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PPT-NS: Prioritized Progressive Trend Based Navigational System on GPS data with Artifacts

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Abstract: ***The Global Positioning System is extensively used in the various context and location service-based applications. Any kind of abnormalities requires an efficient and suitable pre-processing algorithm to be implemented on the data which provides accurate results when used in the application synchronizations. This paper illustrates a framework for various pre-processing techniques applied to the real-time GPS data and its effect on trajectory mapping. The technique used includes Prioritized pattern-based, Savitzky-Golay filtering, outlier elimination, de-trending, and coefficient correlation. The performance assessment of methods discussed in this study is calculated in terms of accuracy with the original and re-created trajectory after the pre-processing and found that the best result is given by moving window method.***

Keywords **:** ***Global Positioning System, Time Series Analysis, navigational System, Artifacts, Digital Filters.***

I. INTRODUCTION

The Global Positioning System (GPS) is an advanced navigation system that uses satellites' signals that provide two essential forms of data namely, global time and location information. Such forms of data can be estimated to obtain other supporting data, such as travel trajectories. The function of the advanced navigation system relies primarily on GPS satellites flying in middle Earth orbit, which broadcast standard time and location signals. Using the navigation equation, the receiver or user who receives the signal from the GPS satellite can obtain its current location on Earth. GPS technology was initially introduced for military application, but it has been available for civilian use since the nineties. At present, GPS has become a popular system that has been used in various applications over the past few decades, including geodynamics [1], vehicle position and navigation systems [2], measurement, mapping, and aviation. The surveyor and mapping community was the first to fully utilize GPS and it significantly increased their productivity by reducing the costs associated with equipment and labor, provided reliable and more accurate results.

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GPS technology allows us to accurately model and map the physical world using features measured from the surrounding environment, such as mountains, rivers, buildings, and streets and utility lines. Governments, scientists, and commercial organizations use GPS technology for smart decision making and efficient use of resources [3]. Recently, various location-based services have been provided based on location discovery services due to the large number of GPS-enabled mobile user devices carried by application stakeholders [4]. Location discovery services using GPS are typically used to locate points of interest or locations that are utilized in a wide range of traffic management applications, including road traffic monitoring to vehicle tracking [5] [6]. With the continuous advancement of digital devices and transportation systems, the application of GPS technology has increased and generated a large amount of data, which seems to be a good source for carrying out event analysis and future prediction. As a result, researchers and developers are now more focused on using traffic data for data mining operations and making thing better. However, due to uncertain factors and GPS signal outage, the quality of GPS data degrades, which become an important issue in data mining and analysis. This is because GPS data is associated with significant errors sourced from i) satellite errors, ii) orbits of satellite, iii) errors caused due to multi-path signal propagation, iv) diversified effects of atmosphere, v) errors caused due to local receiver design, and availability of the selective attributes of GPS signal [7].

In practical applications, the positioning algorithm uses data obtained from GPS receivers, typically subject to fluctuations and positioning errors from the actual path. In order to reduce the impact of these undesirable factors on GPS data, a pre-processing operation is required to perform over GPS raw data.

Currently, there are various methods for correcting GPS artifacts e.g., i) correction of post-processing, ii) rectifying the real-time data, and iii) diversified services of satellites [8-10]. However, it has been analysed that existing techniques are not suitable to deal with the GPS data cleaning and smoothing. Most existing methods are designed to handle specific problems and are very time consuming and have enormous computational complexity. In addition, little work has been done to address the problem of accurately categorizing data quality. Therefore, there is a significant need for developing a solution that considers all these factors and constructs a comprehensive model to address the accuracy problem.

Hence, the proposed system offers a discussion of a compact and comprehensive pre-processing model where prioritization is applied over progressive trends of GPS data for better accuracies. Section II discusses the existing research work followed by problem identification in Section III. Section IV discusses the proposed methodology followed with system implementation discussion in Section V. Section VI presents visualization of Raw GPS data followed by processing with elaborated discussion of algorithm implementation in Section VII. Comparative analysis of the accomplished result is discussed under Section VIII, followed by conclusion in Section IX.

