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AN ARCHITECTURE OF ON-BOARD AUTONOMY FOR CLUSTER FLIGHT OF FRACTIONATED SPACECRAFT MODULES

Abstract

As the expected applications of space systems are becoming more demanding, distributed space systems and autonomous spacecraft technology are being researched more and more. Nowadays more attention is paid to non-traditional requirements such as maintainability, flexibility and scalability of space systems to cope with internal or external uncertainties affecting their functions or performances. Fractionated spacecraft, a revolutionary distributed space system architecture, has been proposed and researched during last five years as one way to fulfill the non-traditional requirements. Meanwhile, in order to handle the essential complexity and uncertainty of fractionated spacecraft modules, to relieve the workload of ground stations, and also to reduce the cost of operating modules after launch, modules in distributed space systems are being assigned more and more intelligence. Autonomy can be generally achieved by means of different technologies, and multi-agent system (MAS) is one particularly promising candidate.

Cluster operations of fractionated spacecraft modules, such as scatter and re-gather maneuver to rapidly evade debris-like threat and cluster reconfiguration to accommodate new modules or remove modules, can be performed in an autonomous way. This paper presents an architecture of on-board autonomy for cluster flight of fractionated spacecraft modules with cooperative mission planning capability, which is based on MAS technology. First, existing potential applications of fractionated spacecraft are reviewed, and then analysis and summary of related cluster organization of each application is presented. Second, rooted on that analysis and combined with MAS technology, an organization of fractionated spacecraft modules based on MAS is proposed, wherein not only the modules but also the functions of each module are modeled as agents. Third, a cooperative mission planning architecture is constructed based on the autonomous architecture proposed. In this paper the mission planning problem is treated as a constraint satisfaction problem (CSP). Therefore, constraints of the entire cluster shared by all agent modules and those special constraints of each agent are, respectively, specified firstly. After that the cooperative mission planning architecture are derived, where the preliminary schedule is generated according to common constraints, and then revised by each agent in accordance with its own special constraints, such as removing conflicts between satisfying solutions to common and special constraints. In such a cooperative way, the constraints are decomposed so that the system will be more flexible, and the computation efficiency will be improved, which will be demonstrated in a simulation employing JADE (Java Agent Development Framework).