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A Review of Non-Linear Kalman Filtering for Target Tracking

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ABSTRACT

Target tracking (TT) with Non-Linear (NL) Kalman Filtering (NLKF) has recently become a thriving and fast-moving research area, particularly in the field of Marine Engineering and Air Traffic control. This paper presents a comprehensive investigation of NLKF algorithms, with emphasis on designing a proposed framework with the aim of improving its implementation results with regard to accuracy and efficiency. Further, the proposed framework demonstrates potential superior performance in terms of robustness, convergence speed, effective computation, and tracking accuracy, compared with state-of-the-art NLKF techniques. It is anticipated that this study will be beneficial to researchers studying Kalman Filtering (KF) algorithms and also serve as a bedrock for future research, especially for those pursuing their careers in Electronics and Information Engineering.

KEYWORDS

Extended Kalman Filter, Locality Sensitive Adaptor, Non-Linear Systems, Target Tracking, Unscented Kalman Filter

1. INTRODUCTION

Kalman filter (KF) or a linear quadratic estimation has received a lot of attention in the area of object tracking in recent years, since it forms the basis upon which all tracking methodologies are built, including non – linear state estimates and is an algorithm that uses series of observable measurements over a certain period. It may contain statistical noise and many other inaccuracies, and produces estimates of unknown variables that may turn to be more accurate compared to those centered on single measurement alone. KF in recent years has become a hot research topic with regards to object filtering and object tracking. KF has many application areas including guidance and navigation and control of vehicles, particularly aircraft and spacecraft (Musoff & Zarchan, 2005); time series analysis in the areas signal processing and econometrics; planning and control in robotics; trajectory optimization and biology in modelling the movement of the central nervous system. The KF is conceptualized as having two distinct phases known as predict and update phases. The predict phase uses the state estimate from the previous time-step to produce an estimate of the state at the current time-step

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(the priori state estimate) but however, it does not include observation information from the current time-step (Wolpert & Ghahramani, 2000). In the update state however, current priori prediction is combined with current observation information to refine the state estimate and thus improve the estimate and is termed posteriori state estimate. The generalization and the extension of KF has led to the development of the Extended Kalman Filter (EKF) and the Unscented KF (UKF) which works best with non-linear systems and it is one of the motivational factors driving this research.

KF is implemented for systems whose dynamics are not linear, to locate the problems by using the two popular extensions of KF. In case of the EKF, it is not necessary that both models (state transition and observation model) be linear functions of the state, but, may instead be non-linear functions (Julier & Uhlmann, 1997a). When both models (state transition and observation model) are highly non- linear, EKF give poor performance because the covariance is propagated through linearization of the underlying nonlinear model. But in case of UKF, a deterministic sampling technique is used known as unscented transform to pick a set of sample points around the mean known as sigma points. The Sigma points are propagated through non-linear functions, from which estimate of mean and covariance are calculated. More so, EKF is used to linearize all non-linear models, So that, we could apply linear Kalman filter (Julier & Uhlmann, 1997a). The other issue is the application of KF to realistically map signals in high dimensional space into a low space and how to obtain a feasible or an appropriate approximation model. The use of a locality sensitive with KF currently seems to be the most practical way to address the issue.

Target Tracking (TT) on other hand is the prediction of the future location of a dynamic object or system based on its estimates and measurements. Moving objects are monitored and detected by sensor nodes and their trajectories further predicted by sensor nodes based on their observations on movements of the target. Topical areas of TT that are of research interest are filtering and prediction, modelling of target dynamics, probabilistic systems, data fusion and associations and sensor assessments. Signals that are transmitted are usually opposed by some form of inertial and these signals need to be subjected to some form of filtering which is done digitally through an algorithm that discriminates defined based on the traits of signals. The filters used to achieve this purpose of Non-Linear KF (NLKF) are the UKF and the EKF, both of which could be implemented in addressing the issues of white noise and other signal defects in nonlinear systems.

It is very imperative that, before signals are subjected to any kind of analysis in the treatment of data to obtain information, the signals are taking through some form of transmutation processes such as sundering, filtering, mixing, selection, conditioning, detection, improving and classifying the information emanating from the captured system. These processes are carried out digitally using an approach that discriminates defined ranges of data based specific characteristics of the signal and it generates variations in the amplitude of the in-coming signal. The filtering criterion used includes EKF and UKF. The first implementation of UKF was carried out in (Julier & Uhlmann, 1997b), proposed to address the issue of error estimation by the distribution of state estimations of the Gaussian variation via approximation of the constants and selecting samples specifically of the estimate values known as the sigma points. The filter was later employed in (Khoder & Jida, 2014) for experimentation of the GPS system which obtained an appreciable results in its application. The EKF is seen to outperform UKF as a result of its computational cost (Cuervo, Guerrero, & Alarcón-Aldana, 2017; LaViola, 2003), though they may have equal optimal level of performance, it has been concluded in (D'Alfonso, Lucia, Muraca, & Pugliese, 2015) that both filters are very efficient but the UKF is numerically stable thus an ideal solution for dedicated motion tracking systems.

Although EKF and UKF have shown a great performance in elimination of errors in diverse applications based on previous studies, there is still the need to further improve its performance and further reduce its computational cost for use in real world applications most especially in capturing and filtering of biomechanical diagnoses and rehabilitation of human entities. More so, even though they both achieve the elimination of errors present in the data captured in various applications, it is still necessary to undertake further research to further reduce the error considerably and hence it is

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