II. RELATED WORK

At present, various works are being carried out towards pre-processing the GPS signal with multiple approaches. The work carried out by Xu et al. [11] have discussed about data transformation of GPS signal as a part of the pre-processing approach considering fitting data scheme. Existing system also uses a mining-based approach towards assisting the navigational process in order to access the pattern of GPS-based routes as seen in the work of Necula [12]. Consideration of analysis of noise towards constructing GPS framework is seen in the work of Baykut [13] considering artificial GPS data. Another means of data pre-processing GPS signal is by using obtaining data trajectory followed by mining the patterns obtained from it (Geng et al. [14]). Significance of trajectory data and its review has been carried out by Wu et al. [15]. Mining approach using both time and distance factor is also found to offer better accuracy in processing GPS data. Study towards such an approach was found in the work of Bogorny and Shekar [16] considering a case study of various mobile applications. Lin et al. [17] have carried out a segmentation-based approach where the sliding window was used for better trajectory approximation. The connection between resource consumption and filtering of GPS data was seen in the work of Taylor and Labrador [18]. Existing studies have also found usage of Kalman filter for performing denoising of the GPS signal as witnessed in work of Wu et al. [19] and a similar form of work was also seen to be carried out by Wang et al. [20]. Effect of ionosphere towards artifacts and removal of it is carried out by Bong et al. [21]. A clustering-based method was also proposed by Tang et al. [22] to remove outliers from the raw traces based on the vehicle trajectory trend. Hu et al. [23] presented an efficient index mechanism for distance calculation for query processing over long distances. Xiao et al. [24] removed the incomplete tracking points and tracking points with an altitude of more than 200 that might provide error analysis. They also applied pre-processing mechanisms to clean orbital data. They converted the UTC to local date and time format and rearranged them as all tracking points. A kernel density was applied in the work of Chen et al. [25] to calculate the density of each GPS point and then remove all low-density points. In the work of Xuyun et al. [24], the author introduces an instant mapping algorithm based on the structure of the road network, on which the road network is split into small grids. In the study of Wang et al. [27], the researchers introduced an optimal density optimization scheme for self-outlier detection and its removal process. Phuengsaeng and Sutthisangiam [28] proposed mathematical-based mechanisms, as well as statistical methods to accurately smooth GPS positioning. The idea behind the presented scheme is that dividing the road data into sections, verifying and producing smooth points, enhancing the smooth elevation, and balancing the appropriate slope values. Liu et al. [29] developed the dual-filter smoother technique, which is implemented in the land vehicle navigation applications is introduced. Roth et al. [30] have used particle methods for improvement of ground truth for such road constraint estimation approaches. The bootstrap particle filter and three different particle smoothers are used to obtain the motion target state estimate. Gong et al.[31] have presented a modified nonlinear two-filter smoother for an offline GPS integrated system. The presented smoother has a two-filter design, i.e., forward filter depending on the central difference Kalman filter, and a backward filter is constructed with modified propagation and a smoothing algorithm. New data filtering technique oriented on Vondrak filters and cross-validation mechanism were developed in the study of Zheng et al. [32] to filter noise from the data series and to mitigate GPS multipath effects in applications. Both the analog data series and the real GPS observations were used to test the proposed method. Bouyahia et al. [33] offered a traffic estimation using GPS data and the fuzzy switching mechanism, which provides a more accurate result in terms of traffic estimation than the traditional hard switch models. Kim et al. [34] introduced a road marking mapping approach using an optimal method considering probe vehicle loaded advance precision sensor for locating an autonomous vehicle in an area experiencing GPS interruption. Wang and Namee [35] have presented a study towards the reliability of navigational data obtained from a noisy signal. Decomposition of empirical values towards denoising principle is carried out by Baykut et al. [36]. Viet et al. [37] have carried out a simulation-based study towards analyzing GPS signals. Xipan et al. [39] have carried out by study towards filtering mechanism towards dynamic information of GPS signal. The study of Nitsche et al. [38] adopted a Kalman filter to carry out preprocessing operation over the track data. Rahemi et al. [41] have used the least squared approach for evaluating the signals obtained GPS. The recent work carried out by Ke [42] have used the hybrid decomposition of empirical values of GPS and applied denoising principle over white noise. Saleem et al. [43] have formulated a receiver module focusing on analyzing the GPS signal. Ryu et al. [44] have focused on fusing navigational data from GPS as well as Inertial navigational services focusing on denoising. The next section outlines the research problems.

III. PROBLEM DECRIPTION

Existing approaches towards navigational support system mainly uses Global Positioning System (GPS) which is actually cost effective input towards various navigational devices operating from the ground. The significant problem which is identified as follows:

- There are various reports of inaccuracies as well as error associated in the GPS data which is mainly due to presence of noises.
- It has also been analyzed that there is very less work particularly on pre-processing GPS data.
- Majority of the reported approaches are found to use complex approaches that are more focused on computational operation with larger dependencies over the samples.
- The noises associated with such random samples are never found to be addressed in any existing approaches in cost effective manner.

Therefore, the statement of problem is "*Developing a cost effective navigational system with enhanced form of pre-processing by reducing the noisy information associated with the GPS data*".

IV. PROPOSED METHODOLOGY

The prime aim of the proposed system is to introduce a very simple and cost-effective solution towards performing a pre-processing operation over the GPS data. The schema adopted for the proposed system is as follows:

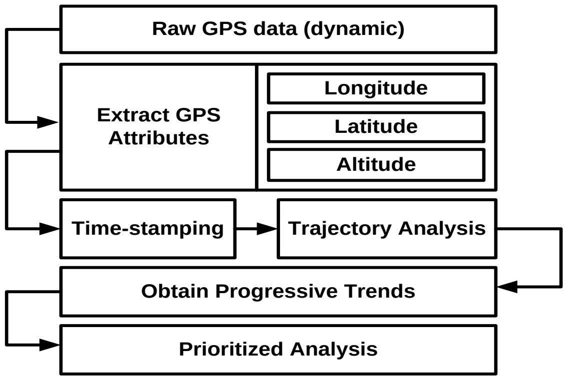


Fig.1 Schematic Diagram of Proposed System

According to Figure 1, the raw data are dynamic GPS signals captured from local GPs device followed by extraction of its attributes. The signals are time stamped followed by analysis of its extracted trajectories. Finally, progressive trends of sampled data are obtained that are further subjected to prioritized analysis to filter the artifacts.

V. SYSTEM IMPLEMENTATION

This section discusses the technique that is adopted in order to carry out the processing of GPS information based on the novel concept of the prioritized progressive trend-based application. This section discusses the attributes involved, implementation strategy, and execution flow.

