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CONSTRAINT PROGRAMMING FOR AUTONOMOUS ON-BOARD RESOURCE MANAGEMENT

Abstract

A number of missions must face challenges resulting from the limited availability of the space-ground link. In the case of interplanetary spacecraft, the communication windows are short and restricted by the capacity of the ground station network and the available onboard power, which must mainly be shared between communications and science instruments. Similar problems can also be found in nanosatellite missions, where the ground segment typically consists of a single ground station.

Since the limited capacity and possibly high round-trip time do not allow for live monitoring and control of the spacecraft from the ground, such missions are planned for the worst-case scenario of the resources available (power, attitude...).

We propose an on-board system that adapts the schedule to the current status of the spacecraft, trying to increase the use of resources, and hence increases mission output.

Subsystems (e.g. payload) request resources from the resources manager in advance. Many activities onboard the spacecraft do not require the resources to be allocated at an exact time (e.g. space environment experiments, self-test procedures...). As such, each request includes an allocation time range. The resources manager then determines an optimal schedule based on earliest unmet requests (which can be re-assessed based on the new request). Resources are allocated to a subsystem only if available. In case of a shortage, requests made by lower priority subsystems are rejected. When conflict still occurs between subsystems of the same priority, the resource manager satisfies the requests for the highest amount of resource usage.

Such a deterministic priority based system allows the designer to choose which payloads to prefer over other. It is then simple for the designer to simulate a wide range of possible scenario to help in determining the correct set of priority values to meet the mission objectives.

Requests and optimisation rules are transcribed as constraints, and fed to a constraint solver. This solver look through each possible solution satisfying the constraints and selects the one which is optimal with respect to the optimisation rules.

A first implementation has been designed for a nanosatellite technology demonstration mission. An open-source COTS constraint solver is used to reduce development time, risk and cost. We have demonstrated, during ground tests, that autonomous on-board resources management can lead to a better resources utilisation than traditional ground-based planning. Moreover, the use of constraint solving algorithms appears to be suitable in terms of reactivity and optimality of the solution.