Predicting Spacecraft Anomalies Using Telemetry Data

Abstract

Spacecraft missions rely heavily on precise monitoring and management of spacecraft health to ensure successful operations and mission success. Anomalies in spacecraft systems can lead to mission failures, making early detection and prediction of such anomalies critical. This paper presents the development of a Django-based application designed to predict spacecraft anomalies using telemetry data and machine learning models. The application aims to support mission controllers in monitoring spacecraft health, improving anomaly detection capabilities, and enhancing overall mission reliability.

The application leverages the Django web framework to provide a comprehensive platform for analyzing telemetry data, detecting anomalies, and delivering actionable insights. The system is designed to manage the entire workflow, including data handling, preprocessing, model training, and anomaly detection. By employing advanced machine learning techniques, the application enables efficient and accurate prediction of spacecraft anomalies, which is essential for proactive mission management and problem resolution.

At the core of the application is the data handling module, which manages the acquisition and integration of telemetry data from spacecraft systems. This module is responsible for collecting real-time telemetry data, ensuring data quality and integrity, and preparing the data for subsequent analysis. By implementing robust data handling procedures, the application ensures that the telemetry data used for anomaly detection is accurate and reliable.

The preprocessing module plays a crucial role in transforming raw telemetry data into a format suitable for machine learning analysis. This involves feature engineering, data normalization, and noise reduction. The preprocessing steps are designed to extract relevant features from the telemetry data, which are critical for training effective anomaly detection models. By optimizing the data for model input, the preprocessing module enhances the accuracy and performance of the anomaly detection process.

For anomaly detection, the application utilizes sophisticated machine learning models capable of identifying deviations from normal spacecraft behavior. The choice of models includes techniques such as Isolation Forest and Autoencoders, which are well-suited for detecting anomalies in complex and high-dimensional telemetry data. These models are trained on historical telemetry data to learn the normal operational patterns of spacecraft systems. Once trained, they can identify and predict anomalies based on new telemetry data, providing early warnings of potential issues.

The anomaly detection module generates alerts and notifications for mission controllers when potential anomalies are detected. These alerts are designed to facilitate timely intervention and response, allowing mission controllers to address issues before they escalate into critical problems. The application includes features for visualizing detected anomalies, providing detailed reports, and tracking anomaly trends over time. This functionality supports effective decision-making and enhances the overall management of spacecraft health.

The application is built with scalability and adaptability in mind, allowing for future enhancements and integration of new machine learning models and data sources. The modular architecture of the Django-based system ensures that it can accommodate advancements in anomaly detection techniques and evolving mission requirements. This adaptability is crucial for maintaining the application's relevance and effectiveness as spacecraft technology and operational needs progress.

Security and data privacy are key considerations in the development of the application. The platform implements comprehensive security measures to protect sensitive telemetry data and ensure the integrity of anomaly detection results. Secure data handling practices, including encryption and access controls, are employed to safeguard the confidentiality of mission-critical information.

In summary, this paper outlines the development of a Django-based application for predicting spacecraft anomalies using telemetry data and machine learning models. The application integrates data handling, preprocessing, anomaly detection, and alerting components to provide a robust solution for spacecraft health monitoring. By enhancing the ability to predict and manage anomalies, the application supports mission controllers in maintaining spacecraft reliability and ensuring mission success. The platform's scalable and secure design ensures its continued effectiveness in addressing the evolving needs of spacecraft missions and anomaly detection.