Kalman FilterOptimal Estimator- A Tracker Development Approach

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***Abstract*-The prediction of position and velocity of an object accurately is the biggest challenge faced by the communication system these days. The algorithm developed fulfils the need to accurately measure and predict the correct position and velocity. The approach used includes using an initial estimated position and then recursively calling the Kalman Filter equations to reduce the error in position and velocity and correctly predict the position and velocity. After successive recursions the predicted and actual position are found to be nearly the same with a very low margin for error**

***Keywords*— LMS, RMS**

I. Introduction

In Kalman filter, filtering means actually estimating the state vector at the present time which is based upon the past observed data. On the other hand prediction is estimating the state vector at the future time [2]. Kalman filter forms the basis of most state estimation algorithms. We use this state estimation just because it is the key for obtaining the best possible navigation solution from the various measurements available with us. Kalman filter uses all the measurement information that is input to it over time, not just the most recent set of measurements. It is actually an estimation algorithm, rather than a filter. It also maintains real time estimates of a number of parameters. Estimates are updated using a series of measurements that are subject to noise. It uses knowledge of the deterministic and random properties of system parameters and the measurements for obtaining the optimal estimates of the information available. It is also called Bayesian estimation technique. [1]

The Kalman filter is also called a tool for estimating the variables of a wide range of processes. In mathematical terms we can say that a Kalman filter estimates the states of a linear system. The Kalman filter not only works well in practice, but it is theoretically attractive too because it can be shown that of all possible filters, it is the one that minimizes the variance of the estimation error. Kalman filters are often implemented in embedded control systems because in order to control a process, we first need an accurate estimate of the process variables [1].

II. ELEMENTS OF KALMAN FILTER

1.State vector: It is a set of parameters which describe a system, known as states, which the Kalman filter estimates. Each state may be constant or may be time varying. For many navigation applications, the state includes the components of position or position error. Velocity, altitude and navigation sensor error states may also be estimated.Along with the state vector there is an error covariance matrix which represents the uncertainties in the Kalman filter's state estimate and degree of correlation between errors in those estimates. This correlation information within the error covariance matrix is important for the following 3 reasons.

(a) It enables the error distribution of the state estimates to be completely represented.

(b) There is not always sufficient information from the measurement to estimate the Kalman filter states independently. The correlation information enables estimates of linear combinations of these states to be maintained while awaiting further measurement information.

(c) Correlations between errors can build up over the integral between measurements. Modeling this can enable us to determine one from the another.

2. System model: This model is also called the process model or time propagation model which describes how Kalman filter states and error covariance matrix vary with time.

Example- A position state will vary with time as integral of a velocity state, the position uncertainty

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will increase with time as the integral of velocity uncertainty, the position and velocity estimation errors will become more correlated. The system model is deterministic for the states, as it is based on known properties of the system.

3. Measurement vector: It is a set of simultaneous measurements of properties of system which are functions of state vector. Along with the measurement vector is a measurement noise covariance matrix that describes the statistics of noise on the measurement. For many applications, new measurement information is input to K.F at regular intervals. But in some other cases the time interval between measurements can be irregular.

4. Measurement model: It describes how the measurement vector varies with the function of true state vector in the absence of measurement noise [2]. The Kalman filter is a set of mathematical equations which provides us an efficient computational (recursive) means to estimate the state of a process, in a way that minimizes the mean of the squared error. The filter is very powerful in various aspects: it supports estimations of past, present, and even future states, and it can do so even when the precise nature of the modeled system is unknown to us.

