IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 5, Issue 4, April 2016

Low-Cost Tightly Coupled GPS/INS Integration Based on a Nonlinear Kalman Filtering Design

Mr. Amol M. Kendre[1], Prof. Dr. Vilas N. Nitnaware[2], Mrs. Vaishali V. Thorat[3]

Student of Electronics and Telecommunication, D. Y. Patil School of Engg, Ambi, Pune, India[1]

Principal and Professor of D. Y. Patil College of Engg, Ambi, Pune, India[2]

Assistant Prof and P.G. Co-ordinator of D.Y. Patil School of Engg, Ambi Pune, India [3]

Abstract: In this paper, describes the literature review for design of a “tightly coupled GPS/INS integration system based on nonlinear Kalman filtering methods”. The traditional methods include linearization of the system around a nominal trajectory, and the extended Kalman filtering (EKF) method which linearizes the system around the previous estimate, or the predication, whichever is available. The recently proposed sigma-point Kalman filtering (SPKF) method uses a set of weighted samples (sigma points) to completely capture the first and second order moments of the prior random variable. The project aims to develop a generic hardware/software platform for positioning and imaging sensor integration. In the current development phase, a tightly coupled GPS/INS integration system based on a linearization around the INS solution has been designed and implemented. The system uses the GPS pseudo range and Doppler measurements to estimate the INS errors. This paper describes further developments of the integration filter design based on the EKF and SPKF methodologies, in order to compare the performance of nonlinear filtering approaches.

Keywords: Global positioning system (GPS), inertial navigation system (INS), Non-linear Kalman filter (KF), Computer with latest configuration, Latest version of MATLAB with GPS & INS tool kit.

I. INTRODUCTION

Navigation is a field that focuses on the process of monitoring & controlling the movement of craft or vehicle from one place to another. This includes four general categories: (i) Land Navigation, (ii) Marine Navigation, (iii) Aeronautics Navigation (iv) Space Navigation. It is also term of art used for the specialized knowledge used by the navigators to perform navigation task. All navigational techniques involve locating the navigator’s position compared to known locations or patterns. Navigation, in the broad sense, can refer to any skill that involves locating the position & direction. In the sense, navigation includes orienteering & pedestrian navigation. Global Positioning System (GPS) based navigation systems have been used in Land Vehicle Navigation Systems (LVNS) due to their low price, easy installation, and other beneficial factors. The level of performance required of an LVNS recently increased with the successful implementation of LVNS in unmanned land vehicles, with the development of augmented reality for land vehicles & the availability of high grade LVNSs [1].
From the point of view of different environmental conditions, The Inertial Navigation System (INS) is ideal, rather than using signals from satellites, in case of GPS.

The INS is based on measurements of linear accelerations and angular velocities. INS measures the linear acceleration and angular rates of moving vehicles through its accelerometers and gyroscope sensors. The main interest is the position determination. The INS error bound grows with time, due to the unbounded positioning errors caused by the uncompensated gyro and accelerometer errors affecting the INS measurements. INS provides high-accuracy in case of three-dimensional positioning when the GPS positioning is poor or unavailable over short periods of time. In addition, it provides much higher update positioning rates compared with the output rate conventionally available from GPS [2].The limitations of GPS are related to the loss of accuracy in the narrow-street environment, intentional disruption of the service, poor geometrical-dilution-of-precision (GDOP) coefficient and the multipath reflections.GPS-based navigation system requires at least four satellites, so a major drawback of GPS dependence navigation systems is that their accuracy degrades significantly with satellites outages. Signal outage is more significant for land vehicle positioning in urban centers, which takes place when encountering highway overpasses or tunnels due to the obstructed signals. So it is suitable to integrate this type of navigation system with a different type ofnavigation system in order to reach a greater autonomy.

Both INS and GPS suffer from various error sources and deficiencies which propel the accompaniment of the two complementary systems. INS exhibit relatively low noisy outputs which tend to drift over time. Contrary to INS, GPS outputs are relatively noisy but do not exhibit long-term drift. Combining both of these systems gives a superior navigation performance than standalone system [3]. So to achieve strong performance, GPS/INS integrated system widely used. But major drawback of GPS/INS integrated system is that some time GPS lost its signals in critical conditions for example in tunnel, hilly areas etc. So at that time it is necessary to some type of mechanism should be adopted to train the INS data during GPS

IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 5, Issue 4, April 2016

outage. For this purpose Support Vector Machine (SVM) is used to train the INS data during GPS outage & the simulated annealing is applied to realize the optimization of the parameters of the kernel function& the penalty function in the SVM algorithm. Therefore the integrated navigation could retail almost as precise as the GPS when GPS is off-line.