A. Attributes Involved

The prominent attribute used in the proposed system are basically three types viz. i) forecasting of the range of the GPS sample, ii) assessment with tested positional value of local GPS data, and iii) prioritized progressive trends. The idea is to maintain a good balance between the cost of transmission along with higher accuracy while attempting to perform pre-processing of the raw GPS data for assisting incorrect vehicle navigation system. In order to assign prioritized value to the pattern, the proposed system also considers the time and distance factor associated with the progressive trend analysis.

B. Implementation Strategy

The proposed system implements a unique implementation strategy that is based on time-series analysis. For this purpose, real-time positional information is collected from a local GPS device in order to construct data. Therefore, there are good possibilities that data collected will possess various arbitrary samples associated with the practical environment, which is also characterized by artifacts. It is observed that if the samples are extensively sampled from all the GPS devices in order to enhance their confidence level than the system design becomes less cost-effective. Therefore, the prime strategy applied in the proposed system is to offer a scheme where more information is obtained from the GPS data samples followed by enhancing the confidence level of only the essential information retained by the GPS data. It is because when all the essential empirical GPS data samples are collected and assigned more prioritized value than the prioritized pattern of GPS trend becomes nearly equivalent to the corrected data value. Time-series is applied in order to identify and obtain the essential points in the data distribution of the trends of GPS samples. However, if the pattern of the GPS data sample is found smooth than only a unit sample could be utilized. Moreover, the similar priority value could be utilized for all the values in order to evaluate progressive trends of the GPS data with respect to time series. Another important strategy involved in the proposed system is the usage of the priority value, which could make the system completely independent from any presence of spikes in patterns. Therefore, the proposed system offers a scheme of pre-processing the GPS data. If the pre-processing operation is carried out over the local GPS device than it performs on-demand artifact removal process. For the entire local GPS device, the sample rate is selected in such a way that the alteration in the data pattern is significant, and it demands the usage of priority values. Hence, the system becomes free from artifacts over the local GPS device followed by transmitting the data with maximized confidence to the receiving terminal. However, if there is very less significant change than only the raw GPS data is forwarded to the receiving terminal in order to conserve the resources that could be otherwise used in performing sampling operation. Interestingly, the system could successfully eliminate the artifacts using prioritized progressive trend analysis even if chances of GPS signal with a unit sample could have the presence of artifacts.

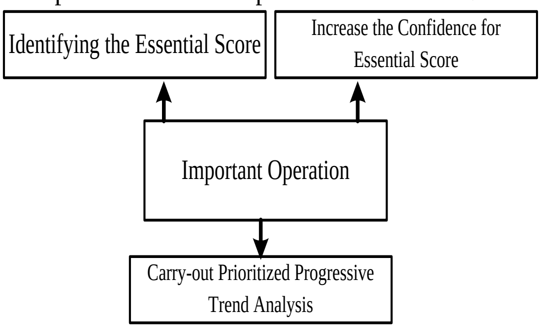


Fig.2 Important operations in Prioritized Progressive Trend Analysis

The important operation carried out by the proposed system is classified in three significant steps i.e. i) identifying the essential score using forecasting of the specific range of patterns of GPS data, ii) increase the confidence for essential score using test value of local GPS device as well as other adjacent devices, and iii) carry out prioritized progressive trend analysis only at the receiver.

VI. VISUALIZATION OF GPS RAW DATA

The user device equipped with the GPS sensors records the data including 1) speed, 2) longitude, 3) latitude and 4) altitude which are essential parameters for the mapping of the trajectory or various applications in the traffic management such as identifying the vehicle with the emergency on the basis of higher speed or even speed becomes zero means there is some trouble in the vehicle. The synchronization of the user device to the gateway through internet fetches the data into a time-stamped data sample as a timetable format as vector P in a static state; the speed varies if there is movement. The following figures demonstrated in this section highlight the trend of the raw GPS data.

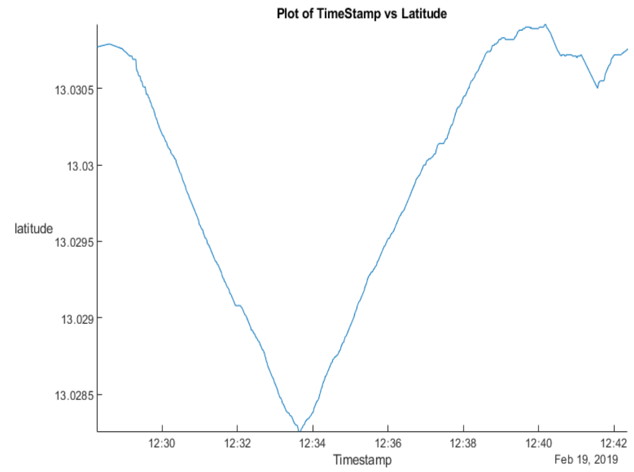


Fig.3Time Stamp VS Latitude

The above figure 3 demonstrates the visualization of GPS position attributes considering Time Stamp VS Latitude.

