IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation & Control (3) (3)

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APPROACHES TO STUDYING THE PERFORMANCE OF SWARM DECENTRALIZED CONTROL ALGORITHMS

Abstract

Swarm is a type of the satellite formation flight involving a large number of satellites that typically requires only bounded relative motion with no other restrictions. The advantages of random relative trajectories in the swarm are the economy of the control source of the satellites, reduced dependence on the failure of the specific satellite and soft demands for the onboard hardware and software. The deployment of distributed systems implies some difficulties caused by the errors in the initial conditions after the separation from the launch vehicle. This leads to a slightly different orbital period of the satellites, the relative trajectories become unlimited and the swarm degrades. Space systems consisting of numerous satellites often require decentralized relative motion control algorithms which also characterized by some implementation errors. The decentralized control performance depends on size of the satellite's communication area and on the number of the communicating satellites which relative motion is taken into account for control calculation. All these factors cause the separation of some members from the swarm.

The total number of satellites remaining in the group is a stochastic variable characterizing the performance of the control algorithms. In this work this variable is investigated in accordance with initial conditions and control parameters. To estimate the stochastic variable mean value and variance a Monte Carlo simulations can be used. Another approach is to consider area in the phase space where the swarm members are initially distributed. This area changes in time according to the relative motion dynamics and the applied control. If the area is considered as an ellipsoid, its evolution can be calculated using quadratic transformation with state transition matrix based on Hill-Clohessy-Wiltshire equations. In case of controlled motion the transition matrix includes additional parameters and it is possible to take into account the constraints on the intersatellite communicational capabilities. Such an approach allows to estimate the control performance on average without the numerous simulations. For examples of decentralized control algorithms implementation using differential drag, electromagnetic interaction and Lorentz forces the swarm motion performance is studied. The results obtained by the Monte Carlo method are compared with the results estimated by the proposed approach of the performance study.