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Author: Mr. Luca Manca
AIKO S.r.l., Italy, luca.manca@aikospace.com

Mr. Gianluca Maria Campagna
AIKO S.r.l., Italy, gianluca@aikospace.com
Dr. Riccardo Maderna
AIKO S.r.l., Italy, riccardo@aikospace.com
Mr. Gabriele Giordana
AIKO S.r.l., Italy, papers@aikospace.com

TOWARD COMPREHENSIVE AI-BASED ONBOARD FDIR: SYSTEM DESIGN AND FIRST RESULTS

Abstract

Health monitoring of spacecrafts is a crucial task in Space operations. Fault Detection, Isolation and Recovery (FDIR) plays a critical role in ensuring the safety and successful operation of a spacecraft by detecting and isolating faults, and then executing recovery actions. Currently, the FDIR process is carried out mostly on ground, with only anomaly detection typically performed onboard the spacecraft, whereas fault isolation and recovery is managed by operators on the ground.

Anomaly detection in traditional FDIR relies on out-of-limit (OOL) thresholds on sensor data. Isolation units are then employed to isolate the fault and transition to a safe mode if necessary. Once the fault is detected, operators analyze telemetry streams to identify the source of the problem (isolation phase) and to select the appropriate recovery procedure to restore nominal operation. Recovery procedures are uplinked to the spacecraft as pre-programmed telecommands at the first useful contact.

This approach has two major limitations. Firstly, OOL approach is not capable of identifying subtle anomalies that occur within the parameters' nominal operational range, limiting its effectiveness in identifying a wide range of anomalies. Secondly, the need for ground investigation to isolate the fault prior to the implementation of a recovery action introduces a delay in the overall FDIR pipeline.

In this paper, we propose an AI-based onboard FDIR solution capable of detecting and identifying anomalies, and to suggest recovery actions in complete autonomy. It is composed of two main modules: a Sensing Service, responsible for anomaly detection, and a Reasoning Service, which deals with isolation and recovery. The Sensing Service relies on Deep Learning algorithms trained on nominal telemetry data to perform time-series forecasting. During inference, anomalous patterns are identified employing a reconstruction-based error technique. This solution allows to identify a wider range of anomalies with respect to traditional OOL techniques. The Reasoning Service is triggered upon reception of an alert from the Sensing Service. The central component is represented by a Knowledge-Based System that validates the alert against false-positives and infers the most likely root causes for the anomaly. Given the classification output, the Reasoning Service determines suggestions on the best recovery action, that can be immediately applied or communicated to the ground for validation.

The proposed solution has been deployed on hardware accelerator to demonstrate the feasibility of running it onboard the spacecraft and it has been tested on both real mission data and flatsat data.