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AUTONOMOUS COLLABORATIVE ON-ORBIT SERVICING OF MODULAR RECONFIGURABLE SATELLITES

Abstract

This paper presents a novel autonomy framework developed for autonomous collaborative On-Orbit Servicing (OOS) capable of planning and scheduling the execution of elementary pre-defined actions to fulfill complex on-orbit servicing missions. The two main components of the framework are: i) a novel bio-inspired discrete decision-making algorithm, and ii) a distributed Guidance, Navigation and Control (GNC) architecture. The framework generates a collaborative plan and schedule of docking and undocking operations for a swarm of servicing satellites, executed with a distributed navigation and control system. The autonomous planning and execution processes uses a cascade flow procedure architecture to plan first (Decision Layer) and to execute later (Executive Layer). The framework can generate optimal plan and schedule for servicing tasks and also perform autonomous close proximity operations, rendezvous, and docking (RVD) with cooperative and non-cooperative targets. The autonomy framework allows cooperation, tasks sharing, navigation and control with other servicing spacecraft to attain the mission goals, enabling mission design scenarios using single or swarm of servicing spacecraft.

The core system responsible for the decision-making is based on a novel bio-inspired incremental planning and scheduling discrete decision-making algorithm. The decision-making algorithm generates an optimal task sequence and an optimal path for each of the satellites in the swarm. The path planning includes collision avoidance constraints with the target spacecraft, as well as with all the other servicing spacecraft. This is essential to provide an optimal synchronized choreography for all of the servicing spacecraft that ensures safety throughout all over the operational plan.

During execution, a distributed GNC architecture is implemented. This distributed GNC architecture provides a multi-sensor fault tolerant autonomous navigation systems that takes the advantages of inter-spacecraft sensors data fusion approach to combine measurements and improve accuracy and redundancy.

The performance of the proposed autonomy framework will be shown in an orbit servicing scenario similar to the proposed demonstration scenario of PERASPERA project. In this scenario, the target spacecraft is formed by a set of active payload modules (APM) connected to the spacecraft bus via a standardized interface. Then a swarm of servicing spacecraft will re-configure the target spacecraft by removing and replacing APMs in a coordinated manner. Different scenario configurations will be presented (number of servicing spacecrafts, different sensors in each servicing spacecraft, different inter-spacecraft communication links) to simulate failures and contingency reactions to show the robustness of the system.