IAF ASTRODYNAMICS SYMPOSIUM (C1)
Guidance, Navigation and Control (2) (2)

Author: Ms. Yaru Zheng
Beihang University, China, zheng_yaru@outlook.com

Dr. Hao Huang
DFH Satellite Co., Ltd., China, waloga@qq.com
Dr. Ming Xu
Beihang University, China, xuming@buaa.edu.cn
Ms. Xue Bai
Beihang University, China, baixue1002@buaa.edu.cn

FORMATION FLYING WITH ROTATING NON-COOPERATIVE SATELLITE

Abstract

Recently, on-orbit surveillance, inspection or repair is a hot topic in aerospace engineering, which requires the maneuvered satellite facing with the other one always, such as the specified sides equipped by solar panel, camera, star sensor, and so on. Natural relative orbital dynamics keeps the two formation satellites flying in a 2:1 elliptical configuration, and also in a periodic attitude interview with each other. Thus, for any side lying in the planar configuration, only an attitude control can work well to force one pointing to the other in formation. For a non-cooperative satellite, an attitude-orbit coupled control is expected to force the maneuvered satellite to follow it. However, the existing controllers on formation flying are weak in following a quick and irregular rotating-satellite, and some similar studies on rendezvous and docking fail in purchasing a 360-degree rotation.

For an irregular rotation owing to both nutation and precession, a spatial (not planar) relative trajectory is planned for the maneuvered satellite, by means of a continuous low thrust. This paper proposes to hybridize solar electric propulsion and relative orbital dynamics on the same maneuvered satellite to enable such a displaced trajectory and relative attitude. A passive solution is found, which satisfies the rotation-following condition strictly in the linearized C-W equation. Under a tolerable looseness on the above condition, it is subsequently used as the first guess to find optimal orbit-attitude pair, using a direct method based on pseudospectral transcription. The performances of different looseness weights are investigated and compared, including the relationships between fuel consumption, deviations on trajectory and attitude.

For potential reconfiguration from one following side to another one of non-cooperative satellite, a fuel-optimal transfer strategy is proposed based on hyperbolic manifolds of equilibrium that is mapped from the strict passive solution achieved above in phase space structure. Some special heteroclinic connections are achieved by cross points on Poincare mapping, which means fuel-free transfers of orbit-attitude pairs between two specified sides of non-cooperative satellite.

A closed-loop strategy for low thrust is proposed to integrate the functions of stationkeeping, autonomous navigation and error estimation in relative atmosphere. A heuristic improvement is given by backstepping control, and the adaptive estimator is enhanced by introducing full relative dynamics and then leaving high-order coefficients of atmosphere model to be estimated. The asymptomatically-convergent coefficients are added into extended Kalman filter to boost navigating errors, which benefits the ability of stationkeeping maneuvers as well.