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NESTED AUTONOMOUS ORBIT DETERMINATION AND CONTROL FOR DISTRIBUTED SATELLITE SYSTEMS: A CASE STUDY ON CONSTELLATION OF FORMATIONS FOR EARTH OBSERVATION

Abstract

Distributed Satellite Systems (DSS) require new advanced navigation and control functionalities to meet the ever more stringent mission requirements of Earth Observation (EO) missions. In particular, Autonomous Orbit Determination and Control (AODC) can significantly reduce operational costs and enable continuous feedback without being limited by ground station link availability. Recent advancements in Global Navigation Satellite System (GNSS) navigation in space, coupled with high-efficiency low-thrust electric propulsion, have made it possible to leverage autonomous and continuous operations to optimise propellant mass and thruster power, improve orbital accuracy, reduce collision risks, and develop new services through distributed operations. Within this framework, we propose a novel concept for a DSS that implements a Constellation of Formations architecture for EO missions, offering the advantage of combining single-pass multiple acquisitions with high revisit frequencies. However, maintaining the formation geometry and constellation parameters sets requirements on the navigation and mission control functions that may conflict with each other. To address this challenge, we propose a nested architecture that incorporates suitable filtering of the GNSS navigation data and establishing inter-satellite communication links within each formation. This filter and orbit feedback control laws are based on well-known Relative Orbital Elements (ROE) and the Eckstein-Ustinov model for osculating-to-mean orbit elements transformation. Our proposed navigation solution leverages state-of-the-art technology, including the Precise Point Positioning (PPP) service for absolute orbit determination and the Real Time Kinematics (RTK) service for relative orbit determination. This information provides the required accuracy for typical EO applications such as Synthetic Aperture Radar (SAR) interferometry and optical instrument acquisitions while ensuring ground track repeatability. We present preliminary findings through numerical simulations to show that GNSS filtered data and low thrust propulsion are sufficient for achieving the desired control of the Constellation of Formations. Our research demonstrates the feasibility of implementing a Constellation of Formations architecture for EO missions with the proposed nested autonomous orbit determination and control strategy.