Extended Kalman Filter for An outdoor navigation System using INS/GPS System Platform

Bolisetti Sai Sandeep*1, and G Shanmugapriya#2

*B.Tech (ECE), CMR Institute of Technology, Hyderabad, India

#Assistance Professor (ECE), CMR Institute of Technology, Hyderabad, India

1saisandeep408@gmail.com

Abstract: Normally low cost GPS receivers do not guarantee accurate continuous data to the positioning system. This is because of the temporary loss of satellite connection and signal error. So in this work to avoid these problems an algorithm would be developed The Inertial Navigation System (INS) is broadly connected to route and direction of moving items. Nonetheless, there exist lapses in the inertial sensor's flag that cause unsuitable floats. To minimize these consequences for the INS framework, a GPS is typically utilized all the while with an INS so as to expand the measurement of the framework; the fancied parameters are assessed by Kalman sifting system connected to the extended framework. The algorithm is based on Extended Kalman Filter (EKF) that incorporates ease GPS information and in-vehicle sensors information to adjust the vehicle show in different driving conditions and to evade the slip because of GPS issue. The proposed framework made out of two sorts of vehicle model set, a kinematic vehicle model and an element vehicle model. These two models are created utilizing Extended Kalman Filter (EKF) and taking into account the driving condition a suitable model will be chosen.

Key words: Extended Kalman Filter, In-vehicle Sensors, GPS/INS integration, Kalman filtering.

I. INTRODUCTION

The Global Positioning System (GPS) provides information about location pon or near the earth. Satellites send information such as their position in orbit and the time the signal is sent to receivers that interpret the data into latitude and longitude coordinates. When GPS information is given to an autonomous vehicle, the computer in the vehicle must interpret the data and make a decision on how to reach its destination. The hardware components and algorithms behind autonomous GPS navigation are constantly changing. This paper reviews state of the art commercial applications and the technology behind them that makes autonomous GPS navigation possible.

One of the adult advances for route is the Global Positioning System (GPS) with the preferences of high precision and time freedom situating. Then again, GPS route is experiencing sign misfortunes due to geographic hindrances and additionally specific accessibility (SA) in unique cases

Today the essentialness of ongoing vehicle situating is more than that in the prior time. Canny transportation framework (ITS) is one of the imperative regions where constant vehicle situating is utilized. Typically, the satellite-based Global Positioning System (GPS) is broadly utilized for situating the vehicle. However these GPS collectors can't give precise data about the situating of the vehicle because of the interim or periodic loss of satellite association and signal mistakes. To beat these issues the situating framework ought to be supported by extra sensors, for example, Inertial Navigation System (INS), computerized guide, cam, radar or laser sensor, vehicle movement sensors, and so forth [1]. The past works will rouse to create a calculation for constant vehicle situating on disappointment of GPS, which ought to beat the whole issue influenced in the past works and that calculation ought to give solid, precise and consistent information. In the proposed framework, the information from in-vehicle sensors, for example, wheel speed sensors, a yaw rate sensor and a guiding plot sensor with GPS information are combined by the assistance of Extended Kalman channel (EKF). To wire these information, the calculation needs great channels. For that various Bayesian channels based sensor combination methodologies have been proposed [13]. The amplified Kalman channel (EKF) is the most generally utilized channel for data combination calculations since nonlinear limitation issues can undoubtedly be illuminated which gives productive and dependable execution to viable applications.

In this project, an algorithm would be produced, which joins the information from in-vehicle sensors, for example, wheel speed sensors, yaw rate sensor and directing point sensor with GPS information. So this calculation gives a more exact, constant what's more dependable conclusion to situating the vehicle. In this work EKF is utilized for the combination of as a part of vehicle sensor information with GPS information. An alternate vital thing is the examination of distinctive driving states of the vehicle. Contingent upon the driving conditions, the information from in-vehicle sensors will change and the event of lapse will be more. So the calculation ought to have suitable vehicle model set for diverse driving conditions. In this work, two-vehicle models would be produced, kinematic and dynamic vehicle model.

The kinematic model is suitable for low speed and low slip driving condition, for example, those in a crossing point or parking area. Element model is suitable under high velocity and extensive slip driving conditions, for example, those in parkway driving. These two models are created utilizing EKF. Kinematic model is focused around the presumption of little wheel slip condition, however in dynamic model tire slip and parallel energy are considered. The choice of these models amid continuous is a testing procedure. This methodology portrays that the framework chooses one of the models from a limited number of distinctive model focused around the pace scope of the vehicle.