II. RELATED WORKS

Extended Kalman Filter (EKF) is widely used for GPS/INS integration. It has main drawback that the filter may diverge when the initial state estimation error is large, because in EKF, Mean and covariance matrix of the state vector are propagated through the linearized nonlinear system model. Large linearization errors can be introduced in the mean and covariance of the posterior distribution leading tosuboptimal performance and even divergence of the filter [4].

Tightly-Coupled integration eliminates the usage of cascaded filters unlike loosely coupled integration. Therefore, correlation of the measurements in GPS navigation filter is prevented. Instead of navigation solution of GPS, pseudo ranges and pseudo range rates obtained from Doppler data are used as the measurement so for the INS/GPS integrated Kalman filter. Choice of these measurements brings nonlinearity to the measurement model of the integrated filter. Even when less than four satellites are available, integration filter will keep on operating since this system does not require a full GPS solution to aid the INS [5]. There is only INS available during GPS outage; therefore it is necessary to establish a well-trained model to predict the positioning information. Artificial neural network (ANN) can be used for this purpose. I comparison with ANN, Support Vector Machine (SVM) can provide better genetic ability, thus it takes shorter time for training to obtain better training performance [1].

III. LITERATURE REVIEW

Various research works are carried out on integrated navigation system. Eric A. Wan et al. presented an alternative method to EKF for nonlinear estimation. This replaces EKF by UKF which consistently achieves a better level of accuracythan the EKF at a comparable level of complexity.[6] Zhen Guo, etal. developed a new approach for tightly coupled GPS/INS integrated system which based on Sigma Point Kalman filter. Theyfound that for different inertial sensor grades SPKF based tightly-coupled GPS/INS system shows good performance concerning the accuracy of the navigation solution and the ability to calibrate the INS[7] HaoWuet al. introduced alternative method to eliminate the linearization error. The Unscented Particle Filter (UPF) was proposed by them for states estimation. According to simulation, it shows that UPF algorithm presents high navigation accuracy in the GPS/INS integrated navigation. [8]

Gannan Yuanet al. proposed UKF design strategy for the ultra-tightly coupled GPS/INS integrated system.INS error models are discussed, which was used to estimate the I/Q signals. The UKF based ultra-tight integration system is stable and accurate, which make it feasible to work at some strict scenarios, i.e. high dynamics or heavy interference. [9] Alex Garcia et al. developed a loosely couple GPS/INS integrated navigation system which is based on field programmable gate array (FPGA). Along with FPGA, they also introduced PDA and web server in the kalman filter. This improves the performance and achieved obtaining access to map information from Google Maps [10].

Myeong-Jong Yu has proposed an adaptive filter for a nonlinear system that estimates measurement noise variance in real time using measurement residual values to consider the noise caused by large measurement errors. A scalar measurement updating U/D covariance factorization filter was used to implement the proposed filter and to calculate the measurement noise variance effectively. [11]

Tamer AKCA et al. investigated an Adaptive Unscented Kalman Filter (AUKF). They changed SUT parameters adaptively depending on the recent covariance of the estimator, and claim that it gives better performance compared to using fixed parameters throughout the scenario [12]. Kamal Saadeddin, et al.suggested a low cost GPS/INS integrated navigation system by comparing six different algorithms to fuse measurements of a low-cost navigation system, in which they introduced a new approach of Adaptive Neuro-Fuzzy Inference System (ANFIS) architectures to achieve high accuracy vehicle state estimates. [13] Garry A. et al. designated a new scheme of integration which is based on four nonlinear bleeding filters, in which, they accomplish that in the UKF, The Root Mean Square Error is minimum than other filters [14].

