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Author: Ms. Maryam Kiani
Sharif University of Technology, Iran, m_kiani@ae.sharif.ir

ADAPTIVE DIVERSITY GUIDED MODIFIED UNSCENTED PARTICLE FILTER FOR AUTONOMOUS ORBIT DETERMINATION

Abstract

Autonomous orbit determination (AOD) is of practical importance for many space missions. In turn, proper functioning and performance of AOD has a significant influence on the satellite orbit and attitude control system. There have been some recent efforts in using the Particle Filter (PF) to solve the nonlinear orbit determination problem. But despite the potential advantages of the basic PF for nonlinear/non-Gaussian state estimation, the common degeneracy phenomenon associated with the sequential importance sampling (SIS) of this algorithm has not yet been resolved completely and effectively. Solutions such as increasing the sample size or SIS re-sampling have either postponed the degeneracy phenomenon or caused particle impoverishment due to introduction of high correlation between particles. A possible solution to monitor the sampling efficiency is to limit the inserting number of re-sampling steps to enhance the PF robustness properties. In this aspect, having a criterion to specify the time of re-sampling step is the problem of diversity measure in PF. In this study an improved PF is proposed to tune the re-sampling step adaptively based on two diversity measures, namely the Effective Sample Size (ESS) and the Entropy-based Diversity Function (Div). In addition, the perturbation step integrated into PF after re-sampling times is adaptively tuned based on the particles weights. Moreover a modified square root Unscented Kalman Filter (UKF) based on Schmidt orthogonal algorithm is adopted as the proposal distribution to approximate the optimal importance function. Verification of the proposed algorithm is initially performed through its application to a well-known nonlinear bench mark function. Subsequently, an AOD problem is attempted. In the AOD problem, the norm of the geomagnetic field is considered as the noisy measurement vector out of which the osculating Orbital Elements (OE) of a Low Earth Orbit (LEO) satellite are to be estimated considering the atmospheric drag as well as the Earth oblateness perturbation effects. The results are analyzed and compared using two criteria of Maximum a Posteriori (MAP) and Minimum Mean Square Error (MMSE). It is seen that although MAP possess a lower convergence time, the MMSE results are more accurate. It is also shown that the OE's estimation errors converge to their bound within just two orbital periods. The results are also in good agreement with those of the Unscented PF which is an indication showing the proposed improved filter fulfills the essential requirements of accuracy for orbit determination.