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A MULTI-AGENT SPACECRAFT AUTONOMY SOFTWARE ARCHITECTURE FOR FORMATION FLYING MISSIONS

Abstract

Spacecraft flying in formation have the potential to increase the robustness and improve the science return for a variety of missions. However, few formation flying and docking missions have actually launched due to their complexity and cost, as well as their need for autonomy. Autonomy in these missions would greatly reduce the need for human oversight, by having each spacecraft handle its own decision-making and scheduling so as to not overwhelm ground operations. Thus, a distributed software architecture designed to increase individual and collective satellite autonomy is necessary to enable formation flying missions.

A distributed software architecture for spacecraft formation flying is proposed. The architecture aims to increase robustness to failure, enable autonomous task allocation within the formation, and increase science return. The software architecture extends MEXEC, developed at JPL, with MONSID, developed by Okean Solutions, and open-source ROS (Robot Operating System) used for message passing and testing.

MEXEC is a lightweight autonomous planning and execution system that monitors the spacecraft state to schedule and execute tasks that satisfy the mission and operation constraints. MEXEC works closely with MONSID, a model-based fault-detection system which monitors the execution of the tasks to identify faults. This allows the software framework to autonomously plan and execute tasks as well as detect and classify faults without ground operator-in-the-loop and is suitable for highly dynamic missions with rigorous time constraints. In addition, this framework can be used to test different subsystems early in the development of the spacecraft, due to the modularity provided by ROS.

The main contribution of this paper is the extension of the software architecture to handle a multi-agent mission. The MEXEC software running on-board each of the spacecraft considers its own resources and constraints and those of the other spacecraft flying in the formation, depending on the type of task. For example, if one of the five spacecraft taking images of a target malfunctions, the other four will replan their science objective to accommodate for the loss.

The software framework is integrated with Caltech's spacecraft simulators, which are a set of five 6-degree-of-freedom air-bearing spacecraft-like robots equipped with on-board thrusters, custom-made

reaction wheels, docking ports and associated sensors. The reliability of the distributed software architecture is tested on the spacecraft simulators to verify the ability to provide autonomy in multi-agent scenarios. Such scenarios include an end-to-end docking mission and an imaging mission of a 67P comet model using four spacecraft simulators.