A Modular Artificial Intelligence Inference Engine System (MAIS) For Support Of On Orbit Experiments

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Abstract

This paper describes a Modular Artificial Intelligence Inference Engine System (MAIS) support tool that would provide health and status monitoring, cognitive replanning, analysis and support of on orbit Space Station, Spacelab experiments and systems.

Introduction

Most experiments flown on Spacelab to date have required considerable support from Mission and Payload Specialist on orbit and console operators and experiment investigation teams on the ground. During the Space Station era, the volume of experiments on orbit necessitates the development of an autonomous system for experiment management, monitor, operation and support.

This paper describes a reusable Modular Artificial Intelligence Engine System (MAIS) that will be flexible, have a low unit cost and will be reconfigurable to meet the needs of different experiments or systems. The MAIS would provide Mission and Payload Specialist with health and status monitoring, recommended actions to be taken and/or analysis of situations based on conditions and the problem encountered. The basic design of the system will allow "new artificial intelligence (AI) capabilities" to be added as needed. Reconfiguration for a new experiment will be accomplished by changing the heuristics and rules that will form the basis of scripts and can be accomplished as often as required.

This paper will also define the goals and objectives of the MAIS and the operational environment.

Operational Concept

Before flight or utilization on orbit, rules and scripts are developed or modified that support a particular experiment. An assessment of AI capabilities is performed, and if required, the software architecture of the MAIS is reconfigured. Interfaces to the experiment are established and graphical user interface displays are created to the user requirements. Limits, signal exceptions and health and status monitor rates are set. The MAIS tool and the experiment are started.

If sensor inputs, experiment signals or health and status updates indicate a problem, exceeded limit or a deviation of a pre-set plan, the tool will access rules and if necessary, apply heuristic or inference techniques (or other techniques as required) to identify and correct the problem. The tool will report the error and identify its most likely source, the applicable rules and what scripts were utilized to correct or replan around the problem. If necessary, the tool will perform as much of an analysis as possible following the steps previously outlined and when completed signal for human intervention.

Goals and Objectives

The high level goals and objectives of the MAIS are:

- Reduce experiment/ system support required by members of the Space Station/ Spacelab crew and ground operations personnel

- Reduce risk by managing and monitoring experiments continuously

- Reduce risk by providing an analysis of problems and recommending/ taking corrective actions quickly

- Provide a reusable tool that can be reconfigured for different experiments/ missions

- Provide analysis of the situation based on conditions and problems encountered

- Provide a technology transfer "autonomous system/process management, monitor and control" for researchers, product development or production environments

General Description

The MAIS will be composed of the following hardware and software elements:

1. Hardware module (containing CPU, memory, power, experiment interface and user interfaces)
2. Modular Inference Engine (design of the code will permit the introduction of additional AI capabilities (deduction, forward and backward chaining etc., as required))
3. Rule sets
4. Scripts
5. Graphical User Interface

