Fuzzy Logic for Autonomous Dynamic Scheduler with Conflict Detection and Resolution

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Abstract. The proposed demo presents a new approach to face the autonomous updating of the on board scheduled activities for space applications. The problem is treated as a multi-criteria decision-making on a dynamic knowledge base of the entire system. A search direction technique is proposed based on different ranking processes on the decisional nodes to be followed for solving violations.

A new and challenging approach has been implemented and prototyped to face the autonomous scheduling of on board tasks for space applications during nominal and contingency operational scenarios.

Nowadays spacecraft autonomy represents a great challenge, as it would permit to overtake several problems rising from restricted visibility periods for ground contacts within earth missions as well as deep communications for interplanetary probes. Augmented on board autonomy will lead to a real time control of the spacecraft allowing the optimisation of the payload goals within the actual state of the system and an eventually immediate detection and recovery of a subsystem fault without waiting for the ground intervention.
All that means increase mission productivity and optimisation of limited ground resources - being able to manage a larger number of spacecraft with the same ground facilities. All that is expected to provide cost savings on the long run.

Autonomy can be thought as an on board closed loop made of a supervisor that monitors the spacecraft state- in terms of selected parameters-, ranks the goals the system has to accomplish within a limited time horizon and takes decisions on activity sequences and resources management to achieve the goals.

The main functions of an autonomous system can be summarised as follows: a scheduling function, an executing and monitoring function and a product refinement function; the first three aforementioned functions involve several decision-making processes.

This work is focused on the implementation of the autonomous on board scheduling management. The problem is split in two main parts: the strictly decision making problem and the scheduling problem.
• The decision making problem solver simulates the analyst way of thinking in dealing with telemetry and telecommands, that it is clearly a non deterministic one based on human expertise: for this reason heuristic methods have been used to implement it.
In particular fuzzy logic theory is a great tool as it works with no sharp boundaries between definition classes: alternatives shift smoothly from a qualitative class to the contiguous one and it is admissible that more than one simultaneously belongs to two different qualities. Thus fuzzy logic theory revealed to be the best fitting method to model those kind of mental processes.
• The scheduling task is faced with a repair-method approach, which builds a complete scheduling scenario and works, thanks to the decision making algorithms, on the flaws reduction towards a complete allocation consistency.

The prototype implementation has been built taking as reference PROBA, an ESA mission conceived for the purpose of demonstrating new on board technologies and benefits of on board autonomy.
The main payload is a Compact High Resolution Imaging Spectrometer the operations of which are based on the observation requests remotely submitted from the scientists to the control centre.
The observation requests may clash with other on board operations such as achievement of particular attitudes for optimal solar power supply or downlink windows or may be in conflict with the on board resources such as power and available on board memory.

Thus an autonomous supervisor must achieve goals related to the payload as well as to the spacecraft housekeeping by managing limited power and memory resources, which play as constraints, highly spacecraft state dependent. Moreover, the scheduling algorithm has to answer re-scheduling performance in order to be possibly robust according to possible on board failures that could involve a partial system reconfiguration.
The allocation in time of the activities is managed as a constrained multi-criteria decision-making problem. Both the starting and the final timelines for the update of the on board functions are not a priori fixed: a decision making block receives observation request number and coordinates as well as status parameters from the on board subsystems and through a fuzzy logic control block gives the duration and the starting time for the next scheduling process. Whenever the status parameters reveal a possible fault a new scheduling session could be activated. No execution module has been developed within the current work.

Within each scheduling window local activities are detected (e.g. different observations, links, etc) and equally evaluated according to the current spacecraft status, as long as no preliminary priority has been fixed.
The inconsistency solution is achieved by iteratively applying different decisional blocks according to the activity-action couple controls to different class of on-board resources.
The demo prototype runs on a Windows PC and makes use of commercial modelling and orbit propagation environment. Realistic cases have been selected to demonstrate and validate the innovative approach.