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DISTRIBUTED COORDINATION ARCHITECTURE FOR MICRO-SATELLITE FORMATION FLYING CONTROL

Abstract

Multiple micro-satellite formation flying can accomplish the acquisition, processing, and analysis of science data by the inter-satellite coordination, thus becoming an emerging and attractive alternative for both space application and space science. There are roughly three approaches to multiple satellite coordination reported in the literature, namely leader-follower, behavioral, and virtual structures. In order to establish the relative dynamics equation, it's a common and basic assumption that a unified coordinated system (like the reference satellite) for each satellite is existed or can be driven to consensus in advance. However, it may be inappropriate and not the best choice when a large number of satellite are involved or stringent inter-satellite communication and satellite-ground link limitations are applied.

A decentralized formation control architecture that is built on the strength of consensus theory in the inertial system is proposed. The design architecture is applied to **Formation Flying Control** (FFC) in **Low-Earth orbit** (LEO) taking into account the satellite constraints. In the decentralized architecture, four major steps need to be carried out. At first, each satellite in the formation processes local measurement information and instantiates a local copy of the state of the virtual center. Then each virtual center is driven into consensus to achieve the desired formation in a decentralized manner. The local instantiation of the coordination variable in each satellite is then driven into consensus by communication with its neighbors following a bidirectional ring topology. The desired states can subsequently be solved when each satellite has knowledge of the virtual center and its own desired formation. At last, a suitable control laws taking into account **fuel equalization/minimization** is proposed for each satellite to track its desired states. At the same time, an improved **pseudo-rate modulator** (PSR) is applied to the control law, assuming fixed-magnitude thrust is provided by a cold-gas thruster or a monopropellant engine.

The effectiveness of the proposed control strategy is demonstrated through simulation results of a tetrahedron formation for geomagnetic study. The architecture introduced in the paper has several key features. First, **J2-invariant relative orbit** is utilized to minimize the fuel consumption. Moreover, it is not a "**coordination then control**" architecture, but a "**control while coordination**" one. Finally, the architecture can accommodate both centralized and decentralized implementation. It is an amenable and promising to control theoretic technique, and provides a uniform architecture to compare and contrast various approaches to formation control.