Information Sciences

Model-Based Fault Diagnosis: Performing Root Cause and Impact Analyses in Real Time

The methodology and its required interfaces have been implemented to become a commercial product for integrated systems health management.

Stennis Space Center, Mississippi

Generic, object-oriented fault models, built according to causal-directed graph theory, have been integrated into an overall software architecture dedicated to monitoring and predicting the health of mission-critical systems. Processing over the generic fault models is triggered by event detection logic that is defined according to the specific functional requirements of the system and its components. Once triggered, the fault models provide an automated way for performing both upstream root cause analysis (RCA), and for predicting downstream effects or impact analysis. The methodology has been applied to integrated system health management (ISHM) implementations at NASA SSC's Rocket Engine Test Stands (RETS).

Previous SSC ISHM systems have focused on integrating distributed smart sensor data into a centralized object model, and on providing high-level, rule-based reasoning for RETS health monitoring. The SSC ISHM did not include advanced health monitoring techniques such as correlation of events at the system level, automated fault diagnosis, failure prediction, root cause analysis, or predictive analysis. The key functional enhancement targeted for ISHM by this project has been the development of an automated, generic, fault-tree-based RCA module designed to enable these additional capabilities. By choosing a generic, model-based diagnostic methodology, a more complete assessment/evaluation of system health is empowered, while advanced techniques for isolating root causes and predicting the onset of failure are enabled. The objective was to create a library of reusable fault models and correlation logic for use across multiple programs.

The domain-specific insight necessary to perform the design and implementation tasks at SSC has been acquired through scheduled discussions with RETS test engineers and scientists. Where possible, validation of these enhancements took place using real-time operational data, as well as of historical data. A discrete number of generic failure modes can typically be identified for many of the components within an ISHM system model. Failure modes are distinct mechanisms by which the components can fail. From these failure modes, it is possible to construct a fault model — a directed graph that depicts the causal relationships between the component failure modes and any of the observable (or measureable) downstream effects. The nodes in the fault model represent these measureable effects, and the directed connections between the nodes characterize both their causal relationships as well as any appropriate constraints that might apply. Within an ISHM system, such generic fault models can be traversed by software to determine the causes of abnormal system behavior. The models can also be traversed for predicting the downstream impacts. While traversing all applicable fault models upon receipt of detected events, ISHM software can also perform the necessary tests to diagnose and isolate the root causes of problems, ruling out other possible explanations that are not substantiated by event data.

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Interactive Schematic Integration Within the Propellant System Modeling Environment

Commercial areas of interest include automotive engine components, petroleum refineries and offshore rigs, and industrial machinery builders.

Stennis Space Center, Mississippi

Task requirements for rocket propulsion test preparations of the test stand facilities drive the need to model the test facility propellant systems prior to constructing physical modifications. The Propellant System Modeling Environment (PSME) is an initiative designed to enable increased efficiency and expanded capabilities to a broader base of NASA engineers in the use of modeling and simulation (M&S) technologies for rocket propulsion test and launch mission requirements. PSME will enable a wider scope of users to utilize M&S of propulsion test and launch facilities for predictive and post-analysis functionality by offering a clean, easy-to-use, high-performance application environment.

PSME Interactive Schematic (IS) is an innovative function that augments PSME's client application to become more efficient by increasing intuitive operation in the model configuration phase. IS diagrams of propellant system components are tied to primary parameter values of a given model configuration. Changes to parameter values are integrated with components of the diagram, dynamically depicting corresponding changes within the diagram. This serves as a visual confirmation of the configuration change made.

The Pressurant Tank IS enables the representation of editable liquid propellant Rocket Propulsion Test Analysis (RPTA) core model configuration parameters as textbox controls, annotating a graphical Pressurant Tank schematic. Edits made within the text boxes reflect dynamically in a changed visual state of the schematic. This enables a first-ever means for editing RPTA model configuration parameters in a visual context of the configuration component being affected.

The prototype development of schematic interaction utilizes Excel's pre-defined graphics called auto-shapes, requiring no other coding or external licensing of other software. The new interactive schematic function, designed as a top layer skin, enables rapid development and customization with little change to the underlying Model Configuration Editor (MCE). PSME's client application interactive schematics design allows for quick and efficient customizations that may be required in support of mission activities.

This work was done by David Coote and Harry Ryan of Stennis Space Center, and Kenneth Burton, Lee McKinney, Don Woodman of Computer Sciences Corporation. For more information, call the Innovative Partnerships Office at 228-688-1929. SSC-00351

Magnetic and Electric Field Polarizations of Oblique Magnetospheric Chorus Waves

NASA's Jet Propulsion Laboratory, Pasadena, California

A theory was developed to explain the properties of the chorus magnetic and electric field components in the case of an arbitrary propagation angle. The new theory shows that a whistler wave has circularly polarized magnetic fields for oblique propagation. This theoretical result is verified by GEOTAIL observations. The wave electric field polarization plane is not orthogonal to the wave vector, and in general is highly elliptically polarized. A special case of the whistler wave called the Gendrin mode is also discussed. This will help to construct a detailed and realistic picture of wave interaction with magnetosphere electrons.

It is the purpose of this innovation to study the magnetic and electric polarization properties of chorus at all frequencies, and at all angles of propagation. Even though general expressions for electromagnetic wave polarization in anisotropic plasma are derived in many textbooks, to the knowledge of the innovators, a detailed analysis for oblique whistler wave mode is lacking. Knowledge of the polarization properties is critical for theoretical calculations of resonant wave-particle interactions.

This work was done by Olga Verkhoglyadova and Bruce T. Tsurutani of Caltech, and Gurbax S. Lakhina of the Indian Institute of Geomagnetism for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47770

Variable Sampling Mapping

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The performance of an optical system (for example, a telescope) is limited by the misalignments and manufacturing imperfections of the optical elements in the system. The impact of these misalignments and imperfections can be quantified by the phase variations imparted on light traveling through the system. Phase retrieval is a methodology for determining these variations. Phase retrieval uses images taken with the optical system and using a light source of known shape and characteristics. Unlike interferometric methods, which require an optical reference for comparison, and unlike Shack-Hartmann wavefront sensors that require special optical hardware at the optical system's exit pupil, phase retrieval is an *in situ*, "image-based" method for determining the phase variations of light at the system's exit pupil. Phase retrieval can be used both as an optical metrology tool (during fabrication of optical surfaces and assembly of optical systems) and as a sensor used in active, closed-loop control of an optical system, to optimize performance. One class of phase-retrieval algorithms is the iterative transform algorithm (ITA). ITAs estimate the phase variations by iteratively enforcing known constraints in the exit pupil and at the detector, determined from modeled or measured data.

The Variable Sampling Mapping (VSM) technique is a new method for enforcing these constraints in ITAs. VSM is an open framework for addressing a wide range of issues that have previously been considered detrimental to high-accuracy phase retrieval, including undersampled images, broadband illumination, images taken at or near best focus, chromatic aberrations, jitter or vibration of the optical system or detector, and dead or noisy detector pixels. The VSM is a model-to-data mapping procedure. In VSM, fully-sampled electric fields at multiple wavelengths are modeled inside the phase-retrieval algorithm, and then these fields are mapped to intensities on the light detector, using the properties of the detector and optical system, for comparison with measured data. Ultimately, this model-to-data mapping procedure enables a more robust and accurate way of incorporating the exit-pupil and image detector constraints, which are fundamental to the general class of ITA phase retrieval algorithms.

This work was done by Jeffrey S. Smith, David L. Aronstein, Bruce H. Dean, and Richard G. Lyon of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15693-1