IV. METHODOLOGY

Proposed work can be accomplished using following steps
Step 1: (State estimation using UKF)

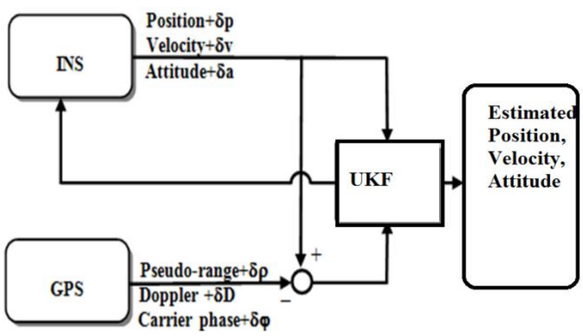

Fig1:-Tightly Coupled GPS/INS Integration Using UKF.

Step 2: (Implementation of training model):
State Vector Machine (SVM) can be implementing using simulated annealing.

Fig.2:-the SVM training model for integrated navigation.

DOI 10.17148/IJARCCE.2016.5438

IJARCCE
ISSN (Online) 2278-1021
ISSN (Print) 2319 5940
International Journal of Advanced Research in Computer and Communication Engineering
Vol. 5, Issue 4, April 2016

It is designed around an Inertial Sensor Assembly (ISA) and provides all the basic IMU outputs including delta velocity (ΔV), delta angular vector (Δθ). The ISA consists of six single axis sensors, three Quartz Rate Sensors, three Vibrating Quartz Accelerometers, the drive electronics, preamplifier circuitry for the sensor outputs, and the digital conversion electronics.

V. PROCESS DESIGN

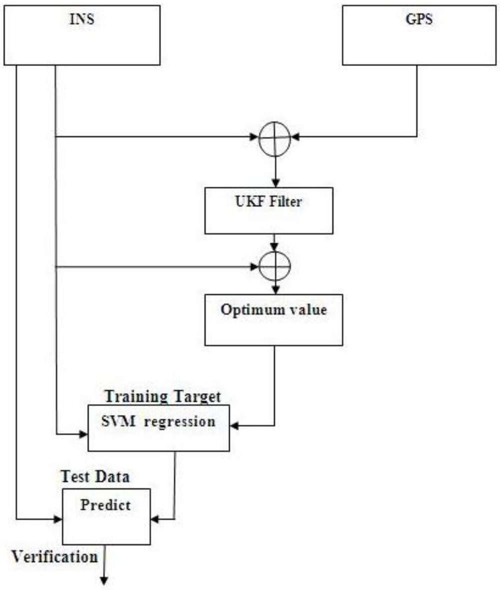

Fig3. Block diagram of proposed system

VI. EXPERIMENT AND ANALYSIS

The design of a tightly coupled GPS/INS integration system based on nonlinear Kalman filtering methods. The recently proposed sigma-point Kalman filtering (SPKF) method uses a set of weighted samples (sigma points) to completely capture the first and second order moments of the prior random variable.

A) Extended Kalman Filter
The EKF applies the Kalman filter to nonlinear systems by simply linearizing all the nonlinear models so that the traditional linear Kalman filter equations can be applied.
The extended Kalman filter (EKF) gives the estimate and the covariance

$$\hat{x}(k+1k+1) = \hat{x}(k+1k) + K(k+1)[z(k+1) - \hat{z}(k+1k)] \quad ...(3)$$

$$P(k+1k+1) = [I - K(k+1)H(k+1)]P(k+1k) \quad ....(4)$$

The prediction of the state and its covariance are

$$\hat{x}(k+1k) = f[\hat{x}(k\,k),k] \quad ....(5)$$

$$P(K+1lK) = (K+1,K)P(Klk)FT(K+1.K)+G(K+1,K)Q(K)GT(K+1.K) \quad ....(6)$$

The prediction of measurement is

$$\hat{z}(k+1k) = h[\hat{x}(k+1k), k+1] \quad ....(7)$$

The Kalman gain matrix is

$$[K(k+1) = P(k+1lk)HT(k+1)H(k+1)P(K+1lk)HT(K+1) + R(K+1)-1] \quad ....(8)$$

where F(k+1,k) and H(k+1) are Jacobian matrices associated with f and h.

