

Project Proposal: AI-Based Anomaly Detection in Spacecraft Telemetry

Authors

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Project Track

Conceptual Design Track

Problem Statement

Spacecraft telemetry data, such as temperature, pressure, and voltage readings from onboard sensors, is critical for monitoring mission health. Anomalies in this data—such as unexpected spikes or drifts—can indicate potential system failures, endangering missions like Mars rovers or satellite operations. Manual monitoring is inefficient and prone to errors, especially with the high volume and complexity of telemetry data. An AI-based system for anomaly detection can automate this process, improving mission safety and reducing operational costs.

Proposed Solution

We propose an AI-based anomaly detection system to identify irregularities in spacecraft telemetry data. The system will use machine learning techniques, specifically an Isolation Forest algorithm or Long Short-Term Memory (LSTM) neural networks, to analyze time-series telemetry data. The system will:

- Collect real-time sensor data (e.g., temperature, pressure, voltage).
- Preprocess data to handle noise and missing values.
- Train an AI model to detect anomalies by learning normal patterns and flagging deviations.
- Alert mission control when anomalies are detected, enabling rapid response.

The solution leverages existing AI frameworks like scikit-learn (for Isolation Forest) or TensorFlow (for LSTM), ensuring feasibility and scalability.

Benefits

- **Enhanced Safety:** Early detection of anomalies prevents catastrophic failures, protecting spacecraft and mission objectives.
- **Efficiency:** Automates monitoring, reducing the workload on human operators.
- **Cost Savings:** Minimizes downtime and repair costs by addressing issues proactively.

- **Scalability:** Applicable to various NASA missions, from rovers to satellites.

Implementation Overview

The system would involve:

1. **Data Collection:** Gather telemetry from spacecraft sensors (e.g., CSV files with time-stamped readings).
2. **Preprocessing:** Clean data (e.g., handle missing values, normalize features).
3. **Model Training:** Use Isolation Forest for static data or LSTM for time-series patterns.
4. **Deployment:** Integrate the model into mission control software for real-time alerts.
5. **Testing:** Validate on simulated or historical telemetry data to ensure accuracy.

Challenges

- **Data Quality:** Telemetry data may be noisy or incomplete, requiring robust preprocessing.
- **Real-Time Constraints:** The system must process data quickly to provide timely alerts.
- **Model Interpretability:** Ensuring mission control understands anomaly alerts for decision-making.

Conclusion

This AI-based anomaly detection system addresses a critical need in spacecraft operations by automating the identification of potential issues in telemetry data. By leveraging established AI techniques, the solution is practical and adaptable, offering significant benefits to NASA's mission success.

References

- NASA Jet Propulsion Laboratory, "Telemetry Data Systems," jpl.nasa.gov
- Pedregosa et al., "Scikit-learn: Machine Learning in Python," Journal of Machine Learning Research, 2011.