IAF SPACE SYSTEMS SYMPOSIUM (D1)
Space Systems Architectures (2)

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NMPC-BASED ORBIT AND FORMATION CONTROL FOR AN EARTH-GRAVITY MONITORING MISSION

Abstract

In the last decades, an increasing attention has been devoted to space gravimetric missions, with the goal of improving the understanding of Earth's mass change phenomena. One of the main tasks of these missions consists in measuring the temporal variations of the Earth gravity field over a long-time span, with very high spatial and temporal resolutions. In this context, the paper focuses on an Earth-gravity monitoring mission featuring a formation with two drag-free satellites. The aim is to design a formation control which is able both to counteract bias and drift of the residual drag-free accelerations and to reach the orbit and formation long-term stability. At this purpose, a Nonlinear Model Predictive Control (NMPC) framework is considered. The advantages of using this control approach consist in the ability to find an optimal control command, to manage state/input constraints and on-line adapt the control strategy according to possible process variations. A key element of NMPC is an internal prediction model, used to find an optimal trajectory over a finite time interval. Here, an integrated formation control (IFC) model, based on a novel set of Hill-type equations, has been used. This model allows a common description of the formation altitude and inter-satellite distance, by defining a specific orbital reference frame called Formation Local Orbital Frame (FLOF). The Next Generation Gravity Mission (NGGM) is considered as a benchmark for the developed NMPC framework. In this regard, a high-fidelity nonlinear model, with the 30th order gravity field and various atmospheric disturbances (e.g., atmospheric drag and solar pressure), has been used. Furthermore, to simulate a realistic situation, the issues related to the transmission of data between satellites is also considered by assuming long sampling times of the measurements due to absence of a radio-frequency inter-satellite link. As a result, the position and velocity of the companion spacecraft is propagated on board of each satellite in the time intervals during which no real-time information is available (e.g., 1 orbit). To deal with such lack of data, orbit propagators with low computational complexity are implemented. The novelty of these propagators is the ability to compute accurately the companion satellite orbit, despite being designed considering a low order gravity field and completely neglecting other atmospheric disturbances. The obtained results demonstrate the effectiveness of the proposed NMPC strategy and show its capability to guarantee long-term stability, despite the lack of companion satellite information and a low command effort.