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POSITION AND VELOCITY ESTIMATION OF RE-ENTRY VEHICLES USING FAST UNSCENTED KALMAN FILTERS

Abstract

Accurate position and velocity estimation of a re-entry vehicle is essential for realizing its deviation from the desired descent trajectory and providing necessary guidance commands in real-time. The Extended Kalman Filter (EKF) is widely utilized for estimating position and velocity of a space vehicle. However, the performance of the EKF declines in highly non-linear applications as the error covariance is predicted based on system model linearization in the EKF. The dynamics of a re-entry vehicle are particularly non-linear in nature, so a more accurate position and velocity estimation is expected using a non-linear estimator. The Unscented Kalman Filter (UKF) has better estimation accuracy than the EKF as it predicts the mean state vector and the error covariance by deterministic sampling and utilizing the non-linear dynamics of the system. However, the processing time of the UKF is much higher than the EKF because of the requirement of multiple state propagations in each measurement time interval. This paper presents the application of two new UKF-based estimation techniques which can reduce processing time significantly. The first method is called the Single Propagation Unscented Kalman Filter (SPUKF) where, the a postiriori state is propagated only once and then the sampled sigma points at the next time instant are approximated by the first order Taylor Series terms. In the second method, called the Extrapolated Single Propagation Unscented Kalman Filter (ESPUKF), the sigma points are approximated to the second order Taylor Series terms using Richardson Extrapolation. The EKF, SPUKF, ESPUKF and the UKF are utilized in a re-entry vehicle navigation scenario using range and elevation measurements. The estimation accuracies and the processing times for different algorithms are compared for the scenario. The result demonstrates that, the UKF provides better accuracy than the EKF but requires more processing time. The SPUKF accuracy is better than the EKF and the processing time is significantly less than the UKF. The ESPUKF provides estimation accuracy comparable to the UKF and the processing time is also significantly reduced. The results indicate the efficiency of these two new UKF variations in the highly non-linear applications.