II. Related Work

The heart of the combination of GPS and INS is the Kalman channel (KF) that can offer a consolidated framework with higher execution in correlation to either framework in stand-alone mode. A Kalman channel is a straight estimator that uses data of the current framework's elements and measured information to acquire an ideal evaluation of the state variables [4]. The mix plans can be isolated into two classes: approximately coupled and hard coupled methodologies [5]. In a firmly coupled plan, all measured information from GPS and INS are prepared in one channel. This kind of plan gives the playing point of saving information accessibility and uprooting poor GPS estimations.

In any case, this plan is more intricate than the approximately coupled plan [6]. Creating route frameworks for area route has pulled in numerous specialists [7, 8]. In [9], the execution

of the reconciliation framework in difficult GPS situations is given. Besides, there is a need to present reconciliation frameworks with low value; the utilization of MEMS based IMU is a decent arrangement because of their minimal effort. Shin et al. have utilized a speed matching arrangement as the alignment system to scaffold the GPS crevice [10]. Mohamed et al. have created a versatile calculation to gauge the framework's clamor lattice and the estimation clamor covariance framework for INS lapse estimation [11]. As of late, Fournier et al. have proposed a versatile calculation utilizing wavelet for INS slip estimation [12]. Nonetheless, all these calculations need to face the issue of continuous prerequisites. The point of our work is to create a constant ease route framework utilizing aparallel Kalman channels structure as a part of request to apply INS/GPS in true circumstances

Numerous calculations advanced in the recent decades to accomplish continuous vehicle situating. Combination of GPS information with vehicle sensors information is the normal answer for enhance the vehicle situating. In past works, extra sensors for example, an inertial route framework (INS), vehicle movement sensors, radar or laser sensor, and so forth were utilized alongside GPS recipient. The combination of GPS information with INS is regularly done in past calculations, where the issue is the establishment of an INS obliges additional expense and exertion; additionally exact INS frameworks are excessively lavish for car application. To handle the issue connected with GPS, a few methodologies have been proposed. Consolidated utilization of GPS what's more an inertial estimation unit (IMU) unit is one arrangement [1], [2], [3]. The principle issue in this calculation is the slips brought on by predisposition in the sensor readings and erroneous readings which will result in mistake in the neighborhood route outline. An alternate arrangement is consolidated utilization of GPS and MEMS (Micro Electro Mechanical System) inertial sensor [4], [5]. The essential focal points of this system are exact and much quicker response yet the execution of the framework would

be influenced by outside elements. Utilization of Differential GPS is an alternate arrangement [6]. It will dodge the lapses happen because of the synchronization issue. Be that as it may it doesn't promise right information at unfailingly. Kalman channel based coordination of DGPS furthermore vehicle sensors is an alternate calculation created around there, however this calculation lives up to expectations just in a straight framework, not in a nonlinear framework [7], [8], [9]. Furthermore another substantial calculation is the combination of GPS information with vehicle movement sensor information utilizing molecule [10]. This calculation gives more exact and right information to the situating framework, however one issue in this technique requires unnecessary computational force. The other suitable work around there is the combination of GPS with INS utilizing communicating various model channel calculations [11], [12]. The main issue is that, INS framework is as well costly.

III. System Model

3.1 Inertial Navigation System (INS)

An INS framework frequently comprises of three accelerometers also three spinners keeping in mind the end goal to measure the increasing speeds in three measurements and the pivot rates around three tomahawks. The advancement of MEMS innovation has been a boost to broaden the application region of INS. Today, an Inertial Measurement Unit (IMU) indeed incorporates a three-level of opportunity spinner and a three-level of opportunity accelerometer [13, 14]. There are two average INS frameworks: gimble and strapdown [15]. The strapdown INS framework is more well known than the gimble framework and is for the most part focused around MEMS innovation that is generally economical and minimized. In the strapdown framework, accelerometers and spinners are altered to the edge of the air ship. Signals from these sensors are handled so as to acquire three Euler edges. The results are amended by gravity quickening and Earth revolution speed.

International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)
ISSN: 0976-1353 Volume 10 Issue 1 –OCTOBER 2014.

