Breakabot Precomputed Model for Anomaly Management

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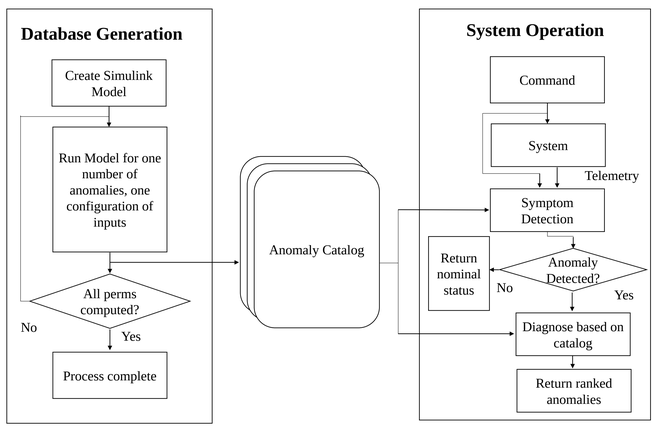
Abstract

Model Based Reasoning (MBR) is a systematic reasoning approach that uses first principles design information to manage anomalies in a complex engineering system. Its computational complexity, however, prevents realtime or near-realtime use. In this study, we use MBR to precompute anomaly scenarios prior to the operation of a system using an enhanced model that specifies the likelihood of specific anomalies; during operation the resulting database can be quickly searched to perform anomaly detection and diagnosis. This modelling framework was implemented on Breakabot, a 3 wheeled mobile robot. Initial testing is verifying the technique and highlighting its value.

Reasoning Architecture



References

- Kitts, Christopher. "Managing space system anomalies using first principles reasoning." IEEE robotics & automation magazine 13.4 (2006): 39-50.
- Rasay, R., *A Graphical Model-Based Reasoning Analysis Environment for Space System Anomaly Management*, Advisor: C. Kitts, SCU Master's Thesis, June 2007.
- Hedlund, Jake, *Implementing Confidences in a Model-based Reasoning System to Build a Prioritized Catalog of Potential Anomalies*, Advisor: C. Kitts, SCU Master's Thesis, draft.

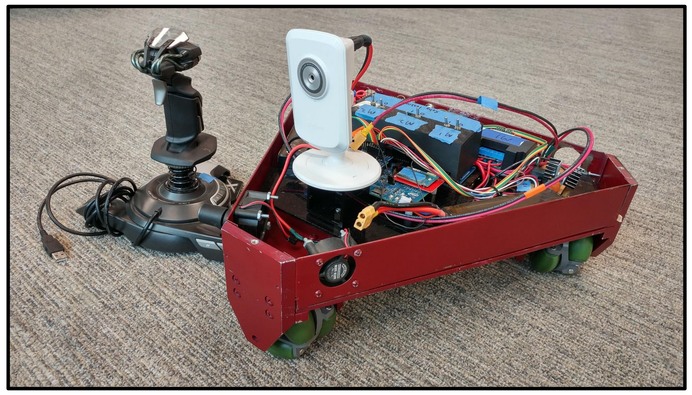
Research Innovation

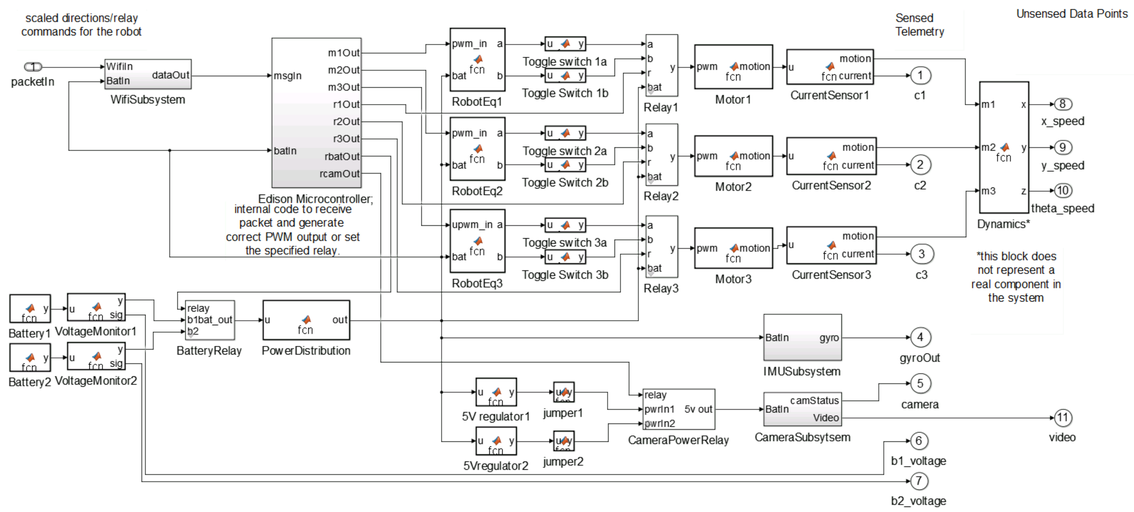
Current MBR Anomaly Management Approach	Proposed Precomputed Reasoning Anomaly Management Approach
• Model Based Reasoning (MBR) uses deliberative reasoning to detect, diagnose, and resolve operational anomalies in an engineering system. • Approach is faster and more precise than human based analysis. • Computational complexity precludes use in realtime or near-realtime control.	• Pre-compute anomaly scenarios using MBR, sort them in a database, and use a realtime production rule system to select viable scenarios based on configuration and telemetry. • Dramatically reduces computation during realtime operations at the cost of creating a large database prior to operation.

The System: Breakabot

Design Features

- Omnidirectional wheels provide holonomic motion
- Remote piloting via an on board camera and a joystick
- Automated telemetry collection
- Redundant components
- Experimental breakpoints





Benefits and Value

Performance Improvement

- Systematic generation of an anomaly catalog
- Likelihood rankings prioritize diagnoses
- Precomputation accelerates detection & diagnosis

Value for Applications

- Lowers personnel costs due to reduced anomaly team manpower
- Improves service level and reduces losses associated with system downtime; this can be millions of dollars for spacecraft missions

Analytics

Statistic	Value
Number of Components in System	28
Number of Connections in System	65
Number of Checked Telemetry Outputs	7
Number of configuration/command permutations	2,496
Number of lines currently in the database	33,424,752
Number of permutations for 1 anomaly with a single configuration	56
Number of permutations for 2 anomalies with a single configuration	1,540
Number of permutations for 3 anomalies with a single configuration	27,720

Status of Work

- Robot model has been verified for several test cases.
- Initial MySQL database has been automatically generated for all single and double anomaly cases.
- Precomputed MBR Anomaly Management appears to be a viable, precise, and fast method for detecting and diagnosing anomalies.

Future Work

- Full validation of simulated telemetry outputs on all input cases.
- Run formal blind experiments to fully validate the modelling technique.
- Further refinement of detection algorithm using traditional MBR techniques.