ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics, Modelling and Determination (6)

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ATTITUDE DETERMINATION FOR SATELLITE FAULT TOLERANT SYSTEM USING FEDERATED UNSCENTED KALMAN FILTER

Abstract

Recently, satellites provide various services which have become essential for human life in modern society. Because satellite images are widely used for many applications such as reconnaissance, geographic information system, etc., the requirements of satellite system have become more severe. To improve the performance of a satellite, high reliability during the long operational life is necessary. Satellite attitude control system including sensors and actuators is a critical subsystem, and any kind of fault in the satellite attitude control system can result in serious problems in orbit during the operation mode. To deal with this problem, attitude determination algorithms using multiple sensors for fault tolerant satellite system have been actively studied.

Most satellites use various attitude sensors such as gyroscopes, sun sensors, star sensors, and so on. There are several algorithms for the satellite attitude determination using the attitude sensors, which include Kalman filter, extended Kalman filter (EKF), unscented Kalman filter (UKF), and particle filter. Among these filters, it is known that UKF is one of the efficient filters for linear system as well as nonlinear system. Moreover, for a multi-sensor system, there are two schemes to incorporate the sensor data in estimators to provide more accurate and robust state estimation values: Centralized Kalman filter (CKF) and Decentralized Kalman filter (DKF). The decentralized schemes in federated configuration have advantages to detect any fault in a local sensor during processing. In this study, a federated unscented Kalman filter is adopted for fault tolerant attitude determination using multisensory data fusion.

Federated unscented Kalman filter can be employed in fault tolerant configuration to implement an effective fault detection and identification (FDI) algorithm, thereby it can prevent mission failures due to undetected and/or un-isolated sensor faults. Generally, there are two FDI schemes. Fault can be detected and identified by (i) monitoring the measurement residual, or (ii) using sensitivity factor. In this study, sensitivity factor is used to detect and identify the sensor faults.

To verify the performance of the proposed algorithm, numerical simulations are performed. The performance of the traditional filters including Kalman filter and EKF is compared with the proposed federated unscented Kalman filter. Numerical results shows that the performance of UKF is more efficient than the Kalman filter and EKF. Moreover, the federated unscented Kalman filter provides accurate attitude determination results and also detects the sensor faults. This result demonstrates that the federated unscented Kalman filter for solving nonlinear estimation problems can be efficiently used for fault tolerant satellite attitude control system.

In conclusion, the federated unscented Kalman filter is designed for an efficient fault tolerant satellite system in this study. The designed filter provides accurate attitude determination results even though any attitude sensor has failures. In KOMPSAT(Korea Multi-Purpose Satellite) III satellite system, one

gyroscope, two star trackers, five sun sensors, two GPS sensors, and two three-axis magnetometers are used for attitude sensors, but gyroscopes, star trackers, and sun sensors are only used for attitude determination. A fault occurrence in the star tracker does not yield the accurate attitude determination results, because the failure of star tracker has severely influence on the performance of whole attitude control system. Therefore, the sensor failure management algorithm including the star tracker fault should be considered. To deal with this problem, in this study, magnotometers will be considered to determine the satellite attitude for star tracker fault case. Using this idea, the attitude determination may not diverge, while maintaining good performance enough to perform the given mission continuously. The sensor failure management algorithm will be studied, and the simulation results as well as the performance analysis will be included in the final manuscript.