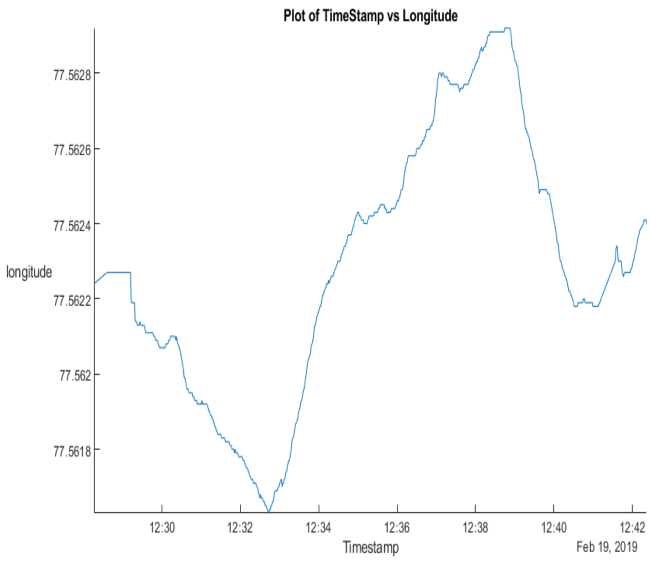


Fig.4 Time Stamp VS Longitude

The above figure 4 demonstrates the visualization of GPS position attributes considering Time Stamp VS Longitude

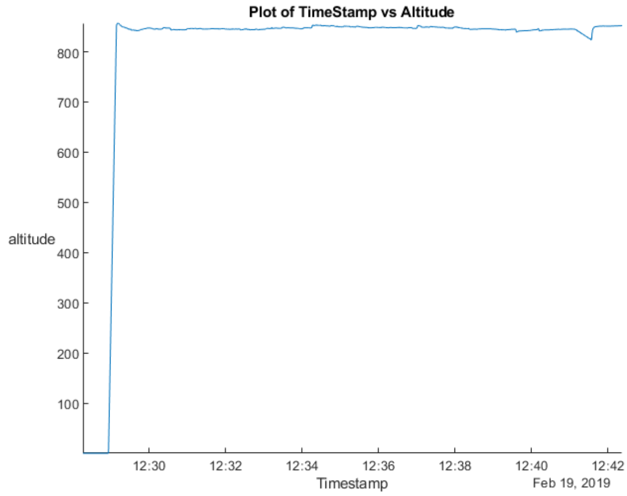


Fig.5 Time Stamp Vs Altitude

The above figure 5 demonstrates the visualization of GPS considering Time Stamp VS Altitude

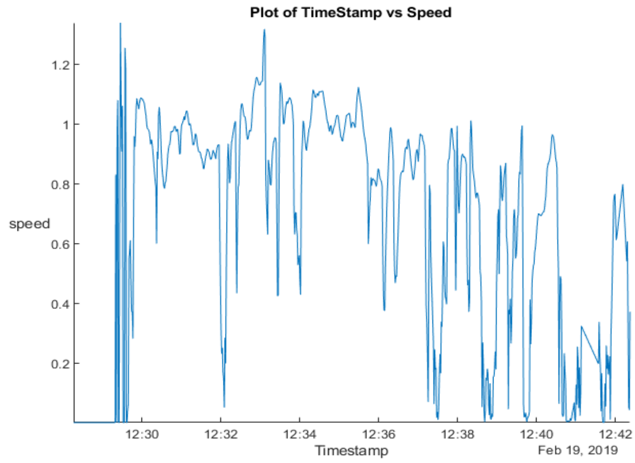


Fig.6 Time Stamp Vs Speed

The above figure 6 demonstrates the visualization of GPS considering Time Stamp VS Speed

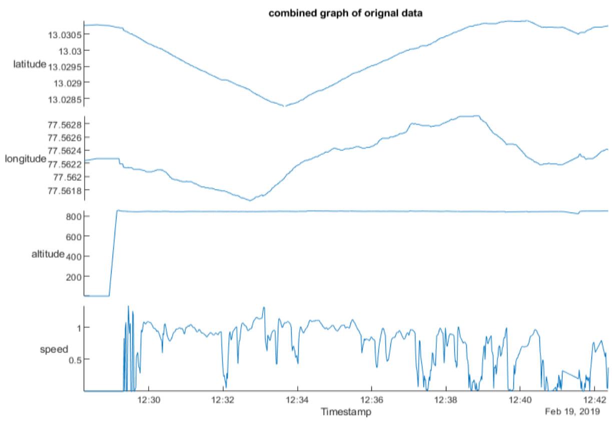


Fig.7 Combined visualization of Raw Data

The above figure 7 demonstrates the visualization of GPS attributes in combined form with in single plot

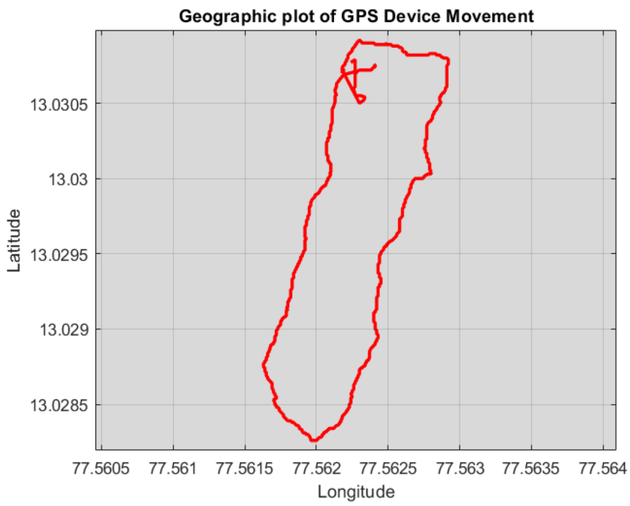


Fig.8 Trajectory plotted with the actual GPS Data

The figure 8 demonstrates Trajectory plot form the raw GPS data. In next part this trajectory is subjected to different kinds of pre-processing operation.

