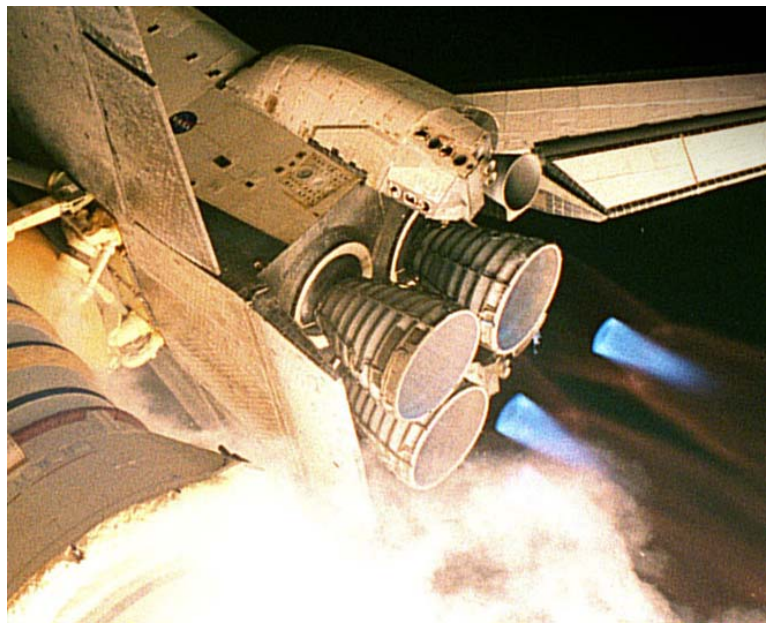
Intelligent Data Understanding for Integrated Systems Health Management (ISHM)

The Ames Intelligent Data Understanding Group can support ISHM in three ways: by using anomaly detection algorithms for fault detection, by using data mining for prognostics, and by using distributed adaptive control for self-maintenance and recovery.

Background

Data mining seeks to discover previously unknown regularities or anomalies in large data sets. The Intelligent Data Understanding (IDU) Group in the NASA Ames Research Center Intelligent Systems Division has extensive experience in data mining research and applications. Our areas of research and development include Prognostics, Data Analysis, Systems Health Management, Adaptive Control, Text Mining, and Fault Detection.



Research Overview

Data-Driven Modeling for Prognostics:
Due to high problem dimensionality, prognosis of future failure states and predicting the types of failures are extremely difficult. The number of relevant dimensions for prognosis of spacecraft failures is in the tens of thousands. There are several scientific approaches to prognostics including data-driven, physics-based, and statistical approaches. We use a variety of advanced real-time data mining techniques that incorporate model-based information with sensor data to identify potential precursors of failure. Using these techniques, we can forecast trends and potentially anomalous behavior based on real-time information.

Wing Leading Edge Impact Detection System:
We are analyzing data from the Space Shuttle Wing Leading Edge sensors. Data consists of thousands of readings from multiple in-orbit sensors on the most recent space shuttle flight. Work will establish background readings and attempt to detect anomalous events, and possibly micro-meteor strikes.

Liquid Propulsion System Health Management:
Our goal is to develop methods that can detect and predict failures in liquid-fueled rocket engines. Data mining researchers in IDU are working with rocket propulsion experts at Pratt & Whitney Rocketdyne to apply data mining algorithms to historical data from the Space Shuttle Main Engine (SSME). We applied two unsupervised anomaly detection algorithms, Orca and GritBot, to data from five test firings of the SSME. The algorithms detected known anomalies and unknown anomalies. For flight use, the algorithms would need to be adapted into real-time algorithms. Better methods for detecting anomalies in SSME data may benefit the Space Shuttle Program by providing engineers with better tools for analyzing data after a test or flight. Our long-term goal is to provide algorithms that can be used on board the Crew Launch Vehicle, which is expected to use engines derived from the SSME.

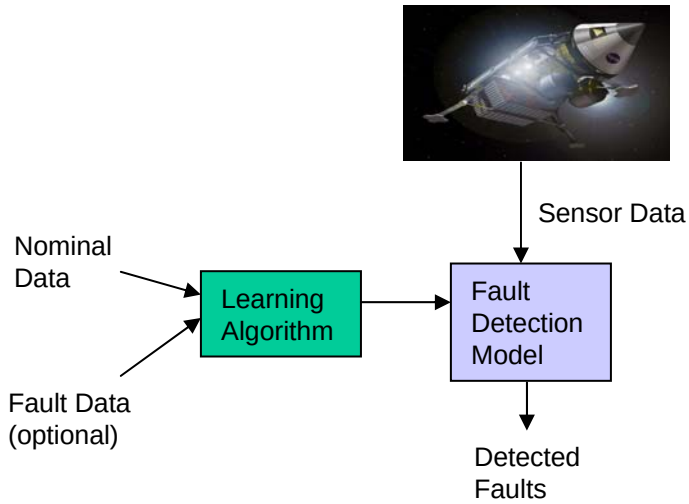
Intelligent Data Understanding for Integrated Systems Health Management

Adaptive Control and Recovery:
Sustainable space exploration requires more reliable and adaptable systems, particularly for missions with significant component degradation such as lunar robots or for prolonged missions like the Jupiter Icy Moons Orbiter (JIMO). Traditional systems which provide redundant components improve robustness, but increase complexity, are costly and wasteful, and provide limited adaptability. In contrast, modular system-of-systems (SoS) architectures provide a firm basis for sustainability through modular, reconfigurable component designs. To reap the maximum benefit from such architectures, intelligent adaptive systems must be combined with modular designs to provide inexpensive, reliable, and reconfigurable space platforms which are self-(re)configuring, self-maintaining and self-healing.

Text Mining for Recurring Anomalies:
The Ames IDU Problem Reporting Information Analysis (PRIA) Team is developing Web-based advanced search and text mining capabilities. The ability to automatically cluster and compare problem reports to find recurring anomalies has now been integrated into the Ames Mishap and Anomaly Information System (MAIS). NASA users can now text mine NESC CARS and ISS PRACA safety report data bases, with more data sets being added in the future. Bring us your haystack, we'll help you find the needle.

Data Mining for Fault Detection:
We are developing methods to automatically detect unusual or anomalous data in either historical or real-time sensor data, to aid domain scientists in finding these anomalies. Our work includes both supervised (using fault examples) and unsupervised (using only nominal training data) approaches. These methods can also be used to help construct monitors for use with a model-based diagnosis system such as Livingstone.

Fault Detection



Relevance to Aeronautics and Exploration Systems Mission Directorates

Integrated system health management will be a key contributor to the safety, reliability, and affordability of future exploration missions and future aircraft. Intelligent Data Understanding can be combined with other ISHM approaches to obtain higher ISHM performance at lower cost.

Points of Contact:

Dr. Ashok Srivastava (Principal Scientist and Group Leader)
650-604-2409; Ashok.N.Srivastava@nasa.gov
http://ti.arc.nasa.gov/people/ashok

Dr. Mark Schwabacher
650-604-4274; Mark.A.Schwabacher@nasa.gov
http://ti.arc.nasa.gov/people/schwabac/

Group Web Page:
http://ti.arc.nasa.gov/datamining

Ames Research Center

NASA