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Error Correction of Radar Long Distance Data using Kalman Filter for Autonomous Vehicle Movement

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Abstract: A novel method is proposed for reducing the errors in distance measuring sensors namely Radar to accurately detect the relative distance of any Autonomous vehicle in a surface movement scenario. Sensor distance outputs are proposed to be taken with appropriate signal conditioning as input to the well known Kalman filter and an appropriate program is proposed to be written in Mathematica-11 on a Broad-Com2837 based Linux Operating system. The distance sensor namely radar data is simulated using Mathematica-11 real random variable built in function. This data is applied as input to the scalar Kalman filter and error corrected data is obtained at the output. The measured values and error corrected values and true values of the radar are plotted along with error reduction scenario. It is observed that the considerable error reduction was obtained through this method.

Index Terms: Radar Sensor, Kalman filter, Broad-Com2837R, Linux, Mathematica-11.

I. INTRODUCTION

An Autonomous vehicle consists of various devices like Radar sensor, Lidar sensor, Camera, Ultrasonic sensor, Wheel encoder and GPS through which it collects data and performs appropriate actions as per the requirement of the situation. The GPS, Digital Compass, Ultrasound Sensors, Digital Camera are controlled by remote motion controller for autonomous vehicle to navigate the multisensory data fusion which enables the movement of vehicle [1]. The radar sensor of Bosch company which detects objects and measure their position and velocity with the frequency range from 76-77 GHz and detects distance range up to long range up to 250m. The opening angle in long range radar sensors is ±20° (5m) with an error ±10 [2]. The error of this radar sensor can be reduced or corrected to the near measured value. The radar sensor which allows to implement a range of driver assistance functions and to fulfill ever-increasing safety standards set by consumer protection organizations and legislators for autonomous vehicle manufacturers. The LRR (Long Range Radar sensor) is mono-static multimodal radar which has six fixed radar antennae. The outer two antennae will expand the field view to ±20 degrees at a distance up to five meters in the near range. The central four antennae record the vehicle surroundings at higher speed with an opening angle of ±6 degrees in long distance detection with minimal interference from traffic in adjacent lines [3]. The data of the radar sensor is used by the Kalman filter to obtain error corrected data to take care of any measurement errors of Radar.

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II. KALMAN FILTER

The Kalman filter is used to predict the next state based on previous state with no need of data history. This filter is computationally very fast making it suitable for real time problems even in error or noisy scenario occurs in environment if suitable fastest computer along with very high frequency and processing speed is available. It is found that Broad-Com2837 (technical details) is suitable for this purpose. The Kalman filter is chosen as this filter will give a good result for Gaussian distribution compared to other filters. The functions used in Kalman filter are linear as there will not be any angle parameter in equation so we can directly use this linear function to Gaussian distribution to get mean and variance. The most of the problems in real life situation are non-linear which can be resolved by Extended Kalman filter [4]. Kalman filter for tracking and data prediction tasks is regarded as optimal solution. This filter purpose is to extract the signal with required information to minimize the loss functions [5]. This Kalman filter is applied to a wide range of navigation problems and tracking in terms of state space method and on the surface area. The linear Kalman filter finds the best linear estimate by going through data and new best estimate for a given set of data. When a new measurement is added by using both the new measurement and old estimate the confidence of some measure in the old estimate is reduced. It solves the problem of least square estimation in recursive manner. The Kalman filter have number of extensions-non linear, non-Gaussian model, continuous all of which could be derived using a simple matrix gradient approach [6].

A. Extended Kalman filter

Extended Kalman filter (EKF) gives approximation of most favorable estimate. The approximation of system dynamics by a linearized version of non linear system model is around the estimation of the last state.

This linearization ought to be great inexact for substantial guess of non direct model in all vulnerability area related with state estimate [7].

III. RELATED WORK

The location of autonomous land vehicle is detected with reduction in location error with contrast to relative location and absolute methods. The data fusion of location algorithm based on Kalman filter is simulated with reduction in location error [8].The vehicle detection using Radar and Vision sensors is accurate to co-ordinate the sensors data obtained from actual sensor for performing sensor calibration which is easy to detect the obstacle of an autonomous vehicle by using sensor fusion algorithm [9]. There are two filters the Kalman filter and Extended Kalman filter which are used for vehicle positioning and errors location of sensor. This Extended Kalman filter method is the extension of Kalman filter used to detect GPS errors of vehicle . The Kalman filter is enough for the error correction of vehicle for controlling on the surface area [10]. The interpolation of sensor reading of neighbouring sensors is used to predict the actual value and measured drift in Kalman filter [11]. The Radar sensor error by region and statistical values has been calculated to reduce the radar internal error and used for business intelligence technique in geographical area using Kalman filter. The error estimation address and subsequent error correction for accurate correction of errors is proposed [12]. A remote underground sensor network on earth's surface applications using sensor nodes is simulated with improved bit error rate by error correction mechanism [13]. The estimated values of radar sensor errors are corrected in very high frequency Omni range and the aircraft density is increased significantly with reduce in time [14].

