Integrated Formulation of Beacon-Based Exception Analysis for Multimissions

BEAM has become a broadly applicable, highly capable means of automated diagnosis.

Further work on beacon-based exception analysis for multimissions (BEAM), a method of real-time, automated diagnosis of a complex electromechanical systems, has greatly expanded its capability and suitability of application. This expanded formulation, which fully integrates physical models and symbolic analysis, is described architecturally in the figure.

In a typical application, BEAM takes the form of an embedded software suite executing onboard the system under study, though many off-board data analysis engines have been constructed as well. The BEAM software performs real-time fusion and analysis of all system observables. BEAM is intended to reduce the burden of diagnostic data collection and analysis currently performed by both human operators and computers. In the case of a spacecraft or aircraft, BEAM enables onboard identification and characterization of most anomalous conditions, thereby making telemetry of larger quantities of sensor information to ground stations unnecessary. Previously BEAM has been described in several prior NASA Tech Briefs articles: “Reusable Software for Autonomous Diagnosis of Complex Systems” (NPO-20803) Vol. 26, No. 3 (March 2002), page 33; “Beacon-Based Exception Analysis for Multimissions” (NPO-20827), Vol. 26, No. 9 (September 2002), page 32; and “Wavelet-Based Real-Time Diagnosis of Complex Systems” (NPO-20830), Vol. 27, No. 1 (January 2003), page 67.

The new formulation of BEAM expands upon previous advanced techniques for analysis of signal data, utilizing mathematical modeling of the system physics, and expert-system reasoning. These components are integrated seamlessly, making possible analysis of varied information about the monitored system, including time-correlated signal performance, state information, software execution, operator command execution, and convergence to state and physical models. BEAM software is highly adaptable and can be implemented at relatively low cost in terms of processor power and training, and does not require special sensors. Unlike some prior methods of automated diagnosis, BEAM affords traceability of its conclusions, which allows system experts to completely reconstruct its decision path for greater operator confidence or to aid analysis of novel conditions. Principal among BEAM’s strengths is its excellent performance in detection and classification of such novelty, meaning faults of previously unknown — and untrainable — type.

In the BEAM architecture, discrete sensor information, state information, and commands are fed as input to the symbolic model, and quantitative sensor data is input to a simplified physical model of the system. These modules are designed to leverage existing system models, which can be high or low fidelity. The symbolic model aids signal-based analysis in terms of mode selection or other discrete outputs. The physical model improves sensitivity through separation of predictable and unpredictable signal components.

Time-varying quantities are analyzed in two groups: (1) signals with a high degree of correlation to others, or signals that are not isolated in a diagnostic sense, are passed to the coherence-analysis component of BEAM; (2) signals that may uniquely indicate a fault, as well as those already suspected to be faulty, are passed through

NASA's Jet Propulsion Laboratory, Pasadena, California

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Determining Direction of Arrival at a Y-Shaped Antenna Array

The direction is computed from differences among times of arrival of signals.

An algorithm computes the direction of arrival (both azimuth and elevation angles) of a lightning-induced electromagnetic signal from differences among the times of arrival of the signal at four antennas in a Y-shaped array on the ground. In the original intended application of the algorithm, the baselines of the array are about 90 m long and the array is part of a lightning-detection-and-ranging (LDAR) system. The algorithm and its underlying equations can also be used to compute directions of arrival of impulsive phenomena other than lightning on arrays of sensors other than radio antennas: for example, of an acoustic pulse arriving at an array of microphones.

The underlying equations express the differences among the times of arrival as functions of the inner products of (1) the unit vector of the direction of arrival and (2) the unit vectors along the baselines of the array. To obtain a solution for the unit vector (and thus, equivalently, the azimuth and elevation angles) of the direction of arrival,