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# Smartphone Position Tracking Using GNSS

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**Abstract**

*The objective of this paper is to estimate smartphones' location which support services that demand lane-level precision like high-occupancy vehicle (HOV), lane Estimated Time of Arrival (ETA) estimation. We focus on developing a model based on raw location measurements collected in an open sky and light urban roads using datasets collected by hosts from Android smartphones. The application of mobile devices for most software products built for services such as cadastral surveying, mapping surveying applications, and navigation has been increasing due to the cost-effectiveness of GNSS smartphones. This paper aims to bridge the link between the geospatial information of detailed human behavior and the smartphone internet with improved granularity. It fixes the issue with the GNSS/INS integrated navigation system's degrading data accuracy during an GNSS signal outage. We aim to improve the currently used GNSS/INS integration algorithm built on the AI approach. The position of a vehicle during a GNSS loss can be predicted utilizing a GNSS/INS integration methodology for land vehicle navigation based on position update architecture (PUA) employing LightGBM regression. It models the connection between INS data and changes in vehicle location using LightGBM.*

## 1. Introduction

The most widely used technologies in transportation systems are navigation and positioning. (Everett et al.) Their techniques are designed to employ satellite data and vehicle dynamics data to compute the precise present location of a vehicle. The robustness of the algorithm is a crucial factor in determining the precision of the vehicle navigation system and its ability to adjust to the surrounding environment (Zangenehnejad and Gao) .

GNSS/INS navigation is an affordable, precise, and flexible navigation solution and it provides real-time updates on a vehicle's location mainly through satellite signals. (Zhong et al.) First, the inertial navigation system collects data on angular and linear motion in relation to inertial space. The system then employs inertial navigation differential equations to determine changes in vehicle speed and location (Chiang et al.) .

As with Android Nougat (2016) and newer versions, users have had access to raw GNSS measurements. Hence, GNSS smartphone positioning has been a focus of considerable interest and study in recent years. Because of their low price, GNSS cellphones may be used for a wide variety of tasks, from cadastral surveys and mapping to surveying and vehicle navigation, as well as for directing pedestrians. (O Zhilinsky)

Regardless of the increasing use of GNSS devices for a broad range of applications, including cadastral surveying, mapping, and navigation, users remain confronted with a multitude of challenges that prevent them from achieving high accuracy location. (Fu, Khider, and Van Diggelen) These include the noise that is present in GNSS measurements, the direct effect that the environment has, the changes in the modes in which a smartphone may be held, and the constraints in the creation of algorithms. In spite of these obstacles, the use of GNSS apps on smartphones has been steadily growing in popularity due to the fact that they are more affordable. (Shen et al.)

Satellites are essential to the operation of the GNSS navigation system. GNSS satellites make a complete orbit around the earth and broadcast signals that allow a receiver to determine how far away it is from each individual satellite. Their orbits have been mapped out, thus it is possible to determine where they are located. (Hegarty)

## 2. Materials and Methods

### *2.1. Dataset*

Google Inc.'s Android Raw GNSS Measurement Datasets for Precise Positioning is the one chosen for utilization. The files contain raw GNSS measurements and inertial sensor readings achieved through a range of dual-frequency and ADR techniques. In order to collect the information, smartphones with (Accumulated Delta Range) capabilities, including the Xiaomi Mi 8 and Google Pixel 4, were employed in the San Francisco Bay Area in the United States. The Global Navigation Satellite System (GNSS) is an umbrella term for satellite-based positioning systems such as GPS, Quasi-Zenith Satellite (QZSS), GLONASS, and Galileo. This type of surveying is extremely accurate because it uses radio waves emitted from the GNSS satellites that orbit the earth to determine coordinates. The receiver at the station can pick up the radio waves from the sky, thus allowing surveying to be performed regardless of weather conditions. GNSS surveying is currently the most popular form of geodetic surveying since it can provide three-dimensional, high-precision results and improve the efficiency of surveying tasks. (Tiberius and Verbree)

The coordinates collected by GNSS like car navigation systems and smartphones are usually expressed in the WGS 84 coordinate system. Both the WGS 84 coordinate system and the ITRF coordinate system are earth-centered systems. Despite numerous revisions to WGS 84, it is still possible to consider the ITRF system to be equivalent and there is no significant practical difference.

