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PATH PLANNING AND GUIDANCE ALGORITHMS FOR FORMATION RECONFIGURATION

Abstract

This paper presents an innovative approach for guidance of spacecraft formations during reconfiguration maneuvers. The specific mission scenario considered is a fractionated Synthetic Aperture Radar (SAR) in a low Earth orbit. The SAR instrument is conceived to be distributed on dozens of identical satellites, arranged in a close formation flight at an altitude of 600 km. An X-band transmitting antenna is considered in the center of the sparse radar, surrounded by receiving-only satellites arranged in multi-helix, multi-pendulum or multi-cartwheel patterns. As the platforms are assumed to be equipped with low-thrust propulsion systems, the radar antennas can be spatially reconfigured to change the acquisition geometry with respect to the transmitter, thus modifying the radar performance.

The guidance algorithms are developed for satellites which are able to communicate among each other.

At first, the final spatial configuration is determined taking into account the formation type and the desired performance in terms of 3D imaging, i.e. vertical resolution and research volume. The design method comprises models of relative dynamics and array theory for the definition of relative geometries. The output of this procedure is a formation characterized by bounded relative orbits, with inter-satellite distances of the order of hundreds of meters.

Depending on the specifics, the reconfiguration may involve the fractionated SAR entirely or partially. For example, imaging a restricted research volume with the same vertical resolution might only require a reduced number of devices. Therefore, a path-planner defines the strategy to reshape the initial formation in a specific time. During this phase, a task-assignment algorithm identifies the satellites that are required to be rearranged in order to minimize the total propellant consumption. The decision process relies on direct optimization procedures aimed at estimating for each candidate satellite the control law and the maneuvering trajectory that satisfy constraints imposed by the thruster technology and collision avoidance.

Two different versions of the path planning algorithm are proposed. In the centralized approach, the reconfiguration strategy is elaborated by a single unit: the maneuvering trajectories are generated considering entirely collision avoidance constraints at expenses of high computational costs. The alternative method is conceived such that each satellite autonomously determines its tasks. This de-centralized architecture allows the algorithm to run faster. However, collision avoidance is approximated to render each optimization independent from the other.

Simulation results show that, once remote-sensing requirements are specified, both the routines can manage autonomously the SAR reconfiguration towards the corresponding operative pattern.