The introduction of the flying machine is controlled by three Euler plot (y, q, f), as represented on Figure 1. The taking after mathematical statement demonstrates the connection between speeds of roll. The orientation of the aircraft is determined by three Euler angles (y, q, f), as illustrated on Figure 1. The following equation shows the relation between velocities of roll, pitch and yaw (p, q and r), and the three Euler angles

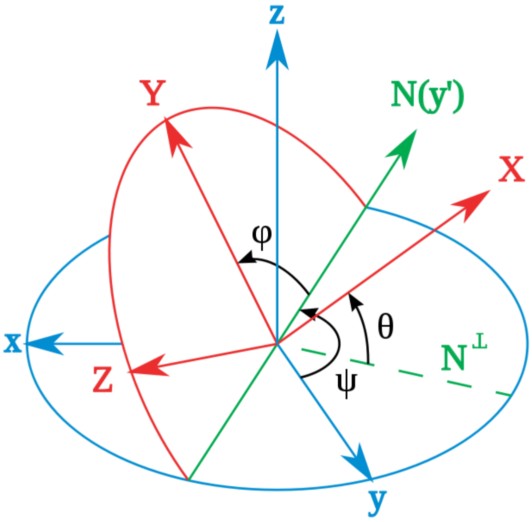

Fig1: After integrating (2), we can obtain U, V and W. Using the Direct Cosine Matrix (DCM), as given by Equation (3) at the beginning of the next page we can convert the movement from the Earth fixed frame to the navigation frame (see Figure 2)

˙U= ax + V.r □W.q + g. sin q
˙V= ay □ U.r +W.p □ g. cos q sin j (2)
˙W= az □ U.q +W.p □ g. cos q cos j

3.2 Global Positioning System (GPS)

The GPS framework comprises of 24 satellites, which fly over the Earth at a tallness of 19200 km with a specific end goal to procure the position of a flying machine (scope, longitude what's more stature) [4]. In any case, structures, burrows, and so forth frequently piece radio signs. To get the right position of the air ship requires no less than four satellites. GPS can be differentiated in three sections

Space fragment: comprising of 24 satellites;
Control fragment: the ground control;
User fragment: the recipient (common and military purposes).

Lapses in GPS are for the most part brought on by the accompanying six elements (excluding specific accessibility slip): ephemeris information, satellite clock, multipath reflection, barometrical postponement, irregular estimation commotion and collector (counting programming).

3.3 Integration of INS and GPS using Kalman Filtering

The INS framework has two fundamental focal points when contrasted and other route frameworks: independent capacity and high exactness for transient route. On the other hand, a genuine issue of INS is the aggregation of gyrator and accelerometer lapses.

Subsequently, in long haul route applications, INS meets expectations with the support of different frameworks, for example, radio route frameworks . Structure of GPS [16]. (Loran, Tacan) or satellite route frameworks (GPS, GLONASS). The vital focal point of these frameworks

is that their execution is steady. Therefore, there is an extraordinary requirement for joining of INS and one of these frameworks. The joining of INS and GPS is considered as a decent consolidation. The heart of the coordinated framework is the Kalman calculation [17]. As specified some time recently, the point of this paper is to create a particular plan for INS/GPS joining that can be utilized as a part of the situation where the GPS sign gets most habitually lost. The coordination framework focused around two parallel Kalman channels is created and tried. The INS/GPS framework can switch between food forward and input plans relying upon GPS situations. The INS mistake mathematical statements are utilized as a framework model what's more the measured data information bolstered to the channel are the contrasts between the INS and GPS positions and speeds. At the point when GPS information is not accessible, the Kalman channel meets expectations in expectation mode and the INS/GPS framework switch to the food forward plan.

3.4 UWB Pulse

Subsequently, UWB gadgets oblige low transmit control because of this control over the obligation cycle, which specifically means longer battery life for handheld supplies. Since recurrence is conversely identified with time, the brief time UWB beats spread their vitality over an extensive variety of frequencies—from close DC to a few giga hertz (Ghz)—with low power spectral density(PSD).

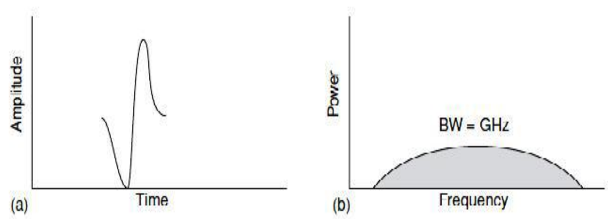

Fig2: A UWB pulse in (a) the time domain and (b) the frequency domain.