### *2.2. Data Cleaning*

When receiving information from satellites, it is often accompanied by unwanted noise. Data cleansing is a method of correcting, deleting, or rectifying invalid, distorted, wrongly formatted, redundant, or incomplete data inside a dataset. As multiple sources of data are often combined, there is a high chance of duplication or misidentification. (Wielgosz et al.)

### *2.3. Exploratory Data Analysis (EDA)*

Visual techniques are utilized to break down data and find trends, models, or to check hypotheses with the support of numerical summations and graphical illustrations. Exact positioning data is essential to make smart phone tracking possible, however, presently satellite positioning is inadequate. Utilizing an inertial measurement unit (IMU) can offer decimeter-level positioning, bringing us nearer to the implementation of automated driving. The RINEX perception archives or Google's GnssLogger records (additionally alluded to as GnssLog) must be processed and create position solutions into NMEA records and at long last bring forth outcome measurements.

### *2.4. Data Visualization*

Folium, a powerful Python library, can be used to create different kinds of Leaflet maps that open in a distinct HTML file. Additionally, Folium maps are interactive. It is possible to make inline Jupyter maps with Folium. Matplotlib, a comprehensive Python library, can be used to produce static, animated, and interactive visualizations and also for mapping out and plotting smartphone tracks. With Matplotlib, tasks that are straightforward are simple to complete and more complicated tasks are still possible. (Adavi and Nisha)

### *2.5. Model Building*

Building a model requires the collection and understanding of data, and the choice of a statistical, mathematical or simulated model to answer questions and make predictions. We will be employing tree-based learning algorithms with a gradi-

