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RECEDING-HORIZON UNSCENTED KALMAN FILTER FOR SATELLITE ATTITUDE ESTIMATION

Abstract

Japan Aerospace Exploration Agency (JAXA) has developed Small Demonstration Satellite (SDS) in order to verify new technologies for components and devices. The SDS-4 project aims to develop a 50-kg class satellite. It is difficult for a small satellite to load two or more star trackers, high accurate attitude sensors because of its size, cost and require power. Moreover, the star tracker suffers from both occultation and interference from the Sun, the Earth, and the other bright sources. The SDS-4 estimates the three-axis attitude with the sun sensor and the magnetometer when the star tracker is unable. In addition, the SDS-4 estimates the attitude with the Extended Kalman Filter (EKF) using the attitude sensors and the gyro sensor. However, we confirmed from the analysis of on-orbit operation data that the attitude error of the sun sensor and magnetometer system is non-Gaussian. The non-Gaussian noise makes the estimate performance inaccurate, because the EKF algorithm is based on the Gaussian assumption. Especially, the accuracy of the estimated attitude gets worse after switching from the star tracker to the sun sensor and magnetometer system. This paper proposes a constrained attitude estimation method to reduce the influence of non-Gaussian measurement noise. A conventional constrained filter, Receding-Horizon Nonlinear Kalman Filter (RNKF), propagates the state value with the model in prediction step, and minimizes the cost function with the constraint in filtering step. The cost function is desired to be a quad program (QP) problem, whose constraint is linear, in terms of computational complexity. If the RNKF is applied to the attitude estimation problem, the appropriate attitude representation is the quaternion, which can define the kinematics model in prediction step. However, the quaternion does not define a QP in filtering step because the quaternion needs to satisfy a single constraint of a unit norm. Therefore, this paper proposes the Receding-Horizon Unscented Kalman Filter (RUKF) which improves RNKF to deal with appropriate attitude representation in each step. In the RUKF, the attitude is represented by the generalized Rodrigues parameters (GRPs) in filtering step owing to the Unscented Transformation (UT). The GRPs is one of the attitude representations with no constraint. It was confirmed from the Monte Carlo simulation result that the RUKF with the constraint is more accurate than the EKF or the RUKF with no constraint.