B) Sigma point kalman filter
Sigma point Kalman filter updates the predication after the measurements arrive:

$$\mathbf{\hat{x}}(k+1k+1) = \mathbf{\hat{x}}(k+1k) + \mathbf{S}(k+1)[\mathbf{z}(k+1) - \mathbf{\hat{z}}(k+1k)] \quad ....(9)$$

Comparing Eq. (9) with Eq. (3), one can find that the sigma point filter has the same prediction-correction structure as the normal Kalman filter. The gain matrix **S** in Eq. (9) can be referred to as the SPKF gain matrix, in similar way to the Kalman filter's gain matrix **K** in Eq.(3).
The estimate covariance is

$$[P(k+1lK) = P(k+1lk\,S(K+1)R(K+1)P_{ZZ}(k+1)l(k+1)S^{T}K+1) \quad ....(10)$$

The SPKF gain matrix **S** is

$$k+1)P\,xz\,(k+1lk)[R(k+1)P\,zz\,(k+1lk\,1)^{-1} \quad ....(11)$$

The SPKF calculates the first and second moments of the priori random variables by utilization of the sigma points. As opposed to the particle filtering methodologies, the sigma points are deterministically calculated from the current estimate of its covariance. The sigma points can be mapped into the state space or the measurement space through the nonlinear functions of the system.

C) Design of integrated kalman filter
As the core of the integrated system the Kalman filter must be carefully designed. Because the tightly coupled GPS/INS integration is a nonlinear system, three filtering schemes are adopted in our system: (1) the linearization around the INS solution (hereafter referred to as the linearization method), (2) the EKF, and (3) the SPKF.

Table1. The integration Kalman filter's state definition

State	Definition	Coordinate System
1-3	Position error	NED
4-6	Velocity error	NED
10-12	Accelerometer error	b-frame
13-15	Gyro error	b-frame

D) Simulation performance

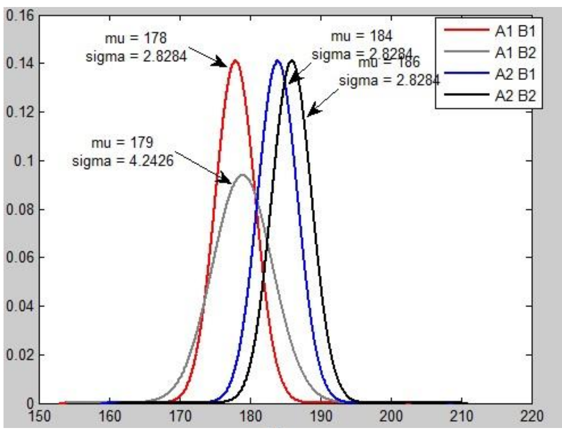

Fig4. Simulation performance

The simulation Performance for Low-Cost Tightly Coupled Gps/Ins Integration Based on a Nonlinear Kalman Filtering Design will be shown as

That displays:
Sigma:
Mu :
Std Deviation :
Mean :

VII. EXPECTED RESULTS

There is only INS available during GPS outage; therefore it is necessary to establish a well-trained model to predict the positioning information. Artificial neural network (ANN) can be used for this purpose. In comparison with ANN, Support Vector Machine (SVM) can provide better genetic ability, thus it takes shorter time for training to obtain better training performance.

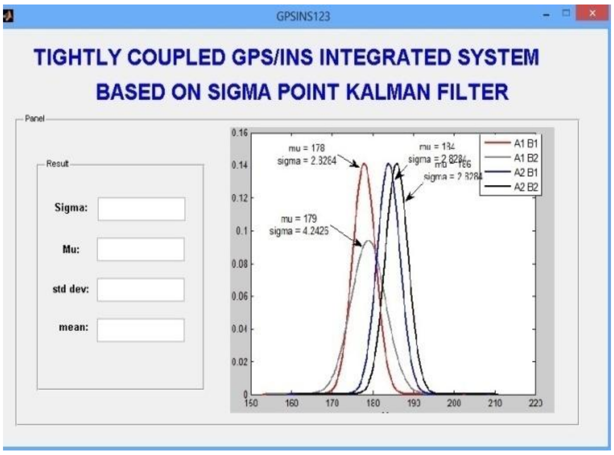

Fig.5. Tightly Coupled GPS/INS Integrated System Based on sigma Point Kalman Filter

VIII.CONCLUSION

A tightly coupled GPS/INS integration system has been designed and implemented on the basis of nonlinear filtering methods. The new nonlinear filter, the sigma point Kalman filter (SPKF), was compared with traditional methods such as the linearization approach and the extended Kalman filter (EKF). In contrast to the EKF, the SPKF is easier to implement because it does not require the computation of Jacobian matrices. Static and kinematic tests have demonstrated that the SPKF can generate solutions of similar accuracy to those of the EKF. However the SPKF has a faster convergence speed.