VII. ALGORITHM DESCRIPTION

This section presents a discussion about the algorithm implemented to carry out pre-processing over raw GPS data. The proposed system initially takes an input value as P-(position information) which is subjected to the process of the multi-level data smoothing operation. This process allows executing on-demand pre-processing, which provides a smooth version of pre-processed data in the form of Ptr (progressive trend). The discussion of the algorithm as follows:

A. Data Pre-processing using Moving Window Methods

Method of Moving Window-(MW) is a mechanism that processes sensor obtained data in small sets at a time, usually to represent adjacent points in the data in a statistical way. The study focuses on the moving average method which is a data smoothing mechanism that computes the average of the points inside each window for a particular set of sample values, thereby removing variations from one data point to the next and then using it to estimate the progressive trend.
i.e.

$$M_{Avg_t} = \frac{O_t + O_{t-1} + \cdots + O_{t-n+1}}{n} \quad \text{(eq.1)}$$

$$M_{Avg_{t}-1} = \frac{O_{t-1} + O_{t-2} + \cdots + O_{t-n}}{n} \quad \text{(eq.2)}$$

Where, M_{Avg_t} is a moving average at time t-(current time period), O_t is observation time at time t and n is the number of time periods in the average. Now, subtracting numerical equation 2 from numerical equation 1 to obtain estimation value at time t+1

$$M_{Avg_t} = \frac{M_{Avg_{t-1}}(O_t - O_{t-n})}{n} \quad \text{(eq.3)}$$

Using Numerical Equation 1 and Numerical Equation 2, the updated moving average is achieved by using the previous moving average with the average change in the actual value from time t to t-n. The algorithm takes input of P (Position Information) and leads to the generation of Ptr1 (Progressive Trend) as an output.

The significant steps are as follows:

Algorithm 1- Extracting Discrete Progressive Trend using Moving window method
Input: P (Position Information)
Output: P_{tr1} (Progressive Trend)
Start
1. init P
2. **For** P=1:n
3. Extract n_P=P(m)
4. **For** i=1:m
5. $p_{tr} \rightarrow f_{m1}$(P, w)
6. **End**
7. **End**
End

The algorithm for the proposed system is basically designed considering the input of P (Position Information) that after processing yields Ptr (Progressive Trend). The algorithm considers all the positional information P from the local device (Line-1) as well as all its quantity n (Line-2). The initial step is to extract m individual information within the *P* matrix, which are based on longitude, latitude, and altitude mainly and stores in a matrix np (Line-3). Finally, a function is constructed for obtaining the progress trend in order to obtain the final value of ptr (Line-5).

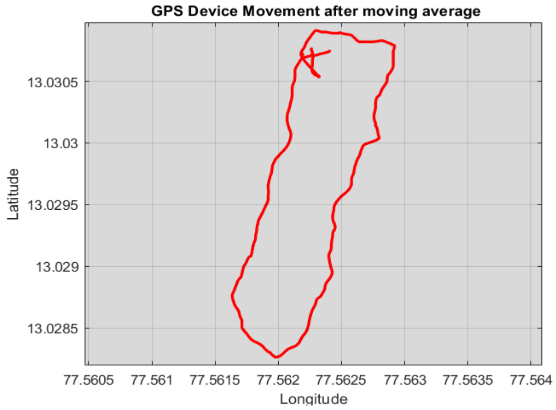


Fig.9 Pre-processed image using Moving Window Methods

B. Savitzky-Golay method

The Savitzky-Golay provides a mechanism to smooth noisy signal present in the raw data. Savitzky-Golay filter is a polynomial fitting function oriented on a weighted least squares regression mechanism which consists of parameters, i) window length and ii) filter order. This approach preserves the characteristics of data. It can be better understood by considering a symmetric window with L(length) = 2K +1 samples about the reconstruction point, followed by a polynomial of order n
i.e.

$$P(q) = \sum_{j=0}^{n} x_j q^j \quad \text{(eq.4)}$$

Where, x_j is the jth coefficient of the polynomial and the polynomial (n) order is a filter order.
That reduces the mean-squared approximation error-(MSE) by fitting into the set of input samples within the window.

$$\epsilon_n = \sum_{i=-K}^{K} (P(q) - a(i))^2 \quad \text{(eq.5)}$$

The filter output is equivalent to the polynomial value at the central point $y(0)$ that means

$$y(0) = p(0) = x_0 \qquad \text{(eq.6)}$$

In order to compute the filter output for the next point, the window moves one unit to the right, and the operation is recurrent at each sample of the input, resulting in generation new polynomials and new values for the filter output. The theory of Savitzky-Golay demonstrated that this filtering procedure is corresponding to convolving samples in windows with a fixed impulse response. Therefore, based on this approach, the filter output can be expressed as follows:

$$y(m) = \sum_{i=-K}^{K} w_i a(m-1) \qquad \text{(eq.7)}$$

This means that the weighted mean of the samples data into the window is identical to the filter output.