IV. SYSTEM OVERVIEW

The below figure describes the general framework review the proposed work. The proposed calculations consolidate the information from in-vehicle sensors with GPS recipient and give dependable and constant position data. Proposed framework is ordered into two sections, a sensor part and a position calculation part. The sensor part is made out of a gathering of invehicle sensors and an ease GPS beneficiary. The situating calculation part made out of two distinctive model, kinematic model and element model. These two models show the vehicle in distinctive driving condition. In the proposed framework, the situating calculation that gauges the vehicle position by joining information from in-vehicle

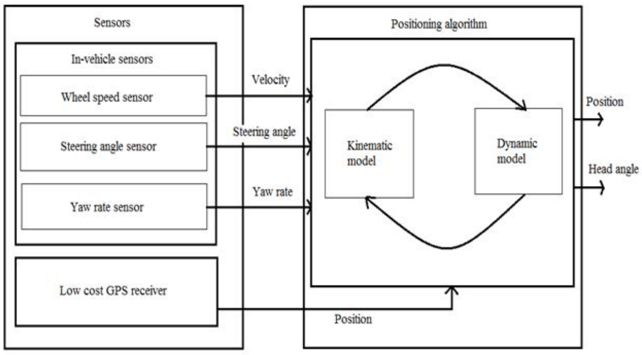

Fig:3 System overview of proposed system.

The above fig.1 depicts the general framework review the proposed work. The proposed calculations consolidate the information from in-vehicle sensors with GPS collector and give solid and persistent position data. Proposed framework is characterized into two sections, a sensor part and a position calculation part. The sensor part is made out of a gathering of invehicle sensors and a minimal effort GPS recipient. The situating calculation part made out of two diverse model, kinematic model and element model. These two models show the vehicle in distinctive driving condition. In the proposed framework, the situating calculation that gauges the vehicle position by consolidating information from in-vehicle sensors with GPS recipient information. This calculation is the blending of Extended Kalman Filters. EKF is utilized as data combination calculation and predicts the following state as for the current state. The essential point of interest of EKF is that it will maintain a strategic distance from the nonlinear limitation issue. At that point focused around the vehicle speed any of the vehicle models will be chosen. Regularly, kinematic vehicle model is suitable in low speed and little tire slip condition, and element model is suitable for fast and huge tire slip condition. So at rapid element model ought to be chosen and so also at low speed kinematic model is chosen.

V. EXTENDED KALMAN FILTER

The proposed situating calculation is focused around the working of augmented Kalman channel. Here two kind of vehicle model set are utilized. These two models are created by utilizing EKF. Under rapid and high slip driving conditions, the element model based channel is utilized on the grounds that it considers parallel constrain and tire slip. So also, under low speed and low slip driving conditions, the kinematic model based channel is utilized on the grounds that the slip plot of the tire is little. Stretched out Kalman channel has turned out to be a helpful technique for acquiring great appraisals of the framework state [15]. It comprises of two steps, forecast step and redesign step. In foresee step, the state and covariance framework of the past state are anticipated. What's more in the redesign step, upgrade the anticipated state and covariance framework.

Predict equation

Predicted state estimate

$$\hat{x}^{i}_{k/k-1} = f_i(\tilde{x}^{i}_{k-1/k-1}, u_k) \qquad i = 1,2$$

Predicted covariance estimate

$$\hat{P}^{i}_{k/k-1} = F^{i}_{k}\tilde{P}^{i}_{k-1/k-1}(F^{i}_{k})^T + G^{i}_{k}Q_{k-1}(G^{i}_{k})^T \qquad i = 1,2$$

Update equation

Innovation or measurement residual

$$\tilde{y}_k = z_k - h(\hat{x}_{k/k-1}$$

Innovation (or residual) covariance

$$S^{i}_{k} = H\hat{P}^{i}_{k-1/k-1}H^T +$$

Near-optimal Kalman gain

$$K^{i}_{k} = \hat{P}^{i}_{k/k-1}H^T(S^{i}_{k})^{-1}$$

Updated state estimate

$$\hat{x}^{i}_{k/k} = \hat{x}^{i}_{k/k-1} + K^{i}_{k}(z_k - H\hat{x}^{i}_{k/k-1})$$

Updated estimate covariance

$$\hat{P}^{i}_{k/k} = (I - K^{i}_{k}H)\hat{P}^{i}_{k-1}$$

Where the state transition and observation matrices are defined to be the following Jacobians

$$\frac{\partial f_i}{\partial x} = F^{i}_{K} \qquad i = 1,2$$

$$\frac{\partial h_i}{\partial x} = H^{i}_{K} \qquad i = 1,2$$

The states of both vehicle models are represented as

$$x_k = [\, v_k \;\; \beta_k \;\; \gamma_k \;\; \psi_k \;\; X_k \;\; Y_k \,]^T \qquad (18)$$