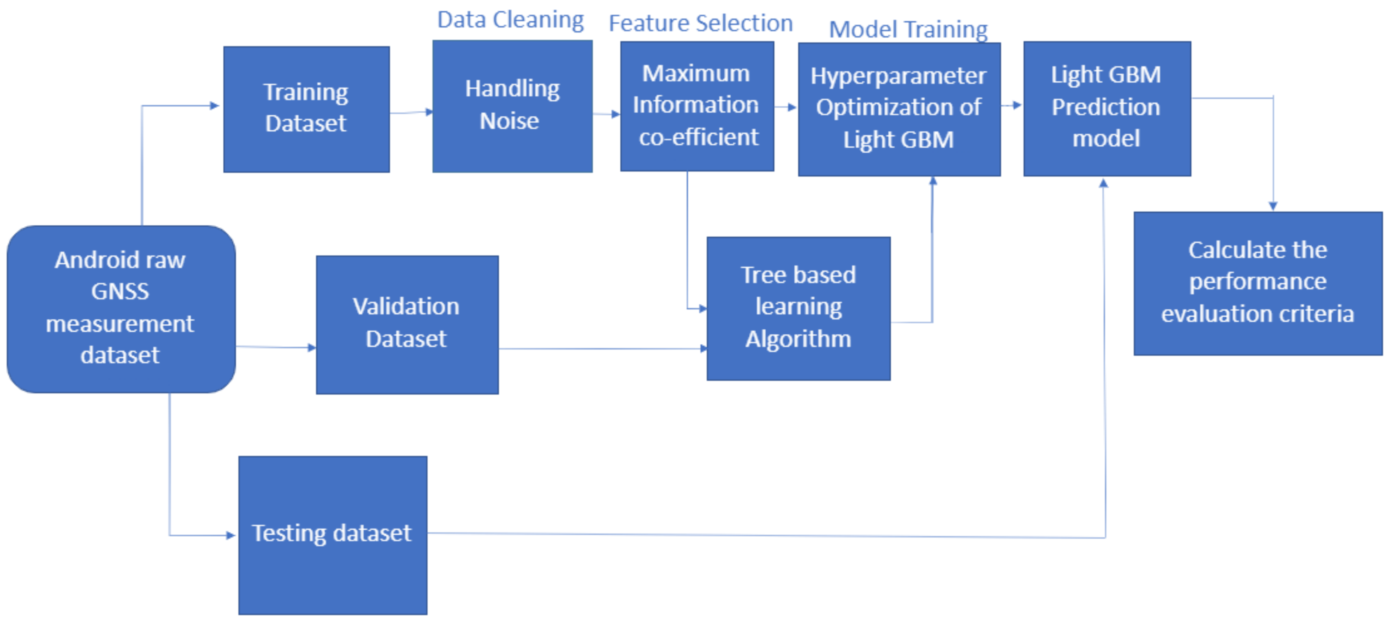


**FIGURE 1.** **Flowchart for working of designed algorithm**

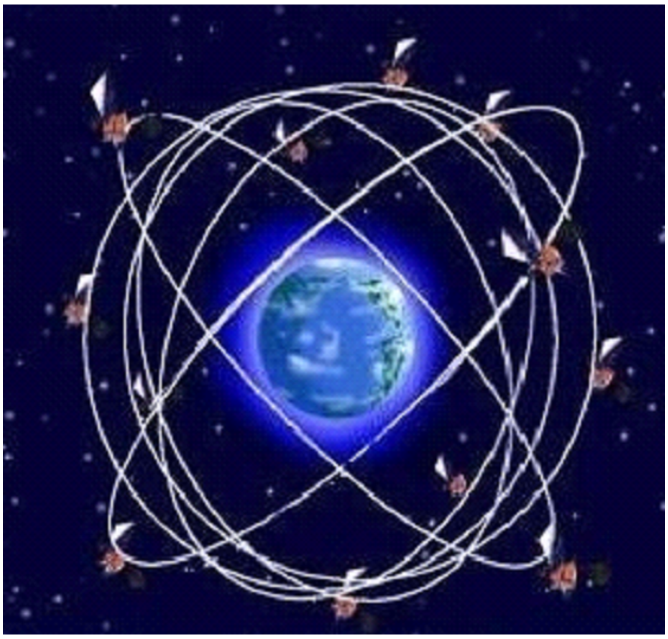

**FIGURE 2.** **GNSS Satellite**

ent boosting algorithm known as LightGBM. This type of algorithm is a supervised learning system designed to address classification and regression by forming a tree-like structure. LightGBM is a gradient boosting framework that is distributed, efficient and has the following advantages: rapid training speed, low memory consumption, greater accuracy, the capability of parallel, distributed and GPU learning, and the capacity to work with huge datasets.

### *2.6. Working of LightGBM algorithm*

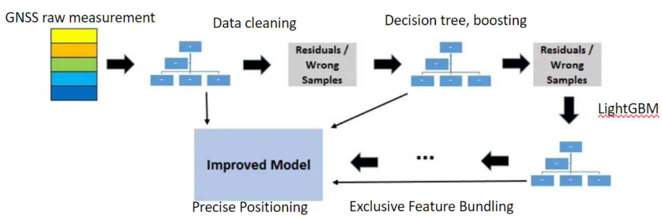


**FIGURE 3.** **Proposed Design of LightGBM Model**

The AutoML tool's Train feature utilizes the decision tree-based LightGBM, which is a gradient boosting ensemble technique. The purpose of LightGBM is similar to other decision tree-based methods, with the goal of optimizing performance in distributed systems. LightGBM implements a leaf-wise growth pattern which means that, given a condition, only one leaf is split based on the gain. If the data set is small, this can lead to overfitting, which can be prevented by limiting the tree depth. LightGBM also has a histogram-based technique which divides data into bins based on the distribution's histogram, instead of iterating, calculating the gain and dividing the data. A sparse dataset can also benefit from this optimization. In addition, LightGBM has exclusive feature bundling, which combines exclusive features to reduce the dimensionality and speed up the processing. Even if the dataset is of smaller size, this approach of optimization can be advantageous. It has the ability to group together certain exclusive characteristics which helps to reduce the number of dimensions and quicken the processing. This is known as unique feature bundling, and is a part of LightGBM.

When employing the LightGBM algorithm, a single-sided sampling (GOSS) is applied to the dataset. GOSS weighs data points with larger gradients more heavily when determining the gain. This approach places higher importance on instances that haven't been used as efficiently for training. To maintain precision, some data points are removed from the evaluation at random, while others are preserved.

## 3. Design

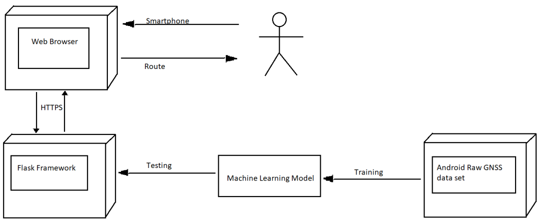


**FIGURE 4. Deployment Architecture**

There are training and testing datasets for the Android raw GNSS measurement dataset. The train set is used to train the machine learning model, while the test set is used to test it. The User Interface of the paper is designed using HTML in association with CSS and Javascript. HTML stands for Hyper Text Markup Language. This is the standard markup language used to create Web pages and is responsible for defining their structure and comprises a set of elements that instruct the browser on how to present the content.