Architecture

MAIS architecture is designed around an inference engine (expert system) which employs heuristics and rules to monitor and respond to sensor inputs or signals from an experiment through an experiment interface. MAIS user interface will display status data from the experiment and actions taken by the system in response to values exceeding limits or being non-responsive. The user interface will also support human intervention in the tool, its actions or the experiment at any time (see Figure 1).
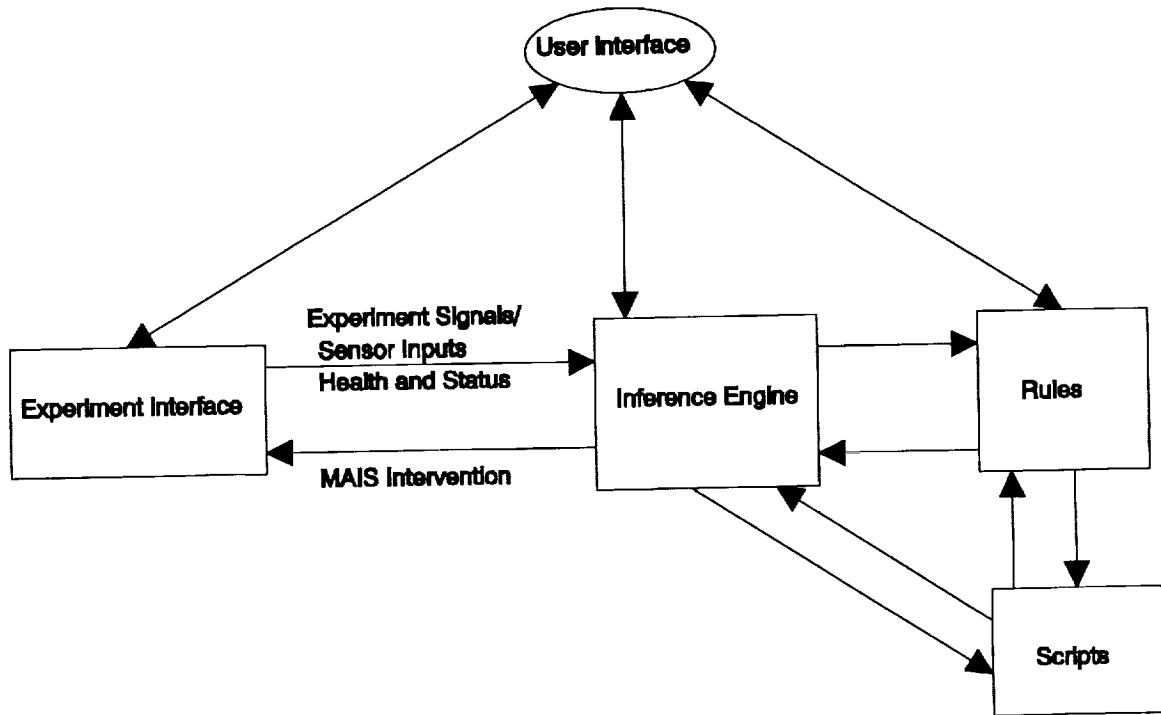
Figure 1. MAIS Architecture

Modular AI Design

One of the advantages of this tool will be the ability to add new AI capabilities to support the needs of different experiments. Some experiments will require deduction techniques, data search techniques or more extensive heuristics. A well designed modular system will support the "plugging in" of new capabilities (see Figure 2).
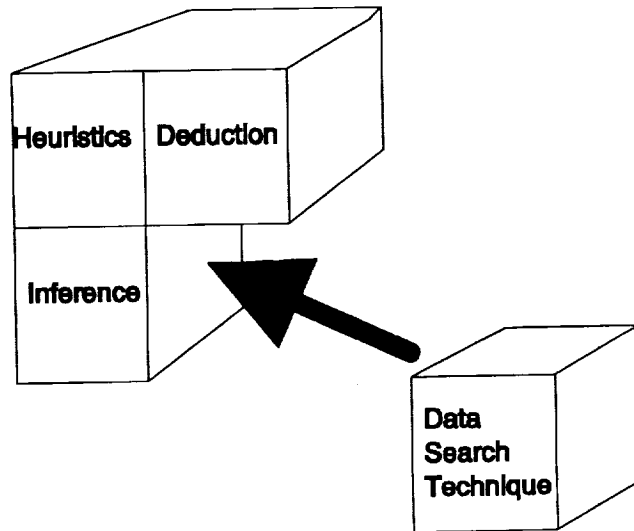

Figure 2. Addition of new capabilities to a modular design

Graphical User Interface

A point and click graphical user interface would be used to communicate a record of its actions, conditions encountered (sensor inputs or experiment signals), and health and status, or to provide human intervention. This will allow a user to configure the graphical user interface to display information in any format a user selects. The graphical user interface will support dynamic representations (widgets) or textual display of data. The user interface will display human readable information when displaying actions taken by the system (i.e., rule 3 invoked based on conditions "r" that utilized script "4.1" with the following actions.....).