Algorithm 2- Extracting Progressive Trend- P_{tr2} using Savitzky-Golay-(SG) filter

Input: P (Position Information)
Output: P_{tr2} (Progressive Trend)
1. Init K W

2. Assign value → K

3. Assign value →W

4. Compute ← S-G Coefficients

[x y] →fsg(K, W)

5. Compute → P_{tr2} *using equation 7*

$$y(m) = \sum_{i=-K}^{K} w_i a(m-1)$$

End

The first step of algorithm initiates variable K and W for executing smoothing operation where W is window length, and k is the order of the polynomial. The algorithm uses a polynomial of order k to approximate W data points. This means that W point is used to compute K+1 polynomial coefficient. Generally, K is chosen considerably smaller than W to achieve some smoothing. The smaller K compared to W, the more smoothing is achieved. The next step of algorithm assigns value for both K and W. the next step computes SG coefficients, which will filtered version of data using step 5.

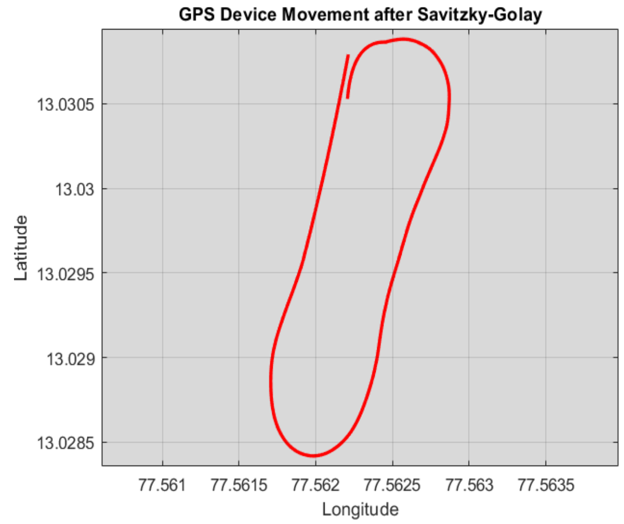


Fig.10 Pre-processed image using Savitzky-Golay method

C. Data Pre-processing using Outlier Elimination Methods

The outlier elimination method is another alternative method to compute the filtered version of data by removing extreme values that deviate from other observation on data. The study considers LOWESS filters that use local regression smoothing technique for the outlier elimination process.

The significant steps are as follows:

Algorithm 3- Extracting Discrete Progressive Trend- P_{tr3} using local regression smoothing
Input: P (Position Information)
Output: P_{tr3} (Progressive Trend)
Start

1. Init n
2. Call →w(x)
3. Compute →Lp
4. Compute→Rw
5. Eliminate →Outlier

End

The algorithm takes input as P-(Position Information) and applies a local regression smoothing method to obtain output enhanced version of raw data i.e., as Ptr3 (Progressive Trend). Initially, the range of the points is computed after that weighting factor is established for the LOWESS smoothing. The weighting function is defined as follows:

$$w(x_k) = W\left(\frac{x_i - x_k}{d_i}\right) \qquad \text{(eq.8)}$$

Where, k = 1..,N
d_i is the distance from x_i to the Nth neighboring point and the largest value is achieved at point x_i. The value is at the 0 range limits. Regression smoothing will now occur based on the least squares method where linear regression function is computed to the LOWESS operation. Only a small number of observed values are considered to estimate the linear regression function. After that, weightings estimated based on the evaluation of residuals and the resulting median. If the residual is greater than or equal to 6 median residual, the robust weighting is zero, which leads in the removal of outliers.

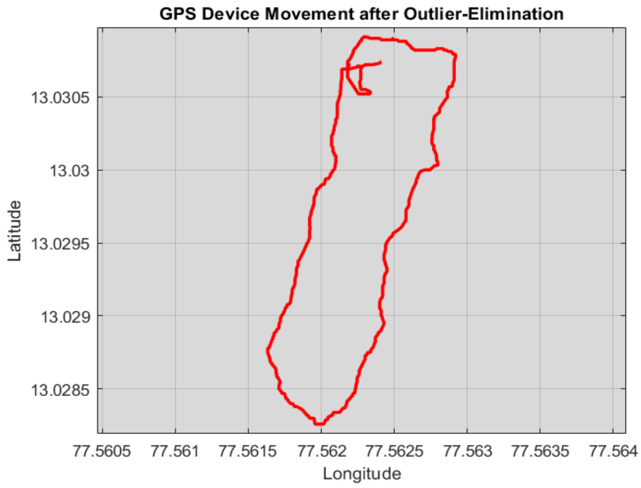


Fig.11 Pre-processed image after outlier elimination

D. Data Pre-processing using filtering Methods

A filtering method is adopted here to smooth high-frequency fluctuations in the input data. The filtering mechanism filters the data based on the differential equation as follows:

$$\alpha(1)y(n) = \beta(1)x(n) + \beta(2)x(n-1) + \cdots + \beta(N_\beta)x(n - N_\beta + 1)$$

$$-\alpha(2)y(n-1) - \cdots - \alpha(N_\alpha)y(n - N_\alpha + 1) \quad \text{(eq.9)}$$

Where,

α and β are the two filter coefficient vectors N_α denotes order of the feedback filter, N_β denotes order of the feed forward filter, n represents index of the x and the resultant $y(n)$ is a linear combination of the recent and existing elements of x and y. The significant steps of algorithm are as follows:

Algorithm 4- Extracting Discrete Progressive Trend- P_{tr4} using filtering method

Input: P (Position Information)

Output: P_{tr4} (Progressive Trend)

Start

1. Init α, ß
2. construct: α, ß
3. call function f_{m3} *using equ 8*
4. Compute p_{t4} → f_{m3}(ß, α, P)

End

The Initial steps are subjected-(algorithm-1) to the same operation as executed in the previous algorithm. The algorithm is executed for performing a filtering operation where the algorithm constructs filter coefficients vectors are α, ß as the numerator and denominator coefficients. The algorithm calls a filtering function fm3 over original data with filter coefficient vectors. After executing step(6), filtered data is obtained as demonstrated in figure 12.