5. Kalman Filter Algorithm: The Kalman Filter estimates a process simply by using feedback control like form. The operation may be described as the process is estimated by the filter at some particular point of time and the feedback is obtained in the form of noisy measurements. The Kalman filter equations can be divided into two categories: time update equations and measurement update equations. To obtain the a priori estimates for the next time step the time update equations project forward (in time) the current state and error covariance estimates. The measurement update equations get the feedback to obtain an improved *a* posterior estimate which incorporates a new measurement into the a priori estimate.[3]

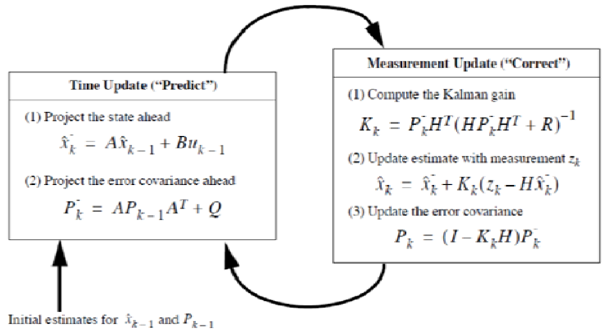

Fig.1 Operation of Kalman Filter

III. APPLICATIONS OF KALMAN FILTER

Theapplications of Kalman Filter includes:

1. Tracking objects (e.g., balls, faces, hands, heads)
2. Channel estimation.
3. Orbit determination
4. Navigation
5. Structural health monitoring
6. Weather forecasting
7. Radar Tracker etc.

IV. MOTIVATION

In the multi sensing environment, some noisy signals are obtained along with the desired signal which corrupts the data because of the changing surroundings. But we need to obtain correct data. Though there are so many algorithms to combat the problem but they have some problems like high convergence rate, computational complexity. So some other techniques should be developed that fulfill the need to accurately measure and predict the correct position of the object even if the object is not directly accessible to the GPS or other similar devices.

For example if the object is passing through the tunnel.

- Now-a-days communication systems are facing a lot of problems in getting the accurate position of any object whether stationary or non-stationary due to increasing congestion, noise etc.
- Some estimation techniques like LMS, RMS have computational complexity and high rate of convergence.

The research is based on following objectives:

1.Track object in real time: In this approach with the help of Kalman Filter object is estimated and tracked. The algorithm used here is the basic algorithm of Kalman Filter. By using its predict and correct equation and recursively calling Kalman filter we can able to estimate and track the position of object.

2. Track object with feature detector: In this approach Kalman Filter along with feature detector is used for better tracking of the object than the previous one. This is the improvement I want to do in my base paper. The algorithm of the Kalman Filter will remain same only the additional feature detector will be added. The feature detector may be the SURF feature detector which is the advanced version of SIFT.

V. RESEARCH METHODOLOGY

In research methodology, system model and flow charts for initialization of Kalman matrices and update of Kalman filter equation is described.

A.SYSTEM MODEL

Discrete time linear systems are generally represented in a state variable format given by the expression:

$$x_j = a x_{j-1} + b u_j$$

where; x_j=state (scalar); a,b=constant; u_j=input; j=time variable.

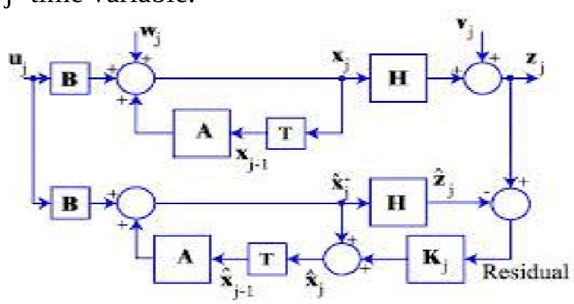

Fig.2 System model of Kalman Filter [3]

B. FLOWCHART FOR INITIALIZATION OF KALMAN MATRICES

The first or the basic step for predicting the position of any object using the Kalman Filters is the initialization of the Kalman variables. The State Transition Matrix, the Observation Matrix, the Filter Error Co-Variance Matrix, the Filter State Vector, the Measurement Noise Co- Variance and the Process Noise Co – Variance Matrix have to be initialized. These allow the filter to make an estimated guess of the position and hence allows calculating the error in the next recursion.