The model input is described as

$$u_k = [v_{whl} \;\; \delta_{SAS}]^T \qquad (19)$$

Measurement input is described as

$$z_k = [\, V_{GPS} \;\; \gamma_{yawrate} \;\; (\beta+\psi)_{GPS} \;\; X_{GPS} \;\; Y_{GPS}]^T \qquad (20)$$

VI. SIMULATION AND RESULT

The proposed calculation was examined through serious recreation and aftereffects of reenactment are plotted as diagrams. The reproduction was performed utilizing MATLAB programming and Simulink bundle is utilized to break down the calculation. The kinematic and dynamic vehicle models are created by utilizing client characterized squares as a part of Simulink where the inputs given to the pieces are speed, controlling plot, yaw rate and position.

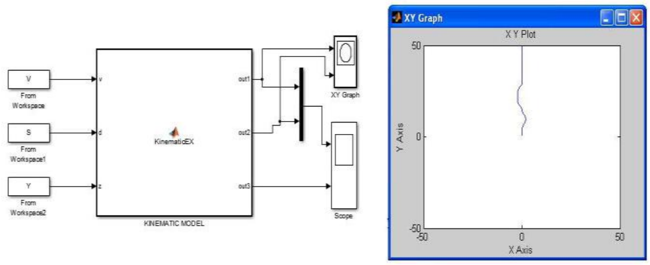

Fig: Simulation result of dynamic model in Simulink

The element vehicle model is comparable expect the incorporation of the parameters, tire slip and parallel power which is portrayed in fig.5. The figure demonstrates the Simulink model of element vehicle model and its yield plot focused around the inputs. The element model is suitable just when the vehicle moving at high velocity. In the event that the vehicle is moving at moderate

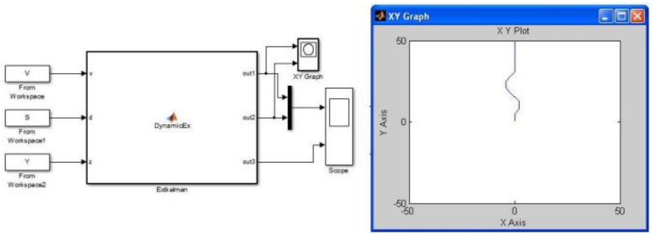

Fig4: Simulation result of dynamic model in Simulink.

Speed then the model won't foresee precise position and yield contain more mistake. The inputs to this Simulink model, ordinarily speed is given as steadily expanding way. So in low speed, the chart plotted utilizing the element model is incorrect that we can see

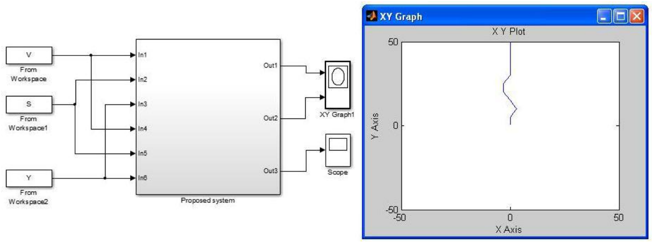

Fig5: Simulation result of dynamic model in Simulink.

At long last, fig.6 demonstrates the proposed model which typified both kinematic and element model where the speed of the vehicle demonstrations as the condition for selecting the model to be performed. The inputs to this Simulink model, regularly speeds are given as progressively expanding way. So focused around the speed of the vehicle the proposed framework will select a suitable model. In the event that the vehicle is moving at moderate speed then the proposed framework select kinematic model and the vehicle is moving at rapid then the proposed framework select element model. The yield of the proposed model discovered to be more exact when contrasted with the yield indicated in fig.4 and fig.5.

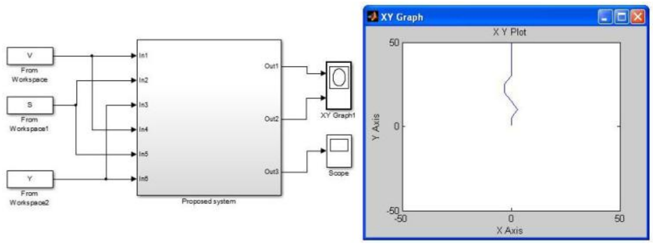

Fig6: Simulation result of proposed model in Simulink.

