SPECIAL THEME: Space Exploration

A critical problem for interplanetary space missions is to maximize scientific results while guaranteeing data return to Earth. A research team of the Institute of Cognitive Science and Technology of the Italian Research Council (ISTC-CNR) has developed an AI system, named MEXAR2, currently in daily use at the European Space Agency (ESA-ESOC). MEXAR2 provides continuous support to human mission planners in synthesizing dump plans for downlinking on-board memory data from the MARS EXPRESS spacecraft to Earth.

The MARS EXPRESS mission has ambitious goals for the scientific experiments on board. The seven payloads with which the orbiter is equipped are expected to maximize their data return to take advantage of the opportunity offered by proximity to the Red Planet.

MEXAR2 Support to Space Mission Planners
by Amedeo Cesta, Gabriella Cortellessa, Simone Fratini, Angelo Oddi and Nicola Policella

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The potential of IPS for an actual rover mission has never been demonstrated in a test environment representing ESA’s Aurora programme. The Mars Mission On-board Planner and Scheduler (MMOPS) project aims to address this. SciSys, with the University of Strathclyde (UK) and Heriot-Watt University (UK), are working on a project to develop an on-board IPS application capable of mission plan validation and repair. Trials involving engineering and operations personnel will then explore the benefits and optimal trade-off between factors such as autonomy vs. complexity, risk and net benefit to a mission.

As these examples illustrate, SciSys’ own experience with the complex and challenging task of robotic planetary exploration has shown that strong relationships with universities and research centres is a key element for success.
New information from Mars is not only arriving to the space scientific community but, through the media, is also being disseminated further.

Obviously, in a deep-space mission like MARS EXPRESS, data transmission to Earth is fundamental. The space probe continuously produces a large amount of data resulting from the activities of its payloads and from on-board device monitoring and verification tasks. All data must be transferred to Earth during bounded downlink sessions. The presence of a single pointing system implies that the space-probe either points to Mars to perform payload operations, or points to Earth, to download the produced data. As a consequence, on-board data must generally be first stored in a Solid State Mass Memory (SSMM) and then transferred to Earth.

The average data production on a single day can be around 2-3 Gbit while the transmission rate of the communication channel, which varies between 45Kbs and 182Kbs, may not be sufficient. The on-board memory is subdivided into different banks, called packet stores, in which both scientific and spacecraft management data can be stored. In particular, the latter must reach Earth daily so as to allow safety checking of the different operations on board. It should be noted that each packet store assigned to science data is managed cyclically, so if new data are produced before the previous data have been dumped to Earth, the older data are overwritten and the related observation experiments have to be re-scheduled. Even if the on-board memory is about 9.4 Gbit, the irregular distribution of transmission windows, the different transmission rates of such windows and the different data rates for data production (e.g., the stereo camera can produce files close to 1Gbit) may frequently create usage peaks close to the packet store capacities.

To complicate matters there is an additional uncertainty factor in data production for some instruments due to different compression algorithms. Dump plans for the on-board memory are usually computed for a nominal expected production of a certain payload activity, a POR (Payload Operation Request), but mission planners may discover that onboard data are more than expected so they have to recompute a dump plan.

The role of the software previously used to support the decision making was secondary; it was relegated to constraint checking tasks. On the contrary, by integrating Artificial Intelligence problem solving methods and Human-Computer Interaction techniques, MEXAR2 implements a proactive approach to plan synthesis while, at the same time, fostering human intervention and control during problem solving. In general, data dump generation can now be performed more quickly and with less effort and the quality of plans exceed that provided by the tools previously used.

From the user standpoint, the problem of uncertainty in data production is addressed very satisfactorily and the time saved for producing plans has been estimated as up to 50%.

The ability of MEXAR2 to generate plans over multiple days very quickly, allows mission planners to consider alternative solutions in order to avoid data loss. It is worth noting that, before the introduction of MEXAR2 in the Mission Planning System, mission planners were satisfied with a single solution; MEXAR2 makes it possible to activate interesting optimizations. This allows problematic intervals in the schedule of future payload operations to be identified and an alternative allocation of the tasks involved to be negotiated with scientists thus minimizing overwrites. Additionally, users appreciate the usability and flexibility of the interface services and the fact that MEXAR2 runs on several platforms so that they can easily employ it from different machines. The previous procedure for synthesizing dump plans quite often obliged staff to work overtime; this effect has been eliminated with MEXAR2.

The scientific community has gained a number of benefits from MEXAR2: observation data are available earlier and data loss is minimized. As already said potential overwrites can be quickly detected and fed back to the scientists for science plan updates. Thanks to MEXAR2 the use of the downlink channel is optimised and more data can be downlinked. We can conclude that the use of MEXAR2 has resulted in an important increase in the scientific return from the mission.

**Link:**
http://pst.istc.cnr.it/

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