IV. PROPOSED WORK

The error will be corrected by assuming the truth values of the sensor with the nearest measured value. These measured values can be generated using the real random variable generation in Mathematica-11 language in Linux environment. The Kalman filter is an iterative process that follows predict and update steps. In predict step the Kalman filter predict the new values from initial value and then predict the error in our prediction present in the system. In update step we take the actual measured value from devices like Radar and we calculate the difference between the measured value and predict value and decides that value to be taken for calculating the Kalman gain. The Kalman gain determines the predicted value or measured value is close to the actual value. The estimated values are given as input to the Kalman filter which filters the estimated value with the nearest truth value in which the error of the radar sensor is reduced.

A. Proposed System Architecture

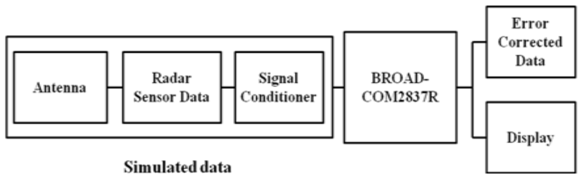

Fig.1 Proposed System Architecture

The Bosch radar long distance sensor data which detects an object range up to 250m with an error of ±10 is simulated using Mathematica-11 random real function in Broad-Com2837 processor as shown in Fig.1 which generates the random real function. This measurement error is given as the input to the Kalman filter with the limits of ±10m. The Kalman filter is designed to run the 10 iterations with various outputs which are enumerated below in terms of Table I, vectors and graphs.

V. RESULTS

A. Experimental Results

The data output of the radar sensor namely BOSCH with a long distance range was observed to be maximum 250m with an error of ±10m. This data is simulated using random real function Mathematica-11 for 10 iterations starting from 0m to 225m. The Kalman filter algorithms are used for true values and the measured value randomly generated from random real function with limits from -10m to +10m. The following results of the Kalman filter are shown in Table I with given Kalman Gain (K), Expected value(X) and Error in Expected value (P).

Table I

S. No	Kalman Gain(K)	Expected value(X)	Error in Expected value(P)
1	0.3333333333	1.333333333	6.666666667
2	0.2500000000	4.000000000	5.000000000
3	0.2000000000	17.61666667	4.0000000000
4	0.1666666667	24.22777778	3.333333333
5	0.1428571429	46.09523810	2.857142857
6	0.1250000000	45.5429563	2.500000000
7	0.1111111111	63.1051201	2.222222222
8	0.1000000000	68.7432650	2.000000000
9	0.0909090909	85.3657279	1.818181818
10	0.0833333333	95.3359445	1.666666667

From the above Table I it is observed that the Kalman Gain (K) is gradually decreasing from 0.333 to 0.0833 and error in Expected value(X) is reduced from 6.67 to 1.67. Hence we can say that Kalman filter is well tuned.

The True value, Measured value, Expected value and Error in Expected value are presented in vector form as below and also represented in Graphical form as shown in Fig.2 and Fig.3.

True value: {0, 25, 50, 75, 100, 125, 150, 175, 200, 225}

Measured value: {-15, 14, 62, 74, 86, 138, 160, 172, 199, 223}

Expected value: {-0.333333333, 13.91666667, 20.40000000, 23.60555556, 39.07579365, 35.2523313, 54.0548005, 71.0192300, 81.1356758, 99.4403159}

Error in Expected value: {6.666666667, 5.000000000, 4.000000000, 3.333333333, 2.857142857, 2.500000000, 2.222222222, 2.000000000, 1.818181818, 1.666666667}