ACKNOWLEDGMENT

We are using this opportunity to express our gratitude to everyone who supported us for writing this paper. We are thankful for their guidance and invaluably advice during this work. We are sincerely grateful to them for sharing their truthful and illuminating views on a number of issues related to this paper. We also appreciative and genuinely thankful to our H.O.D. **Prof. Santosh G. Bari** for providing us the basic infrastructure and other amenities.

REFERENCES

[1] Zhuquing Jiang, Chonghua Liu, Gong Zhang, Yupeng Wang, Chengkai Hung and Jiayi Liang ”GPS/INS integrated navigation based on UKF and simulated annealing optimized SVM ”,978-1-4673-6187-3/13 ©2013 IEEE.
[2] S.Y. Cho and H.K. Lee, “Modified RHKF Filter for Improved DR/GPS Navigation against Uncertain Model Dynamics,” ETRI J., vol. 34, no. 3, June 2012, pp. 379-387.
[3] J. A. Farrel and M. Barth, The global positioning system and inertial navigation, New York: McGraw-Hill, 1999.
[4] Daniel 1. Biezad, Integrated Navigation and Guidance Systems, American Institute of Aeronautics and Astronautics, Inc., 1999
[5] K. Reif et al., “Stochastic Stability of the Discrete-Time Extended Kalman Filter,” IEEE Trans. Autom. Control, vol. 44, no. 4, Apr. 1999, pp. 714-728.
[6] Lewantowicz, Z., Architectures and GPS/INS integration: Impact on Mission Accomplishment, IEEE Aerospace and Electronics System Magazine, Vol.7, 1991, pp.16-20.
[7] Dongliang Huang, Leung, H., and El-Sheimy, N., Expectation maximization based GPS/INS integration for land-vehicle navigation, IEEE Transactions on Aerospace and Electronic Systems. Vol. 43(3), pp. 1168- 1177, July 2007.
[8] Zhen Guo, YanlingHao, Feng Sun, Wei Gao,“Sigma-Point Kalman Filtering for tightly-coupled GPS/INS”,978-1-4244-3531-9/08/©2008 IEEE.
[9] Hao Wu &TianLei ,RongJian,“New Approach for GPS/INS Integrated Navigation”,978-0-7695-3860-0/09 © 2009 IEEE
[10] Gannan Yuan & Tao Zhang,“UnscentedKalman Filtering for Ultra-tightly Coupled GPS/INS Integration”,978-1-4244-2693-5/09/$25.00 ©2009 IEEE.
[11] Alex Garcia Quinchia&CarlesFerrer, “A Low-Cost GPS&INS Integrated System Based on a FPGA Platform”,978-1-61284-4577-0188-7/11/$26.00c 2011 IEEE.
[12] Myeong-Jong Yu, “INS/GPS Integration System using Adaptive Filter fo Estimating Measurement Noise Variance”,”,IEEE Transactions On Aerospace And Electronic Systems Vol. 48, No. 2, April 2012.
[13] Tamer AKCA &Mubeccel DEMIREKL, “An daptive Unscented Kalman Filter for Tightly Coupled INS/GPS Integration”,978-1-4673-0387-3/12/©2012 IEEE.
[14] Kamal Saadeddin, Mamoun F. Abdel-Hafez, Mohammad A. Jaradat, and Mohammad Amin Jarrah, “Optimization of Intelligent-Based Approach for Low-Cost INS/GPS Navigation System”,978-1-4799-0817-2/13/©2013 IEEE.
[15] Garry A. Einicke,Gianluca Falco, and John T. Malos, “Bounded Constrained Filtering for GPS/INS Integration”, 0018-9286/© 2012 IEEE.

BIOGRAPHIES

Mr. Amol M. Kendre, Student of ME in Electronics and Telecommunication, D. Y. Patil School of Engg, Ambi, Pune, India

Dr. Vilas N. Nitnaware (Guide) [M. Tech., PhD] Principal of D.Y. Patil College of Engg. Ambi Pune. Maharashtra, India

Mrs. Vaishali V. Thorat (Co-guide) B.E, M.TECH (VLSI). Asst Prof and P.G. Co-ordinator of D.Y. Patil School of Engg, Ambi Pune