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Enhancing the accuracy of GPS positioning for vehicle tracking system

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Abstract—Vehicle security refers to securing the vehicle against potential thieves. Vehicle makers have been experimenting with various approaches in order to give improved security systems. The usage of GPS and GSM technology can provide security for the car. The security of a vehicle is ensured in this project by tracking its whereabouts. For the integration of the global positioning system, the EKF is widely utilised (GPS) When the system non-linearity grows or the measurement co-variance is erroneous, the EKF’s performance deteriorates. An extended state observer is introduced for the first time to improve loosely coupled GPS navigation performance utilising accurate measurement modelling. The RMS values of positional errors are reduced by 52.57 percent, 48.56 percent, and 34.16 percent in the north, east, and vertical directions, respectively.

Keywords
Navigation performance, EKF, Extended state observer, Global positioning system (GPS)

I. INTRODUCTION

Theft of vehicles has become a major issue in recent years. The majority of the time, the owner of the stolen vehicle is unable to locate it. As a result, there is a desire for more advanced security systems. Previous study described a security system that incorporates GPS and GSM technology. GPS is a communication system based on satellites. The GPS satellites emit signals at L1 and L2 frequencies that carry ephemera’s data, navigation data, codes, and other information that is used to establish the vehicle’s location in three-dimensional coordinates, such as latitude, longitude, and altitude, as well as the precise time. The transmissions from GPS satellites are free of charge, allowing GPS receivers to calculate their location the time, as well as the speed GPS receivers have a tracking sensitivity of -160dBm, which permits continuous position coverage in all conditions. The Global System for Mobile Communication (GSM) is an acronym for Global System for Mobile Communication. Short Message Service (SMS) is a GSM-based alternative to voice calls (SMS). When the security mode is enabled, the GSM modem transmits the GPS parameters of latitude and longitude values. As a result, a user can use their Smartphone to continuously watch a moving vehicle and predict the distance and time it will take to get at a certain destination. The GPS working mechanism is based on distance measurements between the receiver and satellites. The GPS is divided into three sections: spatial, control, and users. The system consists of 24 satellites orbiting the Earth at a distance of over 20 thousand kilometers, with six orbital levels and a 12-hour interval. The Earth stations that regulate the satellites’ trajectories make up the second portion. Finally, the user’s portion incorporates GPS receivers that operate on two frequencies: L1 for civil use at 1575.42 MHz and L2 for military use at 1227.60 MHz. 95 percent of the time, the precision of longitude and latitude coordinates is 10-15 meters. It can be more exact at times, but this is dependent on a number of factors, including signal deviation or delay as it travels through the atmosphere, signal bouncing in buildings or concealment owing to the presence of trees [6,] low clock precision, and receiver noise. The precision of the results obtained in terms of longitude and latitude is lowered to 50% at altitude (15-23 meters 95 percent) This study is based on how to make GPS precision more accurate for tracking the vehicles. Many techniques have been used for enhancing the accuracy of GPS precision, but the latest technique that have been used for enhancing the accuracy of GPS precision is the EKF.
Background and Related work

That is, use the merge algorithm to get GPS, ECF information. Because ECF-based models are, for the first time, roughly, along the line, non-linear systems, the performance loss can yield if the system is in a high degree of non-linearity or unknown, existing factors of a higher order. A number of solutions have been proposed to solve this problem. In the past, it has been demonstrated that the Kalman filter odorless system improves performance. The UCF technique, on the other hand, performs poorly when they are in previous knowledge, matrix, lack of symmetry, positive uncertainty. Wang et al. (2019) proposed a singular value decomposition of the UKF (SVD) tracking system. Ran et al. (2019) collaborators of the extended state observer, GPS Functions (ESO) for general thought estimation of non-nonlinear second-order multi-agent systems. Based on ESO results, improve anti-interference behavior. We present an improved ECF methodology for the integrated GPS. To check the operation of the proposed design-GPS system, use simulation and field tests of cars. The standard EKF comparison approach will be in terms of navigation functions, as well as functions that will determine which method the result is. The results of modeling and field experiments, as well as comparison and analysis of the results of using GPS technology are presented. The last section of the results.

