunar missions. As such, CubeSats require almost complete autonomy and higher reliability. However, these missions currently lack customised standards and well-established procedures. Additionally, the use commercial off-the-shelf (COTS) equipment may lead to malfunctions since they were not designed for space application. By classifying currently adopted, state-of-the-art, and emerging FDI techniques into three distinct categories, based on the methodology and techniques used, this study addresses these challenges. The performed research focuses on the application of these FDI techniques for CubeSat gyroscopes. After having performed in-depth trade-offs, three methodologies were selected, designed and optimized to be compatible for a specific case study. Based on a wide range of evaluation metrics, including performance, complexity, computational effort, and scalability, a thorough comparative analysis was conducted. The LUMIO mission, which is a CubeSat operating on the far side of the Moon, is an In Orbit Demonstrator (IOD) of new. Due to this, and due to the high autonomy requirements, it was considered as a suitable study case for the activity. The first approach represents a Signal-Based model that exploits statistically defined thresholds and signal processing techniques. The method is straightforward, but it has experienced difficulties in handling complex faults. The second model uses a Model-Based approach, which applies the parity-space methodology and relies on a Simulink model of the unit and its environment. The research showed that it delivers high accuracy, even though it uses substantial resources. The last approach relies on a Knowledge-Based model that utilises a LSTM (Long Short-Term Memory) network alongside training data from a detailed LUMIO simulator. The method is promising, but encounters reliability issues. Based on these results, an hybrid approach is identified as the best strategy for the study case. This methodology incorporates the advantages of both the Knowledge-Based and Signal-Based approaches, while minimising their limitations. The research findings, not only suggest the best practices for CubeSat gyroscope FDI, but they also contribute to the advancement of the field through the acceleration of the development of more durable and reliable CubeSat systems for more complex upcoming space missions.