B. Graphical Representation

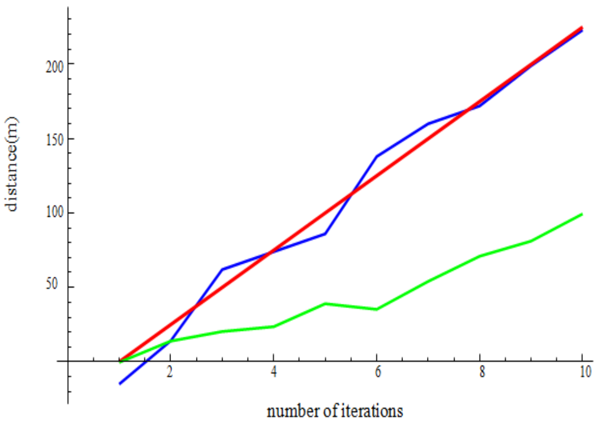

Fig.2 Plot of True value, Measured value and Expected value

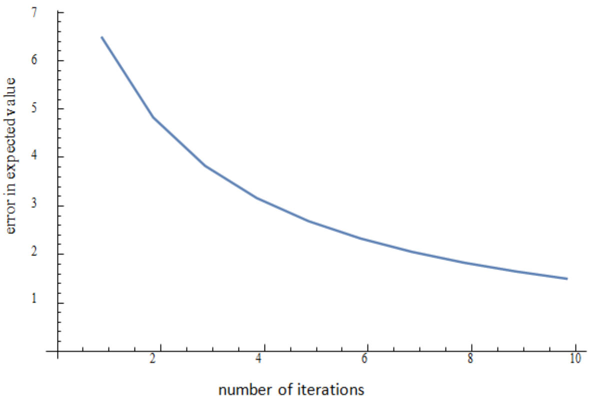

Fig.3 Plot showing reduction in error for each iterations

The Fig.2 represents Plots of the True value which is indicated in Red color, the Measured value is indicated in Blue colour and the Expected value is indicated in green colour. The Fig.3 is the representation of Plot showing reduction in error for each iterations. From the above it can be seen the error is gradually reducing for each iteration from 6.67 in first iteration to 1.67 in tenth iteration.

VI. CONCLUSION

The error correction of radar sensor data of a long range distance 250m range with an error of ±10m is carried out successfully using Kalman filter on a Hardware system based on Broad-Com2837 processor in Linux Environment. The basic operating system is in Linux Environment with Mathematica-11 functions are used successfully to realize an error reduction of more than 30% is achieved.

VII. FUTURE SCOPE

This can be observed for shorter distance range with the speed of the Kalman filter may have to be increase with better crystal frequency. This system is very compact as Linux is used which can be extended to any type of protocol for the purpose of interfacing and control.

REFERENCES

1. Malavika Panicker, Tanzeela Mitha, Kalyani Oak , Ashwini M. Filter for the Improvement of Aircraft Density",2017. Deshpande and Chandrajit Ganguly "Multisensor Data Fusion for an Autonmomous Vehicle" Conference on Advances in Signal Processing(CASP),2016.
2. BOSCH Radar Senor Available: https://www.bosch-mobility-solutions.com/en/products-and-services/passenger-cars-and-light-commercial-vehicles/driver-assistance-systems/left-turn-assist/long-range-radar-sensor/.
3. Radar sensors for assistance and automotive applications http://www.bosch.co.jp/tms2017/pdf/CC-ProductDataSheet-MRR-LRR-EN.pdf.
4. Kalman filter https://towardsdatascience.com/kalman-filter-an-algorithm-for-making-sense-from-the-insights-of-various-sensors-fused-together-ddf67597f35e.
Tony Lacey Tutorial: The Kalman Filter Chapter 11 page no.133.
5. Brent Perreault "Introduction to the Kalman filter and its derivation,2012.
6. Maria Isabel Ribeiro "Kalman and Extended Kalman Filters: Concept, Derivation and Properties" Chapter 5 page no. 32.
7. Qingmei Yang, and Jianmin Sun "Location System of Autonomous Vehicle Based on Data Fusion",2006.
8. Jihun Kim, Dong Seog Han and Benaoumeur Senouci "Radar and Vision
9. Sensor Fusion for Object Detection in Autonomous Vehicle Surroundings",2018.
Stanley Baek, Chang Liu, Paul Watta, and Yi Lu Murphey "Accurate
10. Vehicle Position Estimation Using a Kalman Filter and Neural Network-based Approach",2017.
Dheeraj Kumar, Sutharshan Rajasegarar, Marimuthu Palaniswami
11. "Automatic Sensor drift detection and correction using Spatial Kriging and Kalman filtering" IEEE International Conference on Distributed Computing in Sensor Systems,2013.
12. Jimmy Anderson Florez Zuluaga , Jose David Ortega Pabon , Jesús Francisco Vargas Bonilla, Carlos Mario Suarez Rios "Radar error calculation and correction system based on ads-b and business intelligent tools",2018.
13. Prasanth M.Warrier and Rahul Lal "A study of modulation schemes and
14. error correction mechanism in a Wireless underground sensor network" International Conference on Control, Power, Communication and Computing Technologies (ICCPCCT),2018.
15. K. Ramakrishna, M R K Murthy, N S Murthy Sharma "A Novel Method
16. for Very-high Frequency Omni Range (VOR) Azimuth Error Correction using Kalman

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