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OPTIMAL CONTROL OF 6-DOF ELECTROMAGNETIC FORMATION USING THE LEGENDRE PSEUDOSPECTRAL METHOD

Abstract

Satellite formation flying is an enabling technology for many space missions. Propellant is a critical consumable which can be exhausted and pose additional problems. A potentially technology allows a system of electromagnets, in concert with reaction wheels (RW), to replace the propellant. The system of electromagnets, powered by solar energy, generated by high temperature superconducting dipoles, can act as relative position actuators. Electromagnetic formation flying (EMFF) offers mission's life-pam being independent of the consumables, in exchange of a highly coupled, nonlinear dynamic model.

The magnitude and orientation of electromagnetic force are determined by magnetic dipole strength, relative separations and relative attitudes. So control force's upper bound is time-variable, but it should not be simply restricted by a threshold which can result in degraded precision. Another feature is that whenever a shear force acts on the satellite, a shear torque is introduced. Due to system's inherent coupling and nonlinearity, an integrated coupled relative position and attitude dynamic model is studied in this paper.

For the purpose of determining the states and controls that minimize the cost function which includes maneuver time and the evaluation function of angular momentum management, the Legendre pseudospectral method (LPM) is applied to solve this constrained optimal control problem. Without using any toolbox, this constrained nonlinear program (NLP) can be solved in a numerical way. The constrained NLP can be transformed into an unconstrained NLP by applying the generalized Lagrangian method. The quasi-Newton method can be used to minimize the penalty function, which involves equality/inequality constraints on dynamics, initial and terminal conditions, energy matching condition, formation configuration, path planning, control force and RW saturation. Both DFP and BFGS method can be used to implement the quasi-Newton method, and the latter has better calculous performance. In this paper, a novel method, namely a switching of DFP and BFGS, is adopted to can reach higher accuracy under reduced computation complexity while searching the feasible expanded state series, .

The simulation indicates that the selection of Lagrangians and bounds of iteration times are critical to the accuracy and even the convergence. The simulation results verify the validity of the proposed optimization method and demonstrate that the LPM has the advantages of fast convergence rate, high accuracy and insensitive in prediction of the initial values.