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DIGRAPHS BASED ALGORITHMS FOR FORMATION FLIGHT CONTROL

Abstract

The addressed problem is the construction and maintenance of a satellite formation. Given a group of tens of small satellites or a swarm with relatively small relative distances, achieving and maintaining a desired geometric configuration is not an easy task. A simultaneous relative drift elimination faces the problem of bandwidth restriction, i.e., a small satellite cannot receive a signal from all of its partners. Instead, a communication constraint of some sort must be implemented, and therefore, only the local information of the closest satellites is obtainable for a control algorithm. We propose a control algorithm construction approach based on the use of directed graphs. These graphs represent the possible one- or two-way connections between satellites, and allow us to study formations with one 'mothership' or several 'shepherd' satellites. An analytical study of the proposed controlled system is performed. It is shown that the linearized dynamic equations of a system have a close connection with a generalized Laplacian matrix, and accordingly, the spectral properties of a digraph determine the behavior of the controlled motion. The spectral properties of the aforementioned graphs are studied. Different modifications (i.e., weighted digraphs) to a proposed technique are also considered. Several strategies for 'shepherd' satellites to prevent formation degradation and maintain relative drift are considered. The resulting control algorithms were validated using Monte-Carlo simulations.