This HTML page is implemented with flask. Flask is a popular web framework written in Python, that facilitates web page development. Flask helps with scalability and flexibility and is easy to negotiate and lightweight, therefore allowing developers to concentrate on coding better. The application is then deployed to remote access on other laptops using python ngrok tunnels. These tunnels provide a secure option to host localhost applications on remote systems enabling instant access to multiple laptops accessing a testing application.

## 4. Comparative Analysis

The trained LightGBM algorithm can accurately forecast the performance in a short amount of time compared to the conventional procedure of " modeling-setting parameters-building performance simulation," considerably reducing labor and time costs. When compared to other algorithms like Decision Tree, KNN, and Random Forest, the LightGBM algorithm's classification prediction performance is the best. The categorical features may introduce bias if they are encoded as numbers because they will be considered as ranking numerical features in the prior research publications that use the XGBoost algorithm. Because of this, one-hot encoding must be used before feeding into XGBoost. Thus, in order to enable categorical input type, LightGBM is required.

When compared with research publication (Li et al.) PUA (position update architecture) LightGBM Model, it can further be improvised by the integration of SLAM(simultaneous localisation and mapping) with PUA-LightGBM Model. It can be useful in the events of GNSS outage.The link between INS data and changes in vehicle position is modeled using LightGBM.To ensure that all measurements are accurate for the extended Kalman filter (EKF) update process, multi-sensor fusion is a vital component in the development of autonomous driving systems, which can be enabled by using SLAM.

## 5. GNSS Smartphone Positioning Challenges and Future References

Although much effort is being put into smartphone positioning, GNSS smartphone positioning is still in its infancy. The biggest influence on GNSS accuracy is atmospheric interference, which occurs as signals travel across space and enter the earth's atmosphere. Since GNSS smartphones employ GNSS chipsets and antennas suitable for cell phones, the observations are quite noisy. Most contemporary GNSS receivers have fairly good accuracy because they can observe many satellites. Yet occasionally, satellite positioning systems may cause multipath because of the way they reflect off structures like buildings. If the gadget receives both reflected signals and direct signals from the line of sight, the positioning might be less precise. Additionally, this makes it more challenging to discriminate between direct line of sight (LOS) transmissions and non-line of sight (NLOS) signals, the latter of which would cause a substantial impact of multipath on GNSS readings.

The goal of this paper is to provide readers a better knowledge of global navigation satellite systems and how they might be applied to smartphone positioning. Here, we employ the gradient algorithm lightGBM, which has a 96.73% accuracy rate and can be helpful in GNSS research work, to match smartphone GNSS measurements with the ground truths supplied by NovAtel Span ISC 100C receivers. Hence promising to increase location accuracy and opening up new consumer and business opportunities.

The global market for GNSS smartphones is expanding quickly, which presents enormous opportunities for both the academic and industrial sectors. In addition to the studies emphasizing great accuracy. Industrial companies are also interested in positioning and employing mass-market products in this field. Industry insiders predict that in the future, high-accuracy applications will be broadly adaptable to mass-market gadgets.

## 6. Results and Discussion

The model was trained for the learning rate 0.1, with the LightGBM Classifier.The limited user base of LightGBM is one drawback, however things are quickly changing. Apart from being faster and more accurate than XGBOOST, this technique has not been widely used because there is not as much documentation. However, compared to other boosting methods, this technique has shown noticeably superior outcomes.

Instead of moving forward with respect to the tree's nodes like the Extreme Gradient Boosting Machine, the Light Gradient Boosting Machine moves forward with respect to the leaf.In gradient boosting algorithms, gradient-based one-side sampling and exclusive feature bundling are the two key methods employed by light GBM.When compared to other gradient boosting models, Light GBM operates more quickly and requires less memory.

**TABLE 1.** **Accuracy score**

| Type | Percent |
|---|---|
| LightGBM Model Accuracy Score | 96.73 % |
| Training Set Accuracy Score | 96.64 % |
| Test Set Accuracy Score | 96.73 % |

## 7. Conclusion

Smartphone users will gain advantages from services that have precision down to the lane-level, improved experience with location-based gaming, and more detail when it comes to road safety issues. Android's access to unprocessed GNSS data gives rise to the potential of creating newer GNSS applications for smartphones with accuracy and validity that wasn't feasible before. Because of the affordability of GNSS smartphones, they can be used in many different applications like mapping surveys, pedestrian navigation, car navigation, and more.

**Authors' Note**

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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