LITERATURE SURVEY

The accuracy of single-frequency data is improved by calibrating TEC(total electron concern) of the beneath the satellite. Data from a global network of GPS devices provides timely, continuous, and globally well-distributed observations of ionospheric electron concentration. Because the true refractive index profile at a specific location is rarely known, the neutral atmosphere delay is typically accounted for using prediction models. [3] Two novel reference station design strategies have been developed for differential GPS implementations. A single frequency reference station cannot accurately remove multi path faults in broadcast adjustments. The two frequency technique is capable of predicting and removing multi path effects from acquired corrections with accuracy. The algorithms improved the accuracy of the basic corrections by 6 and 20 decibels, respectively. The amount of time it takes the army to establish a stable state for the operation’s steady state phase is one of these considerations. [4] Nearly half of all GPS points recorded with the Quartz Q1000XT GPS units were within 2.5 metres of the intended position (49.6%), 78.7% were within 10 metres, and the median inaccuracy was 2.9 metres. The dynamic spatial precision of this device isn’t ideal. [5] A group of scientists show that how a proposed method for kinematic placement can rectify the multi-path effect. The experiment was conducted out with the rover moving in a smooth motion, allowing the approach performance for kinematic and static processing to be observed. [6] People want their automobile security to be in good hands, so vehicle monitoring systems are becoming increasingly popular. This technology is fully integrated, allowing the user to simply track their vehicle at any time and from any location. The user can utilise this method to find out where the car is and how far it has travelled. This arrangement is relatively straightforward to upgrade, making it adaptable to future needs without having to rebuild everything from the ground up. [7] The GPS accuracy of consumer-grade tablets is insufficient for reliable initialization in AR applications. While specialised equipment (even inexpensive equipment) can achieve significantly higher accuracies and reliability than consumer-oriented tablet devices, even the most precise devices have shortcomings. On-device filtering was used by some of the devices to filter the data from the received GPS data, showing the usage of prediction. When creating apps that demand precise, accurate GPS capability, this type
of functionality must be considered. [8] A group of researchers from the University of California, Berkeley, has created a new method for tracking GPS-based location. They were able to obtain centimeter-scale tracking precision that was 7-20 times greater than "normal" GPS positioning techniques, as well as sub-meter accuracy that was up to 20 times better. A group of researchers has devised a novel method for tracking satellite data that relies solely on low-cost commercial GPS sensors. They claim that it could open the door to future study and applications that are currently impossible, out of reach, or prohibitively expensive. [9] It is possible to use the PGPS method, which is a living thing approach to GPS calibrating. This approach has the advantage of being reactive to carrier activity and requiring no hardware. It infers carrier motion and improves GPS location accuracy by using GPS data as guidance reference units. [10] Wearable GPS devices are a logical next step in establishing a link between location and health. To visualise the data, maps representing the spatial and temporal boundaries traversed by people might be employed. Traditional health determinants can be used to categorise data in order to see if there are any consistent spatio-temporal patterns among groups with similar characteristics, or if there are any properties of places in time that can explain health variation. [11] Researchers from the University of California have presented a method for recovering vehicle trajectories and speeds from video processing of unmanned aerial vehicles (UAVs). They discovered that with good precision, UAVs can extract the same trajectories as a GPS (Global Positioning System) sensor mounted on board. More research is needed, however, to validate that the established approach can be used to all "non-instrumented" autos travelling through the areas under investigation. [12] The outcomes of low-cost GPS receiver point positioning are dependent on receiver tracking capabilities, i.e. hardware-based-limit, and measurement error handling. Multipath is the limiting factor if atmospheric biases are adequately accounted for. The method can be used in both static and kinematic situations. It is possible to get a 3D inaccuracy r.m.s. of about 50 cm. [13] The