ASTRODYNAMICS SYMPOSIUM (C1)
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PRACTICAL CONSIDERATION OF SPACECRAFT ATTITUDE AND RATE DETERMINATION USING NUMERICAL GYROS

Abstract

To meet the 0.012 degree, 3-sigma, per axis, absolute bus attitude knowledge requirement flown-down from Remote Sensing Instrument (RSI), a Gyro-Stellar Inertial Attitude Estimation (IAE) design is considered for a particular mission to provide the spacecraft Attitude and Orbit Control System (AOCS) necessary spacecraft attitude and rate determination. The IAE employs the micro-Advanced Stellar Compass (μASC) consisting of three Camera Head Units (CHUs) to correct the attitude resolved by a set of four single-axis fiber-optics gyros mounted on a stable optical bench common to the RSI structure. The μASC is a highly advanced and fully autonomous star tracker produced by the Measurement Instrument System (MIS) Section of the Ørsted Department of the Technical University of Denmark (DTU). The gyroscopes considered in this mission are the fiber-optics rate sensors, μ-FORS3UC, manufactured by Litef, a Northrop Grumman branch in Germany. The μ-FORS3UC is originally designed to meet the requirements of a wide range of air, land, and sea applications, and was later certified by NSPO for space applications after a series of environmental tests.

To account for the possibility of more than one gyro failure due to lack of space-flight heritage, a gyro-less attitude and rate determination algorithm is developed as a back-up for the IAE design. This paper describes the detailed development of a gyro-less attitude and rate determination algorithm which uses the computed gyro data (numerical gyro data) instead of physical gyro data as in a typical gyro-stellar attitude determination system. The numerical gyro data are computed using the assumed spacecraft dynamics (or Euler equations of motion). By perturbing the spacecraft kinematic equations, the linearized attitude error equations are obtained. Similarly, by perturbing the spacecraft dynamic equations, the linearized rate error equations are obtained. With the obtained linearized attitude error equations and the linearized rate error equations, a reduced-order (6-states) Extended Kalman Filter (EKF) providing spacecraft attitude and rate estimates is then implemented in the algorithm.

In this paper, the proposed gyro-less attitude and rate determination algorithm is incorporated and tested in a 6-DOF nonlinear, high-fidelity simulation model to assess its performance which is sensitive to spacecraft inertia tensor uncertainties, reaction wheel momentum uncertainties, and torque uncertainties produced by torque-rods during normal operations. In addition to the performance, this paper also provides certain practical insight into the implementation of gyro-less IAE design.