Survey of various Filtering Methods for Sensor Data

Sumit N Shukla[1] Tushar A Champaneria[2]
[1]Student [2]Assistant Professor
[1,2]Department of Computer Engineering
[1,2] L.D. College of Engineering, Ahmedabad, Gujarat, India

Abstract— Kalman filter is a less discrepant technique, in which filtering accuracy is improved by taking series of measurement. It has numerous application like vehicle navigation, sensor data filtering etc. For optimal estimation, various flavours of Kalman filters are proposed time to time. In this paper, we have discussed and compared about Kalman filter (KF), Extended Kalman filter (EKF) and Unscented Kalman filter (UKF), their basic theories, advantage disadvantages and opinion about which one is better for sensor data and real time environment.

Key words: Kalman Filter, Sensor Data Filtration, Unscented Kalman Filter, Extended Kalman Filter

I. INTRODUCTION

The data generated from the various sensors placed in smart transportation environment is huge in amount and in the way course of transmission from sensors up to the data collection unit there are prominent chances of getting error involve in data or some missing values. So, for this reason filtering of data is required to remove noise and erroneous values from data. Kalman filter and its various versions are being used from past for filtering and data fusion purpose.

Kalman filter uses a series of data taken against time to estimate unknown variable with more accuracy. It is widely applied in many fields like target tracking, navigation, positioning of GPS, sensor data fusion etc [1].

The remainder of paper is structured as follows. To fully understand about the details of various filtering techniques available section II provides different types of filtering techniques applicable. To get notion about the applicability of each filtering algorithm, Section III shows table in which all the filtering techniques are surveyed across various parameters. Section IV provides concluding arguments, discussing the main issues raised throughout the paper.

II. VARIOUS TYPES OF FILTERING TECHNIQUES

Kalman filter mainly includes Kalman filter (KF), Extended Kalman filter (EKF) and Unscented Kalman filter (UKF).

A. Kalman Filter

Kalman filter is one of the famous Bayesian filter which follows linear optimal status elimination phenomenon [2]. Two equations are must to be discussed when we talk about Kalman filter, that are status equation and observation equation. Status equation is linear representation of $w_{k,}$ u_{k-1} and x_{k-1}. Observation equation is a linear representation of x_k and v_k.

Where x_k, w_k, u_{k-1}, v_k are status vector, system noise vector, system control vector and observation noise vector. wk and vk satisfy positive definite, symmetric and uncorrelated, zero mean Gaussian white noise vector [3].

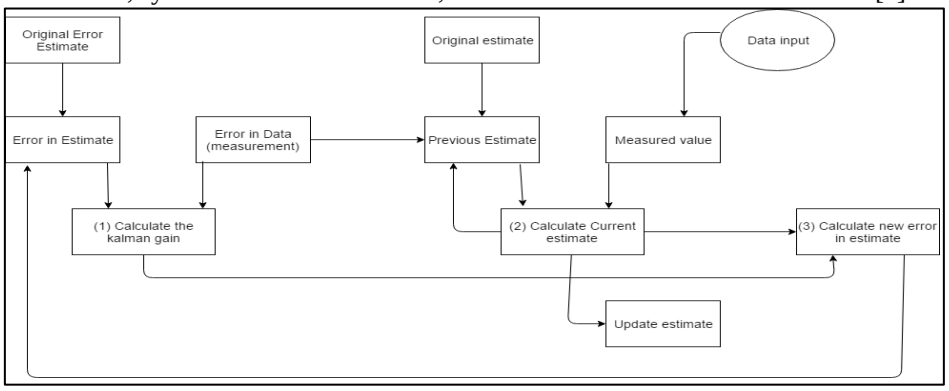

Fig. 1: Shows basic working of Kalman filter

1) Merits

- Multiple objects can be tracked simultaneously under moderate changes [4].
- Can be combined with machine learning to estimate instantaneous positions of a moving target [5].
- Can be applied in security surveillance [6].

2) Demerits

- It doesn't show good performance under low resolution, velocity change [4].
- Suitable only for linear systems and requires linear observation equation only.
- Application of standard Kalman filter is limited.

B. Extended Kalman Filter

Many of the practical scenarios are the non-linear systems, which are not appropriate for Kalman filters. Such cases require concept of extended Kalman filter. The basic idea of EKF is to focus on first - order nonlinear Taylor expansion around the status of the estimated, then transform the nonlinear system into a linear equation [7]. It linearizes the non-linear model around the previous state estimates using a first-order Taylor series approximation.

1) Merits

- Easy to implement.
- Good performance for road vehicles in motion.
- Better adaptability for the uncertainty of noise [9]

2) Demerits

- Status and measurement of noise affects the filtering result.
- Improper estimation result in cumulative error, which may lead to divergence of filter [8].

C. Unscented Kalman Filter

It's another class of method that applies sampling strategy close to nonlinear distribution. It uses linear Kalman filter framework based on Unscented Transform (UT) and uses definite sampling strategy instead of random sampling strategy. Generally, it has small number of sampling points. Can be combined with particle filter for usage in camera tracking.

1) Merits

- Easy to implement as compared to EKF as it avoids calculation of various complex matrix [10].
- Convenient for real time processing [11].
- Better real time tracking accuracy [12].
- Able to avoid divergence phenomenon.
- It can handle the cases of non-additive noise and discrete systems and extend the range of application [5].
- Using this we can get a better solution of nonlinear problems with higher accuracy and faster convergence.

2) Demerits

Requires more real time data for proper operation.

III. SURVEY OF DIFFERENT DATA COLLECTION WAYS

Type of Filter	Implementation	Type of system supported	Support for real-time environment	Accuracy	Application
Kalman filter	Moderate to implement	Only linear	No	Moderate	Applicable in object tracking, recognition but mostly of linear systems
Extended Kalman Filter	Easy to implement	Both linear and nonlinear	No	Good	Suitable in non-linear vehicular model
Unscented Kalman Filter	Easiest to implement	Both linear and nonlinear	Yes	Best	Most suitable for real time environment tracking, GPS positioning etc

Table 1: Survey of Different Data Collection Ways

This tabular comparison can also be useful for proper selection of which technique should be used to be implemented for filtering of sensor data. The table consist of various parameters. Implementation field describe difficulty level in implementing the technique. Second field describe the supported system. Third field tells which filtration method is suitable for real time environment.

Accuracy tells about how accurate the technique is. And the last field tells about the application of filtration technique.

IV. CONCLUSION

In this paper, we have reviewed various data filtering methods like KF, UKF, EKF along with their merits demerits summarized through comparison on various parameter and their application to sensor data filtering is discussed. Methods like KF and EKF lack real time reliability while EKF can provide better and accurate result in real time environment especially when used in combination of some other technique.

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