Inference Engine

The MAIS inference engine will support replanning of experiment activities (adaptive planning), problem deduction (inference) and assertion based on facts (beliefs) and their relationship to rules. The inference engine will use fact, concrete and abstract representation to develop expressions for each fact, denoting a part of the fact base (rules) that the system believes. Contradictions in facts (beliefs) based on an application of rules (conflicting states) will require human intervention.

Rules

Rules are developed or modified to support a particular experiment. These rules may or may not be different for each experiment and will control the use of scripts that govern actions taken by the tool in response to sensor inputs or signals from the experiment. Each experiment can benefit from the rules and the associated scripts developed for previous experiments.

Scripts

Scripts control actions taken in response to a predefined set of conditions as stated in the rules developed for each experiment. Scripts are a non-inference technique and similar to flight software fault protection and error recovery systems.

Cognitive Replanning

Experiments that operate by utilizing detailed plans, sequential steps, (not to be confused with programs) that detect a departure from these steps require the ability to replan. Replanning will be accomplished by reordering/ deleting steps as required. Replanning will require the use of inference techniques and rules to determine a the least cost path of action to take in accomplishing the replanning objectives (see Figure 3).
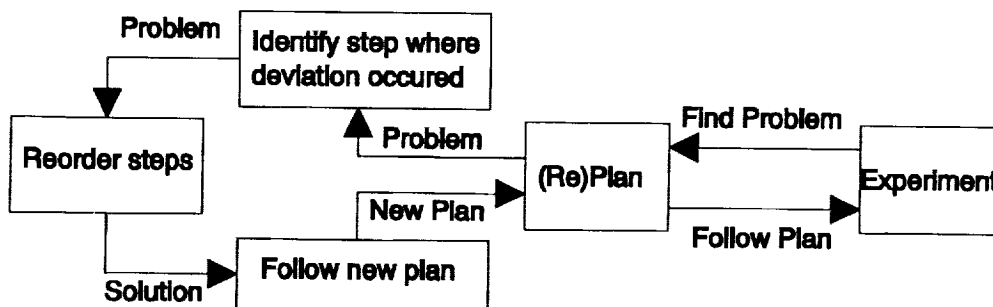
Figure 3. Replanning Model

Summary

Creation of the MAIS, a modular, reusable system that can support different types of experiments over the life of the Space Station or Spacelab program will:

1. Reduce cost
2. Allow the capture of experience from each previous experiment
3. Be reusable
4. Reconfigurable, even on orbit, to support a dynamic environment
5. Promote the development of "spin-offs" to industry
6. Reduce ground support personnel costs and free up crew time on orbit
7. Be smaller, cheaper and faster than any other system in use today

This tool can be developed quickly and could be ready to support experiments on Space Station starting at human tended capability.

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13. ABSTRACT (Maximum 200 words)

The AIAA/NASA Conference on Intelligent Robotics in Field, Factory, Service, and Space (CIRFFSS '94) was originally proposed because of the strong belief that America's problems of global economic competitiveness and job creation and preservation can partly be solved by the use of intelligent robotics, which are also required for human space exploration missions. It was also recognized that in the applications-driven approach there are a far greater set of common problems and solution approaches in field, factory, service, and space applications to be leveraged for time and cost savings than the differences in details would lead one to believe. This insight couple with a sense of national urgency made a continuing series of conferences to share the details of the common problems and solutions across these different fields not only a natural step, but a necessary one. Further, it was recognized that a strong focusing effort is needed to move from recent factory-based technology into robotic systems with sufficient intelligence, reliability, safety, flexibility, and human/machine interoperability to meet the rigorous demands of these fields, the scope of which is beyond the capability of any one area.

The papers in these proceedings are evidence that users in each field, manufacturers and integrators, and technology developers are rapidly increasing their understanding of integrating robotic systems on Earth and in space to accomplish economically important tasks requiring mobility and manipulation. The 21 sessions of technical papers in 7 tracks plus 2 plenary sessions cover just the tip of this major progress, but reveal its presence nonetheless.

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