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PROPOSAL OF AN INDEX OF SATELLITE HEALTH FOR ANOMALY DETECTION

Abstract

Early detecting anomalies is significant for non-repairable satellites to prevent their system failure, and anomaly detection methods for satellites such as limit checking and rule/model-based anomaly detection have been investigating. However, as satellite systems are getting more complicated, building the models and rules from expert knowledge is becoming costly. Thus, in recent years, anomaly detection methods using unsupervised machine learning algorithms are actively studied in this field. In order to detect anomalies as soon as possible, on-orbit satellite systems should be able to compute in real-time autonomously. However, since housekeeping data of a satellite contains a large amount of telemetry, anomaly detection methods using machine learning require a large memory capacity, high computing speed, and hyperparameter optimization. On the other hand, we propose that early anomaly detection is possible to focus only on necessary information rather than on every relationship in the housekeeping data and construct *an index of satellite health* from a set of housekeeping data for early detecting anomalies in a satellite.

When a satellite system is in good health, its telemetry behaves the same as usual. Here, the telemetry vector constructed from the respective telemetry values, such as voltage, current, and temperature which has seasonal variations depending on the satellite's orbital period, moves in a high-dimensional space of the housekeeping data. Thus, when the satellite system is in normal operation, the telemetry vector keeps moving regressively around its mean values. In addition, the mean values have trend variations that move with long-term changes in the satellite system health, such as equipment degradation. Therefore, we defined *an index of satellite health* from the seasonal and trend variations.

In this paper, we first explain the calculation method of *an index of satellite health*. Second, we apply the index to an actual satellite data of Japanese X-ray astronomy satellite, SUZAKU (ASTRO-EII), to confirm that the index can represent system failures by comparing among normal data, intentionally-created abnormal data, and actual abnormal data and verify that the index can represent the health of satellite system by comparing in the long term from steady status in ordinary operation to unstable status at the end of operation. Third, we apply the index to the previous anomaly detection method and confirm its usefulness and effectiveness for anomaly detection. Finally, we discuss constructing the more representable index and detecting signs of failures before various anomalies.