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NONLINEAR LYAPUNOV-BASED COOPERATIVE CONTROL FOR MULTIPLE SATELLITES

Abstract

Satellite cluster consisting of large number of satellite is becoming a promising topic in space research, due to its low cost and robustness. As opposed to the traditional space system architecture, the cluster usually has autonomy to some extent. The current work offered a novel distributed control framework for the convergence of an autonomous satellite cluster to the same orbit under limited low thrust capability, by using Lyapunov stability theory. The target orbit is a priori unknown, merely a result of cooperative protocol on the basis of local exchanged information.

This framework was build on the information exchanging between satellites. Each satellite broadcast information to and obtained information from all or some of the other satellites. The communications between satellites was represented as graphs. The shared information was used as feedback to synthesize the control. The satellites communicating with satellite i were categorized as two subgroups, i.e., to whom and from whom the satellite i obtained or sent information. Two indices set N_i^+ and N_i^- are defined accordingly. Let x and z be respectively the state and exchanged information for each satellite. The control is in the form of $u_i = f\left(x_i, z_i, z_j, N_i^-\right), j \in N_i^-$.

The control was developed after introducing and analyzing an appropriate Lyapunov function defined on all the satellite communication pairs. Under dynamics modeled by Gauss's variational equations, a closed-form expression was obtained for the controller. A rigorous analysis showed that, the controller is globally asymptotic stable if the underlying communication graph is connected and the information function is well defined. The framework also addressed the thrust saturation to permit a more realistic application. A special case of Lyapunov function was discussed which resulted in an interesting weighted distributed controller.

Numerical simulations were performed to validate the analysis of this work, as well demonstrating the application of this method. The controller might be used for the satellite cluster flying around and monitoring a distant planet, or a low-Earth-orbit (LEO) cluster flight waiting for in-space assembling.