VII. CONCLUSION

A calculation for ongoing vehicle situating framework is effectively recreated which fuses both kinematic and dynamic vehicle model utilizing EKF. The stage utilized for mimicking the calculation is Simulink which is an extra bundle of MATLAB programming. The reenactment result demonstrated that the evaluations of the created calculation were exact and solid under the different driving conditions. Because of the constraints of the two level of opportunity, the estimation of vehicle position in a sharp inclined driving environment and substantial longitudinal tire slip condition was denied. As an augmentation of this work, stochastic calculations can be coordinated, which serves to enhance the exactness in the result of the framework.

VIII. REFERENCES

[1] M. Omerbashich, "Integrated INS/GPS navigation from a popular perspective," Journal of Air Transportation, vol. 7, pp. 103–119, 2002.

[2] S. J. Randle and H. M. A, "Low cost navigation using micro-machined technology," in Proc. IEEE Intelligent Transportation Systems Conference, 1997, pp. 1064–1067.

[3] S. Panzieriy, F. Pascucciz, and G. Uliviy, "An outdoor navigation system using GPS and inertial platform," IEEE ASME Transactions on Mechatronics, vol. 7, pp. 134–142, 2002.

[4] A. Gelb, Ed., Applied Optimal Estimation. The Massachusetts Institute of Technology Press, 1974.

[5] D. T. Knight, "Rapid development of tightly-coupledGPS/INS system," IEEE Aerospace and Electronics Systems Magazine, vol. 52, pp. 14–18, 1997.

[6] C. Jekeli, Ed., Inertial Navigation Systems with Geodetic Applications. Walter de Gruyter, New York, 2001.

[7] R. Wolf, B. Eissfeller, and G. W. Hein, "A Kalman filter for the integration of a low cost INS and an attitude GPS," in Proc. Int. Symp. Kinematic Systems in Geodesy, Geomatics and Navigation, 26-29 Apr. 1997, pp. 143–150.

[8] H. Qi and J. B. Moore, "Direct Kalman filtering approach for GPS/INS integration," IEEE Trans. Aerosp. Electron. Syst., vol. 38, no. 2, pp. 687– 693, Apr. 2002.

[9] F. Caron, E. Duflos, D. Pomorski, and P. Vanheeghe, "GPS/IMU data fusion using multisensor Kalman filtering: Introduction of contextual aspects," Inf. Fusion, vol. 7, no. 2, pp. 221–230, Jun. 2006.

[10] Y. Cui and S. S. Ge, "Autonomous vehicle positioning with GPS in urban canyon environments," IEEE Trans. Robot. Autom., vol. 19, no. 1, pp. 15– 25, Feb. 2003.

[11] R. Toledo-Moreo and M. A. Zamora-Izquierdo, "IMM-based lane-change prediction in highways with low-cost GPS/INS," IEEE Trans. Intell. Transp. Syst., vol. 10, no. 1, pp. 180–185, Mar. 2009.

[12] D. Huang and H. Leung, "EM-IMM based land-vehicle navigation with GPS/INS," in Proc. IEEE ITSC, Washington, DC, 2004, pp. 624–629.

[13] Kichun Jo,Keounyup Chu and Myoungho Sunwoo, "Interacting Multiple Model Filter- Based Sensor Fusion of GPS With In-Vehicle Sensors for Real-Time Vehicle Positioning" in IEEE Trans. Intell. Transp. Syst., vol. 13, no. 1, Mar. 2012.

[14] S. S. Haykin (Ed.) Kalman filtering and neural networks (pp. 123-174). New York: Wiley. 2001.

[15] C. Barrios, H. Himberg, Y. Motai, and A. Sadek, "Multiple model frame- work of adaptive extended Kalman filtering for predicting vehicle loca- tion," in Proc. IEEE ITSC, Toronto, ON, Canada, 2006, pp. 1053–1059.

[16] R. Rajamani, Vehicle Dynamics and Control. New York: Springer-Verlag, 2006.

[17] M. Tanelli, L. Piroddi, and S. M. Savaresi, "Real-time identification of tire-road friction conditions," IET Control Theory Appl., vol. 3, no. 7, pp. 891–906, Jul. 2009.

AUTHOR DETAILS:

Bolisetti Sai Sandeep pursuing B.Tech Degree in Electronics and Communication Engineering from CMR Institute of Technology, Hyderabad, India

G. Shanmugapriya is presently working as a Assistant professor,Dept of Electronics and Communication Engineering from CMR Institute of Technology, Hyderabad, India.She obtained ME in Anna University, Tamilnadu