An interacting Fuzzy-Fading-Memory-based Augmented Kalman Filtering method for maneuvering target tracking

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In this paper, the interaction and combination of Fuzzy Fading Memory (FFM) technique and Augmented Kalman Filtering (AUKF) method are presented for the state estimation of non-linear dynamic systems in presence of maneuver. It is shown that the AUKF method in conjunction with the FFM technique (FFM-AUKF) can estimate the target states appropriately since the FFM tunes the covariance matrix of the AUKF method in presence of unknown target accelerations by using a fuzzy system. In addition, the benefits of both FFM technique and AUKF method are employed in the scheme of well-known Interacting Multiple Model (IMM) algorithm. The proposed Fuzzy IMM (FIMM) algorithm does not need the predefinition and adjustment of sub-filters with respect to the target maneuver and reduces the number of required sub-filters to cover the wide range of unknown target accelerations. The Monte Carlo simulation analysis shows the effectiveness of the above-mentioned methods in maneuvering target tracking.

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1. Introduction

Standard Kalman Filtering (SKF) methods such as Linear Kalman Filter (LKF) and Extended Kalman Filter (EKF) produce reasonable results for tracking non-maneuvering targets, but they may not yield desirable accuracy in presence of maneuver [1–3]. There are two main approaches to handle this problem [3]: the Input Estimation (IE) approach and the Multiple Model (MM) approach.

1.1. The Input Estimation approach

The IE approach was developed to improve the estimation accuracy of the SKF methods in presence of unknown target accelerations [4]. One method that simultaneously combines the benefits of both SKF method and IE approach is a SKF-based target tracker with IE approach [5]. This method changes the maneuvering target model to the non-maneuvering one by using a state augmentation technique to create the standard Bayesian model. By applying the LKF or EKF to this model, one yields an Augmented Kalman Filtering (AUKF) method, which can estimate the unknown target acceleration along with the original target states. The AUKF method eliminates the need for a separate maneuver detector system and provides better performance with respect to the LKF or EKF in tracking non-maneuvering and low maneuvering targets.

However, the AUKF cannot produce acceptable state estimation in presence of high maneuvers due to the poor modeling of target acceleration dynamics [6,7]. To cope with this problem, several methods have been proposed in recent years with varying degrees of success [7–13]. Unfortunately, most of these techniques have some major problems. The fading memory factor proposed in [8] and forgetting factor proposed in [9] are determined off-line and remained unvarying during the operation, so the performance of these methods is obviously degraded with the changes of target acceleration. To deal with this trouble, a soft computing approach has been proposed in [10,11], which resets the covariance matrix at each sampling time based on the values of target acceleration. However, due to the deficiency of its maneuver detector system, this method has not increased the performance of AUKF method effectively. In [12], the authors tried to handle this dilemma by proposing an intelligent approach based on the fuzzy logic for covariance matrix resetting. Unfortunately, the fuzzy system used in this approach is not accurate enough. Among the above-mentioned methods, the Fuzzy Fading Memory (FFM) technique [13] is reasonably successful. During the maneuver, the FMM technique corrects the covariance matrix using a suitable fuzzy system. This modification enables the filtering algorithm to produce reasonable state estimation in presence of unknown target accelerations.

In this paper, by choosing the EKF as the filtering algorithm, it is shown that the FMM-based AUKF (FFM-AUKF) method yields more accurate results than the standard EKF and AUKF methods for the state estimation of non-linear dynamic systems in presence of maneuver.

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