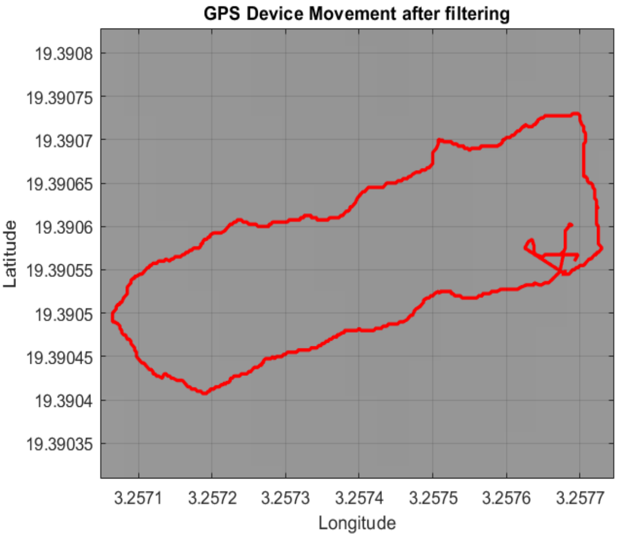


Fig.12 Pre-processed image after filtering

E. Data Pre-processing using Detrending Methods

The study considers Detrending approach as a pre-processing approach which follows mathematical operation for eliminating trend from the data for the analysis of consistency in data. A simple approach is carried out using a linear trend in a mean, which is eliminated by subtracting a least-squares-fit straight line.

Algorithm 5- Extracting Discrete Progressive Trend- P_{tr5} Detrending Methods

Input: P (Position Information)

Output: P_{tr5} (Progressive Trend)

Start

1. Compute: → P_{mean}
2. D_{trend} → f_D (P)
3. T → P- D_{trend}
4. Compute → D_{mean}
5. Display → P_{tr5}

End

The algorithm takes input as P, which is subjected to detrending function f d, which applies a linear fit to the input data P and then eliminated the trend from it. This means that detrending substrates the means average or a best-fit line from the raw data. The trend-T is then computed by subtracting detrending value form the original data. After executing it provides detrending of input data demonstrated as follows:

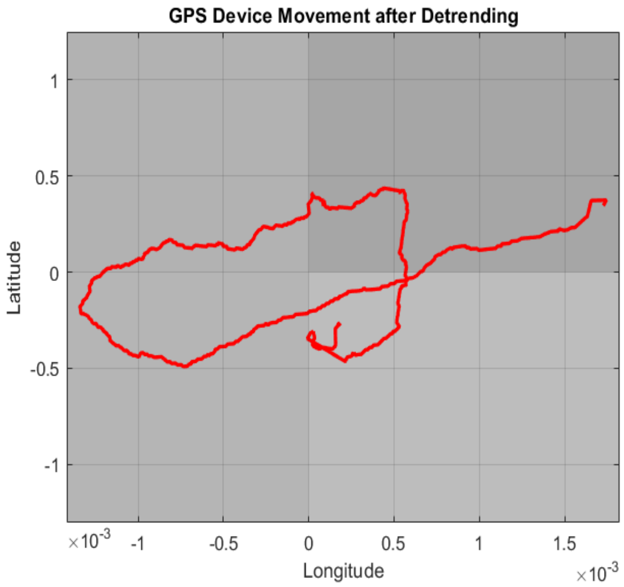


Fig.13 Detrending image of Input data

F. Correlation coefficient

The study uses the concept of correlation coefficient to evaluate the strength of the correlation between the relative motions of two variables GPS raw data.

