CAST Extensions to DASME to Support Generalized Information Theory

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Abstract. The Data Analysis and System Modeling Environment (DASME) is a computer-assisted modeling environment, currently under development at NASA's Goddard Space Flight Center, designed to support ground-based mission operations with a mixed discrete/continuous modeling capability. This paper describes planned CAST-based extensions to DASME to support a broader range of systems theoretical computing models, and in particular models utilizing concepts from Generalized Information Theory (GIT) such as fuzzy systems, possibilistic measurement, and possibilistic processes. Support for model-based diagnostics and trend analysis of spacecraft systems is targeted.

1 Introduction

This paper describes a software systems development project ongoing in the Software and Automation Systems Branch (Code 522) of NASA's Goddard Space Flight Center in Greenbelt, Maryland. Code 522's role—within the overall Goddard mission of Earth and space science research with earth-orbiting satellites—is to conduct research and development to support mission operations and data systems. Code 522 provides systems engineering, development, and operation tools, and prototypes demonstrating new technologies and advanced systems architectures. Their areas of technology expertise span from systems modeling and human-computer interaction to software engineering and knowledge-based systems.

The overall thrust of Code 522 research is to move towards increasing autonomy and automation of both spacecraft platforms and their ground-based control and support systems. The foreseen development path moves from rule- and object-based approaches, characteristic of expert systems; through model-based approaches, typical of enhanced knowledge-based systems; and aiming towards sophisticated agent-based AI approaches.

One of the important research areas of Code 522 is the development of methods for trend analysis of spacecraft systems and components. In trend analysis,
mathematical representations of spacecraft health are developed from telemetry analysis. These analysis methods are then employed to reveal any long-term trends indicating degradation in system health, or any incipient threat of failure.

The initial focus of the trend analysis program is the battery subsystem for the Small Mission EXplorer (SMEX) family of missions. Batteries provide a particular challenge for trend analysis because of the complexity of their environments (loads and charges) and the complexity and inherent limitations in our knowledge of their electrochemical dynamics. These conditions have resulted in great difficulties in battery quality assurance, and a number of spacecraft platforms are at risk for failure.

Existing Code 522 facilities for trend analysis provide only basic visualization and rudimentary statistical analysis of telemetry. More sophisticated approaches to supplement these methods are under development, including a Model-Based Diagnostic (MBD) approach.

In addition, due to the many forms of uncertainty inherently present in complex engineering systems like spacecraft, and especially in their battery subsystems, Qualitative Modeling (QM) methods for MBD are especially appropriate [10]. To support qualitative MBD, we plan to use the Generalized Information Theory (GIT) computational paradigm, and especially its possibilistic modeling techniques. GIT is the synthesis of modern mathematical theories of uncertainty, including fuzzy systems, random sets, evidence theory, and possibility theory [9, 16, 17]. GIT promises to provide a key generalizing technology for QM methods in systems theory [9, 11].

This paper describes the Data Analysis and Systems Modeling Environment (DASME), which is being used as the development environment for this approach, and our proposed CAST-based extensions to DASME to support a broader range of computational models (for example finite automata, petri nets, or neural nets), and especially a qualitative approach to MBD using possibility theory and possibilistic processes.

2 The Data Analysis and Systems Modeling Environment (DASME)

DASME is a computer-assisted modeling platform developed by Henderson to support ground-based mission operations. It has the dual capacities of telemetry analysis and systems modeling using a mixture of discrete-event and discrete-time methods. DASME's general and flexible architecture allows it to be easily adapted to fulfill multiple tasks, although it will be first applied in model-based trend analysis of spacecraft battery subsystems.

2.1 DASME Design

DASME is a collection of behavioral components, input components, output components, a graphical model editor, and a run-time executive.