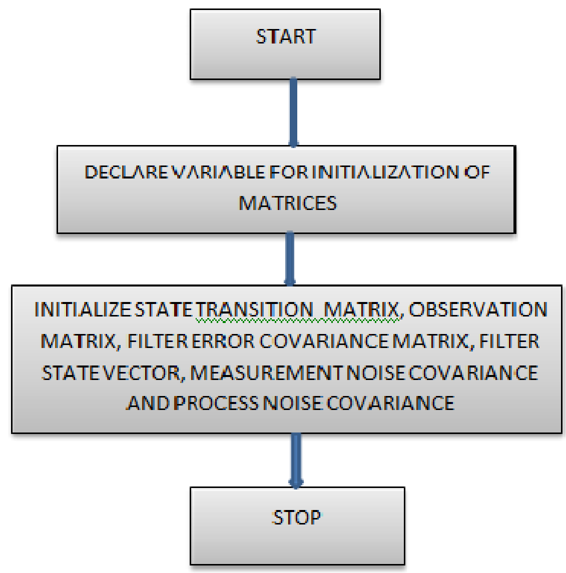

Fig. 3 Flow Chart for Initialization of Kalman Matrices

C.UPDATE OF KALMAN FILTER EQUATIONS

Here we calculate the Kalman Gain. Using the Kalman Gain, we can calculate the Residual or the Innovation. The value of the Filter State Vector initialized in the first step is now updated along with the Filter Error Co-Variance Matrix

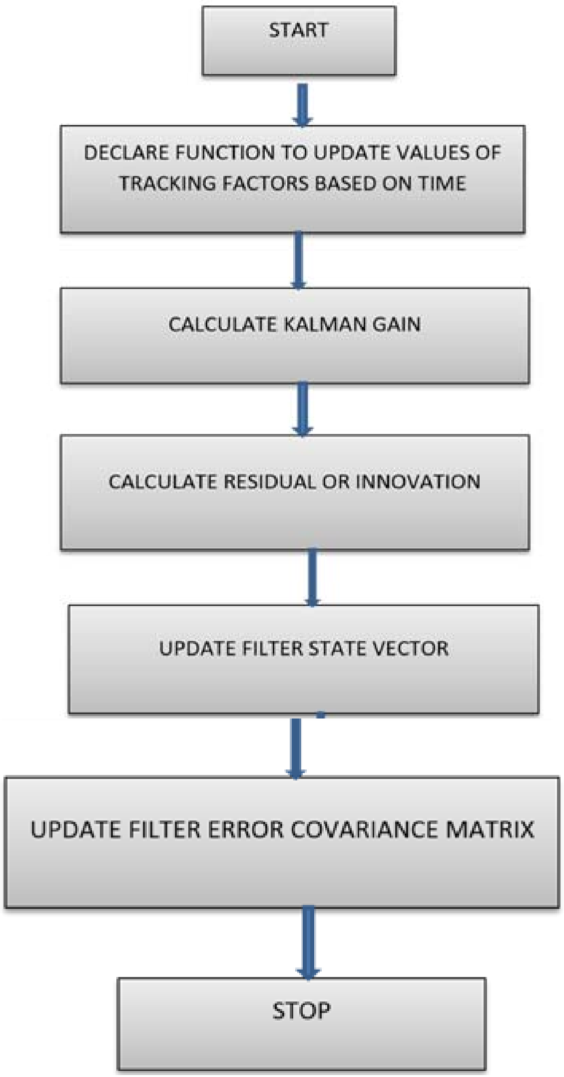

Fig. 4 Flowchart for Kalman filter Update Equation

VI. CONCLUSION

By the use of the algorithm applied in base paper, the trajectory can be estimated with an accuracy of 96.5%. But accuracy may be altered by changing some of the parameters involved in the algorithm for e.g. by changing the pre-defined model of filtering to a more accurate model of the object. If an initial estimation of the position will be taken, it will help in increasing the accuracy.

The algorithm used here can be modified for objects having accelerated trajectories which is generally the case in practical scenario. The values of all the matrices would be differently initialized for that purpose and also a very different pre-defined model of object would have to be used. The accuracy of the algorithm in that case would highly depend on the predefined model.

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