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ENHANCING SPACEFLIGHT AUTONOMY WITH MACHINE LEARNING: FAULT DETECTION IN LIFE SUPPORT SYSTEMS

Abstract

Machine learning (ML) methods have seen a continuous rise in interest and a number of applications over the last years. The potential of ML for future spaceflight is now being actively researched by various space agencies, despite the many challenges involved. In the field of Life Support Systems (LSSs), ML is being developed to detect faults and anomalies, improve resource utilization and enable greater autonomy. This is particularly important for future human exploration missions to Mars, where a more self-contained solution is required to reduce the need for real-time ground control.

This paper represents the current state of research at the University of Stuttgart's Institute of Space Systems (IRS) in the field of ML for LSSs. With the help of the modern simulation tool V-HAB, a model of the Columbus Science Laboratory on the International Space Station (ISS) was developed. The model was further extended to allow the simulation of component failures, which enabled the generation of a dataset comprised of nominal and off-nominal operational cases. A ML toolchain was developed for the Carbon Dioxide Removal Assembly (CDRA) to detect anomalies, thereby reducing monitoring tasks. Initial efforts were made to enhance the algorithm and realize module-wide fault detection.

The architecture presented in this paper provides a foundation for future fault detection methods and serves as a basis for improving control algorithms. Space stations such as the Lunar Gateway and spacecraft designed for the trip to Mars can greatly benefit from these methods, as they decrease the need for ground control, especially with the increased communication delay, and allow crew members to focus on other tasks.