Non-Traditional Robust UKF Against Attitude Sensors Faults

Demet Cilden Guler[1], Halil Ersin Soken[2*], Chingiz Hajiyev[1]
[1]*Istanbul Technical University, Turkey;* [2]*JAXA, Japan*
ersin_soken@ac.jaxa.jp

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Attitude estimation algorithms for small satellites using magnetometer and sun sensor measurements have been developed in several studies. Kalman filtering is mostly used method for integrating the measurements under the propagation model of the satellite dynamics and attitude of the satellite possibly along with the sensor biases or noise increments can be estimated. The basic idea is to compare the vector measured in the body frame with the known vector in the inertial (or any other reference) frame to estimate the attitude of the satellite. The traditional approach to design a Kalman filter for satellite attitude estimation uses the nonlinear measurements of reference directions [1-4]. The measurement models in the filter are based on the nonlinear models of the reference directions so the measurements and states are related via nonlinear equations. In this study, non-traditional approach has been applied using linear measurements which are coarse attitude quaternions from a single-frame method directly. In the linear measurements based approaches the attitude angles are first found by using the vector measurements and a suitable single-frame attitude estimation method [5]. Vectors coming from the selected sensors and developed models can be used in Wahba's loss function and minimization of the loss can be achieved using those methods. Methods depending on only the measurements but not the dynamics of the satellite's motion cannot determine attitude for the period in which there is no vector data coming to the sensor such as eclipse period. On the other hand, the Kalman filter can adapt its gain for crucial time intervals and estimate the attitude during no vector data coming. For this purpose, conventional non-traditional Singular Value Decomposition (SVD) aided Unscented Kalman Filter (UKF) algorithm has been proposed. SVD aided UKF have a naturally adaptive structure because of the usage of measurement noise covariance directly from SVD. In this research, non-traditional R-adaptive UKF which uses the measurement noise scale factor (MNSF) determined from equality of the theoretical and the sample innovation covariance to adapt the noise covariance of the filter. The adaptation is achieved by reducing the effect of the innovation term of the faulty sensor and eliminating the estimation error caused by the faulty measurements.

Two types of non-traditional approaches in the sense of adaptation rule difference have been contrasted for the attitude and rate estimations of the nanosatellite. Moreover, for this purpose, two different scenarios have been introduced in case of magnetometer and sun sensor measurement faults. In the first scenario, constant continuous bias is considered additionally to the measurement model. Secondly, measurement noise increment as magnetometer fault is added to the system. Thus, two types of approaches are compared undergoing two different faulty processes. Conventional SVD aided UKF method is based on the SVD's covariance at a single time therefore measurement faults are sensed immediately in the filter right after the SVD's coarse determination algorithm. On the other hand, the MNSF based R-adaptive UKF method relies on the covariance of the innovation sequence and the comparison between their real and theoretical values therefore the difference between them affects the Kalman gain.

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