The MECA Project — Ontology-based Data Portability for Space Mission Operations

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Abstract*— This article describes the authors' experiences with a pragmatic, ontology-based approach to data portability and knowledge sharing, as used in the first Mission Execution Crew Assistant (MECA) *Proof-of-concept demonstrator software.

***Index Terms*—crew autonomy, knowledge sharing, space missions**

I. Introduction and Background

MECA is a European Space Agency (ESA) research project that aims to boost the cognitive capacities of astronaut/machine teams during planetary exploration missions in order to allow them to cope autonomously with unexpected, complex and potentially hazardous situations. The MECA software acts in a ubiquitous computing environment as an *electronic partner*, helping the crew to assess a situation, to determine a suitable course of problem-solving actions, and to safeguard the astronauts and the mission from failures [1, 2].

II. Ontologies and Data Modeling in MECA

To achieve the necessary high level of autonomy, the MECA software must have a semantically rich view of the world in which it operates. It must have an understanding of high level mission objects (such as goals, resources, actors, tasks, procedures, plans and schedules) but also of lower-level system information (such as vehicles, payloads, instruments, sensors, actuators, processors, telemetry, test results, and fault diagnoses).

In order to assist the astronaut optimally, MECA must also be aware of issues such as trust, task load, stress levels and other cognitive aspects of human-computer interfacing. Following the general objective of human-machine partnerships, a major part of the information should be easily shared (i.e. understood) by both human and machine actors.

An ontology-based approach to these requirements was developed as part of the incremental, modular cognitive engineering development process of MECA. The resulting MECA ontologies are based on Work Domain Analysis methodology [3] as well as human factors theories and models.

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III. The MECA Software Architecture

For the MECA Proof of Concept demonstrator, the MECA team created a service-oriented architecture supported by a distributed RDF (Resource Description Framework) Knowledge Base. The Knowledge Base contains heterogeneous data described by OWL (Ontology Web Language) implementations of the various MECA Ontologies.

The common semantic world view provided by the RDF data allows the software to be aware of and reason about connections between concepts and data that are not normally considered interoperable (e.g. astronaut stress levels automatically influencing task scheduling). The knowledge base is also instrumental in implementing parts of MECA as semantic web services, facilitating the sharing of knowledge among heterogeneous agents.

IV. Evaluation results

Human-in-the-loop evaluation and test sessions with representative users were used in order to validate the MECA architecture, providing requirements for further refinement. In this article we focus on the experiences and results related to the underlying MECA data modeling and knowledge base, which were central to the Proof-of-concept Demonstrator software.

V. Conclusions and Future Research

The MECA ontologies enable easy information sharing between human and synthetic actors and consequently are an important foundation of its collaboration support function to enhance, situation awareness, resource planning and sensemaking. We discuss the pros and cons of the ontology-based approach, and give an outlook on further application of these techniques in the space operations domain..

References

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