measurement noise of the EKF and UKF GPS positions was calculated using the European Space Agency (ESO). The ESO can efficiently collect precise observations and improve the precision of the system’s state estimate. In terms of integrated GPS/INS performance, it outperformed the standard Ekf, UKF, and IEKF. The velocity errors in vertical directions are 42.13 percent, 31.38 percent, and 33.86 percent, respectively. Because it is mostly controlled by the IMU’s quality, the improvement in attitude performance is minimal. [14] In the analysed devices, GPS components were used. The findings of our research reveal that GPS yields varying results depending on the application. The study compared the accuracy of the apps Endomondo, RunKeeper, and MapMyRun across a one-kilometer distance. It’s still unclear how long-distance measurements work; for example, a marathon (42.195 kilometres) would result in a discrepancy of 2531.7 metres. This would alter a runner’s performance by 12.6585 minutes if he or she runs at a 5 minute per kilometre speed. [15] The beacon stations use maritime radio beacon frequencies. In real time, the corrective data often offers 1- to 5-meter accuracy. The beacon station calculates the error correction factor and delivers it to the field receiver of GPS. [16] In an intermediate city, the LoRa communication system for public transportation could be used. It includes positioning the gates in strategic locations with sufficient height and visibility to the routes from where the automobiles would broadcast signals. In the end, about a quarter of the messages sent by the devices were not received. [17] The approaches established enable the degree and direction of error caused by the GPS system to be determined. Another receiver uses this adjustment to correct its own position, increasing positional accuracy and allowing for the most exact distance measurements. Experiments with various sets of data yield positions that may be used to determine distances, with errors ranging from 1 metre in 95% of cases to 0.2 metres in others. [18] there is a critical demand for devices that can correctly assess a variety of physical activities. Pedometers have been demonstrated to be fairly accurate in counting steps but imprecise in calculating energy consumption. The ability of different types of activity trackers to accurately monitor energy expenditure has been quite diverse. More study is required to identify the best gadgets now available on the market so that the general public may make well-informed judgments. [19] People can use the system to track their vehicle’s location, speed, stops, and movements. Setting speed and geographical limitations, obtaining historical data of the vehicle’s
travels, and real-time tracking are all part of the monitoring process. If the automobile is suspected of being stolen, this technology can also be used to prevent car theft by combining the device with the car alarm and receiving a map indicating the car’s location. [20] Long-term acquisition of wide-field image sequences is becoming more capable of overhead persistent surveillance systems. The capacity to monitor a single vehicle of interest or all observed vehicles through broad, crowded regions while they remain visible in the images is extremely desirable. There are numerous difficulties in processing this type of data, some of which will be discussed in this study. [21] A innovative way of vehicle tracking and monitoring systems that will improve vehicle security has been discussed in this research. Along with the speech output, we also incorporate the monitoring of engine temperature and even speed control at specific spots identified by the GPS. As a result, this strategy will be simple to incorporate in car systems in the near future. [22] A complex air pollutant, is easily inhaled, it has the potential to cause serious diseases. In this research, we propose a new picture-based predictor of concentration (PPPC) that uses images taken with mobile phones or cameras to estimate PM 2.5 concentration in real time. In terms of prediction accuracy and implementation efficiency, the PPPC model outperformed existing relevant state-of-the-art predictors. [23] Driving Assistance Systems are manufactured to assist drivers. To test the system, many cars having 802.11-based communication capability are employed. 2 receivers are placed in each car to provide a consistent baseline reference. The GSG’s single-epoch Real-Time Kinematic solutions are now significantly more reliable. [24] Wavelets can be utilised to lessen multi-path effects in GPS applications, according to a group of scientists. The distances between receivers and satellites are taken into account by the DD functional model. Other issues must be addressed, such as the addition of extra reflectors and varying distances from the antenna. [25]