The correlation coefficients range from -1 to 1, where

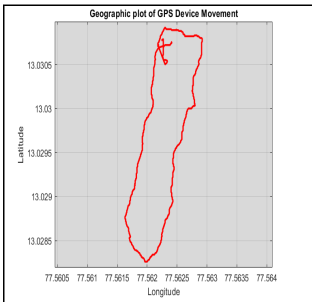
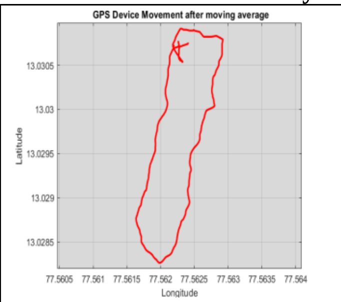
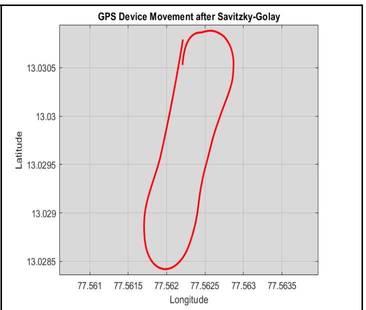
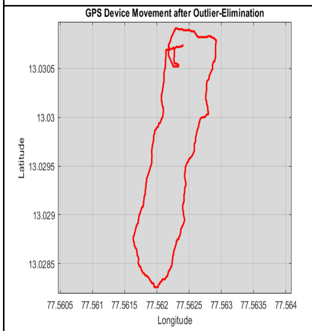
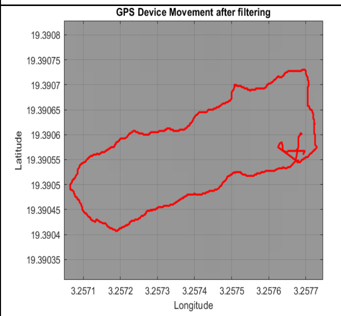
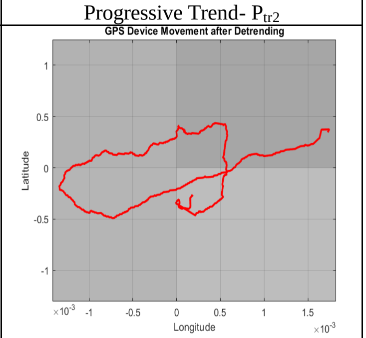
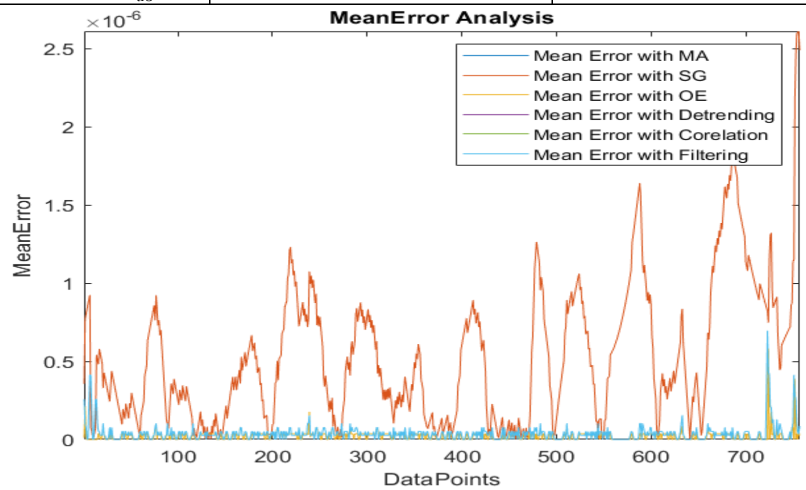
- A value close to 1 represents a positive linear relationship between the data.
- A value close to -1 represents that one data has an anti-correlation factor with another data.
- A value equal to 0 denotes no linear relationship between the data.

The correlation coefficient of input data is determined using of correlation coefficients matrix, which can be referred to as function fcc(P). The correlation coefficient is found to be closer equal to 1 which means that the data has positive co-relationship. The next section will present result analysis and discussion.

VIII. RESULT DISCUSSION

The proposed system is implemented in MATLAB, where the proposed system is implemented on numerical computing tool-(MATLAB) installed on windows O/S 64bit machine. Here, a typical GPS data acquisition system is built with the synchronization of the in-premise device with the cloud. Table 1 displays the analysis of the result obtained from the proposed multi-level pre-processing techniques along with the original GPS raw data. Also, the study has performed mean square analysis to analyze the effectiveness and stability of each technique adopted for pre-processing over GPS RAW data- (P). From the results in Table 1, it can be seen that the proposed system provides multi-level data smoothing technique. The proposed study applied various algorithms such as moving window method, Savitzki – Gollay filter, outlier elimination, filtering, deterring and coefficient correlation. Finally, the experimental outcomes justified the scope of each proposed technique in terms of mean error analysis.

Table.1 Outcome analysis

 Original Raw Data	 Progressive Trend- P_{tr1}	 Progressive Trend- P_{tr2}
 Progressive Trend- P_{tr3}	 Progressive Trend- P_{tr4}	 Progressive Trend- P_{tr5}
 Mean error analysis		

The reflectance of the average error analysis in table 1 demonstrates that the pre-processing based on the moving window method exhibits an impressively higher precision than the other methods adopted in this study.

The technique based on the Savitzky-Golay method produces excessive smoothing form of the data, which is not practical for considering suitable option for GPS data pre-processing. The prime reason behind this is that it doesn't carry any form of prioritized-based analyzing, thereby failing to identify the essential information within the GPS signal. Similarly, the pre-processing technique subjected to outlier elimination also exhibits performance similar to that of Technique-1. Further the pre-processing based on the filtering mechanism shows considerable performance. But is less significant compared to the moving window method and the outlier elimination method. However, the average error of the Detrending method is also analyzed to be lower than the pre-processing based on filtering and Savitzky-Golay techniques. However, Detrending here is a representation of the moving average, indicating that the trend of data in the time series slows as the characteristics of the data sequence gradually change. Thus, the proposed system provides a user-selected multi-level pre-processing technique to perform smoothing operations on GPS data.

IX. CONCLUSION

At present, there are various commercial applications where navigational system is designed on the basis of the aggregated data from the conventional GPS signal. However, there are already reported problems associated with inaccuracies as well as noises. Therefore, the current model addresses this problem by following contribution viz. i) incorporation of the priority-based based information of the GPS signal in order to retain the essential information of signal, ii) empirical mechanism of identifying and repairing the artifacts, iii) incorporation of time-series analysis for better trend analysis. Apart from this, the study presents user interactive multi-model for GPS data preprocessing.

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