Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: NEWSPA
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Type: Oral
Status of corresponding author: Regular

Title

Applying Machine Learning to Routine Satellite Ground Segment Operations by Means of Automated Anomaly Detection

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Abstract
Once a spacecraft is in orbit, engineers in charge of its maintenance and daily operation depend on telemetry data to track and analyze the satellite's status and health. As modern spacecrafts generate more and more data, manually handling, inspecting and interpreting these data becomes increasingly difficult. To assist the engineers with these challenges, a novelty detection tool called Automated Telemetry Health Monitoring System (ATHMoS) was developed at the German Space Operations Center (GSOC).

In this paper, we first give an overview of the unique challenges and requirements the domain of spacecraft operations poses to such an anomaly detection system. These do not only apply to the algorithm and the resulting software tool itself, but also to the specification of the use-cases and how the final tool shall be used. They include for example the irregularity of the transmitted telemetry data, limitation of resources and intuitive interactions with the tool for the end user.

Next, we want to describe the solutions to the aforementioned challenges and requirements developed at GSOC as well as the reasoning behind the selected algorithm, workflow and user interaction patterns. The core algorithm within ATHMoS, Outlier Probability Via Intrinsic Dimension (OPVID), is designed to be very generic to avoid fine-tuning for each telemetry parameter. ATHMoS itself has been developed to be a flexible framework. It can easily and quickly be adapted to not only satisfy the use-case of assisting subsystem engineers with routine operations, but also to enable data scientists to tackle specific analysis tasks. Furthermore, it has proven its reliability and efficiency in many research projects.
The post-processing steps included in ATHMoS have the goal to reduce the number of false positives as well as to provide explainable detections to the end user. Because even small false positive rates can result in a large amount of detections due to the sheer number of parameters under observation. Providing an explanation as well as auxiliary data along with the detections allows the end users to separate important novel behaviors from, e.g., planned operations.
ATHMoS has been integrated into our Visualization and Data Analysis software (ViDA) in order to display the detected novelties in the satellite's telemetry data. Both systems have reached an operational level and are used in routine operations in our satellite control center at GSOC.

In the final section, we describe the lessons learned and give a short outlook on possible future projects related to ATHMoS at the GSOC.