II. METHODOLOGY

A. The EKF

The following is a summary of the discrete-time EKF algorithm: (1) \( \hat{x}_0 \) and \( P_0 \) are the initial state vector and state covariance matrix, respectively. (2) Calculate the Kalman gain matrix as follows:

\[
K_k = P_k^{-} H_k^T \left[H_k P_k^{-} H_k^T + R_k\right]^{-1} \tag{1}
\]

(3) Update-state vector:

\[
\hat{x}_k = \hat{x}_k^{-} + K_k \left[z_k - h(\hat{x}_k^{-})\right] \tag{2}
\]

(4) Update-error co-variance

\[
P_k = \left[I - K_k H_k\right] P_k^{-} \tag{3}
\]

(5) Predict state vector and state co-variance matrix for a new state.

\[
\hat{x}_{k+1} = f_k(\hat{x}_k^{-}) P_{k+1}^{-} = \Phi_k P_k^{-} \Phi_k^T + Q_k \tag{4}
\]

The linear approximation equations for system and measurement matrices are generated using the relationships.

\[
\Phi_k \approx \frac{\partial f_k}{\partial x_k} \bigg|_{x_k = \hat{x}_k^{-}}, \quad H_k \approx \frac{\partial h_k}{\partial x_k} \bigg|_{x_k = \hat{x}_k^{-}} \tag{5}
\]

\( (P_k) \) is the state-error co-variance matrix defined by in the following equations, where \( x_k \) is an estimation of the system state vector \( x_k \).

\[
E \left[ (x_k - \hat{x}_k) (x_k - \hat{x}_k)^T \right] \tag{6}
\]

B. improved Extended Kalman Filter model for GPS

This section divides the traditional EKF technique and the improved EKF approach based on extended state observer into two sections. The EKF approach as it is known. The typical EKF equation can be stated as follows using the GPS navigation model provided in (1):

\[
\begin{cases}
X_k^- = \Phi_k \cdot X_{k-1}^+ \\
P_k^- = \Phi_k \cdot P_{k-1}^+ \cdot \Phi_k^T + G_{k-1} \cdot Q_{k-1} \cdot G_{k-1}^T \\
K = P_k^- \cdot H_k^T \cdot \left[H_k \cdot P_k^- \cdot H_k^T + R_k\right]^{-1} \\
X_k^+ = X_k^- + K \cdot (Z_k - H_k \cdot X_k^-) \\
P_k^+ = (I - K \cdot H_k) \cdot P_k^-
\end{cases}
\tag{7}
\]

Using the formula below, you can determine \( Q_k \). The predicted and corrected error co-variance matrices at time \( k \) are \( P_k \) and \( P_{k+1} \), and \( K \) is the gain matrix. The noise distribution matrix at time \( k+1 \) is \( G_{k+1} \).

\[
\Phi_k = I + F \cdot dt_k \tag{8}
\]
where the kth sample time is denoted by $d_t^k$. In the EKF, both the process and measurement noises, $w_k$ and $v_k$, are considered zero-mean white sequences with known co-variances $Q_k$ and $R_k$. $R_k$’s value is frequently incorrect, which is a major weakness in this kind of assumption.

C. Improved EKF

The system Integrated GPS / INS contribute to ESO when this situation is measuring the $Z_k$ very large telescope signal. On the one hand, compared to directly using the $Z_k$ in the update process, the EKF output with effectively increases the accuracy of the state estimation. On the other hand, ESO uses the estimated perturbation and update the EKF noise co-variance in real time. Note that ESO is used to estimate the magnitude of the radiation noise measurement and does not change the nature of the noise. We would like to express nonlinear systems, the second one, roughly as shown below:

$$\begin{align*}
\dot{x}_1 &= x_2 \\
\dot{x}_2 &= f(x_1, x_2, t) + \nu
\end{align*}$$

(9)

where $\nu$ represents $v_k$ in (5), $f(x_1, x_2, t)$ represents unknown system interference, and $x_1$ represents, GPS location and the GPS position observable. Assume that the entire interference vector is $x_3 = f(x_1, x_2, t) + \nu$ and that the total interference vector is $x_3 = (x_1, x_2, t)$. The following is a rewrite of the equation:

$$\begin{align*}
\dot{x}_1 &= x_2 \\
\dot{x}_2 &= x_3 \\
\dot{x}_3 &= \eta(x_1, x_2, t)
\end{align*}$$

(10)

To estimate the system’s states $x_1$, $x_2$, and total interference $x_3$, the ESO can be expressed as follows:

$$\begin{align*}
\dot{z}_1 &= z_2 - \beta_1 \cdot \varepsilon \\
\dot{z}_2 &= z_3 - \beta_2 \cdot g(\varepsilon, \alpha_1, \delta) \\
\dot{z}_3 &= -\beta_3 \cdot g(\varepsilon, \alpha_2, \delta)
\end{align*}$$

(11)

The majority of ESO’s convergence speed is due to measurement noise. The higher the value 1, the faster the signal $y$ is followed by $z_1$. The value of $z_3$ is proportional to three (Wu et al., 2014) and the output vector’s $x_1$ and $x_3$.

