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Author: Mr. Zhengqing Fang
Tsinghua University School of Aerospace, China

Prof. Zhaokui Wang
Tsinghua University, China
Prof. Roberto Armellin
The University of Auckland, New Zealand

CONSTELLATION RECONFIGURATION AND TASK SCHEDULING OPTIMIZATION FOR EMERGENCY EARTH OBSERVATION RESPONSE USING LOW-THRUST

Abstract

Earth Observation (EO) satellite systems provide a global perspective and deliver image information feedback for locations experiencing sudden incidents, such as natural disasters including earthquakes and tsunamis. In the event of such circumstances, the effective dispatch and allocation of operational EO satellite resources to enhance responsiveness are essential for emergency respond missions.

One promising option to increase the operational responsiveness of EO systems is orbital maneuvering. Most satellites in newly established Earth observation constellations (Jilin-1, Starshield, etc.) are equipped with low-thrust control systems, which can provide valuable benefits such as better coverage properties, reduced revisit times, selectable targets, and local overflight times through reconfiguration of the constellations.

However, the reconfiguration of EO constellations necessitates the simultaneous optimization of resource allocation and maneuvering strategies. This represents a high-dimensional complex combinatorial problem, for which traditional multi-objective optimization methods are difficult to converge and unable to satisfy the computational timeliness requirements. In addition, low-thrust control brings in many-revolution long-duration transfers, which make it extremely difficult for numerical optimization to converge and computationally complicated to operate on small satellites in real time.

To this end, an overall strategy for on-orbit resource allocation and maneuver using low-thrust is established. The joint optimization of constellation task scheduling and maneuvering strategies is formulated as a mixed-integer nonlinear programming problem (MINLP). Under the constraints of given ground targets and maximum revisit time, a multitree search (MTS) framework is employed to select satellites requiring maneuvers from the constellation, while an adaptive multi-objective evolutionary algorithm (AMOEA) is utilized to optimize the objectives of orbital maneuvers. In addition, for computational efficiency, the analytical low-thrust orbit transfer method previously developed by our team is adopted.

In conclusion, the research presents a scheduling and control method of Earth observation constellations, furnishing a practical and powerful solution for the management and operation of future mega-constellations.