$$\begin{align*}
X_k^- &= \Phi_k \cdot X_{k-1}^+ \\
P_k^- &= \Phi_k \cdot P_{k-1}^+ \cdot \Phi_k^T + G_{K-1} \cdot Q_{K-1} \cdot G_{K-1}^T \\
K &= P_k^- \cdot H_k^T \cdot [H_k \cdot P_k^- \cdot H_k^T + R_k]^{-1} \\
X_k^+ &= X_k^- + K \cdot (Z_k - H_k \cdot X_k^-) \\
P_k^+ &= (I - K \cdot H_k) \cdot P_k^-
\end{align*}$$

(12)

$R_k$ is the generic co-variance matrix of $z_3$ at time $k$, and $Z_k$ is the value of $z_1$ at time $k$. The ESO and EKF are two separate sections, as can be seen from the above. With position measurement difference $Z$, the ESO’s primary purpose is to get accurate position measurement difference information while reducing measurement noise. In the EKF update process, the former substitutes $Z$, while the latter is utilised to update noise variance in real time.

III. Experiment and results

Throughout this section, we employ approach modelling to examine the efficacy of the proposed algorithm, as well as discuss the institution’s efficacy and the economics of EU member states that impact the situation’s assessment. The picture depicts a car whose courses pass the strength test in two dimensions. On the photo, the dynamic profile and speed are marked. In the north and east directions, speed ranges from around +10 m / s to 10 m / s. GPS and GPS have output frequencies of 1 Hz and 200 Hz, respectively. It is around the year 2000. We feel that GPS position cannot be measured for GPS/INS integration. We added noise to the measurement since it contains noise in the regular surroundings.

A. Positioning performance

The RMS errors of the IEKf methodology are 54.63% percent, 54.15%, and 59.63 percent lower than the method in the north, east, and up directions, respectively.
IEKF-estimated and real states Error using RMS.

Above Figure: Finding error by Comparing EKF and IEKF

Below Table 1:

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>v(k) N(m)</th>
<th>E(m)</th>
<th>U(m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEKF</td>
<td>0.2319</td>
<td>0.2293</td>
<td>0.2022</td>
</tr>
<tr>
<td>EKF</td>
<td>0.5002</td>
<td>0.5002</td>
<td>0.5009</td>
</tr>
</tbody>
</table>

Measured noise is $v_k$, the proposed technique outperforms the EKF by a small margin. It’s important to understand that $2v_k$ denotes a noise amplitude twice that of $v_k$. When the noise starts at $2v_k$, IEKF outperforms EKF significantly. We’ll use $2v_k$ as an example in this research. Inaccuracies in the estimated value

Reduce positioning error of EKF and IEKF using RMS

Above Figure compares EKF and IEKF location estimate errors for EKF with $2v_k$ measurement noise. For varying degrees of measurement noise, the KF’s position estimate errors are smaller than the ‘s. In the N, E, and U directions, the RMS errors of location predictions for the approach are 52.57 percent, 48.56 percent, and 34.16 percent lower, respectively. The UKF method was used in the field test to compare the state errors and system performances. [14]

Below Table 2:

<table>
<thead>
<tr>
<th>IMU</th>
<th>Bias-stability Gyroscope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerometer(mGal)</td>
<td>100</td>
</tr>
<tr>
<td>Noise ARW(°/h)</td>
<td>4000</td>
</tr>
<tr>
<td>VRW(m/s/h)</td>
<td>0.5</td>
</tr>
<tr>
<td>MEMS</td>
<td>3.0</td>
</tr>
<tr>
<td>Navigation grade</td>
<td>0.027</td>
</tr>
<tr>
<td>15</td>
<td>0.003</td>
</tr>
<tr>
<td>0.03</td>
<td></td>
</tr>
</tbody>
</table>

IV. CONCLUSIONS

The ESO was utilised by the researchers to obtain precise observations of the EKF and to assess the system’s measurement noise. In terms of integrated GPS/INS performance, the recommended approach outperformed the EKF and UKF at various degrees of measurement noise. When compared to the EKF technique, the proposed approach’s RMS of positioning errors is 52.57 percent, 48.56 percent, 47.63 percent, and 12.21 percent in the north, east, and vertical directions, respectively. The RMS values of
the velocity errors are 48.20 percent, 43.17 percent, and 22.65 percent lower in the simulation test.

**REFERENCES**


