

COMPARATIVE EXPERIMENTAL EVALUATION OF THE ERROR OF GPS SENSORS: NEO-6M AND WALKSNAIL WS-M181

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<https://doi.org/10.23939/acps2025.02.191>

Submitted on 14.09.2025

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Abstract: The study compares the accuracy of two GPS sensors, the budget NEO-6M and the more expensive Walksnail WS-M181. The study has been aimed at evaluating their accuracy in various operating conditions, including open spaces, urban environments with many buildings, and forest areas. To do this, both sensors have been connected to a laptop via the UART interface, which allowed for the constant real-time recording of coordinates. The tests have established that the NEO-6M sensor has comparable accuracy to its more expensive counterpart. The disadvantages of the NEO-6M sensor are its long time of cold start satellite search and response frequency. However, these disadvantages are not critical in the case of using GPS on static points.

Index terms: GPS sensor, NEO-6M, Walksnail WS-M181, positioning accuracy.

I. INTRODUCTION

Modern navigation and location technologies rely heavily on the accuracy of GPS sensors [1], which are widely used in many areas, from domestic to industrial. With the development of the Internet of Things (IoT [2]), automation, robotics, and drones, the need for high-precision and reliable GPS modules is becoming increasingly urgent. The choice of a GPS sensor for a particular application can significantly affect the performance and functionality of the system in which it is used. At a time when the market offers a wide range of GPS modules of different levels of complexity and cost, it is essential to determine the feasibility of choosing more expensive models and what advantages they can provide compared to more budget counterparts. Sensors NEO-6M and Walksnail WS-M181 represent two different price segments, but their metrological characteristics are practically identical and require comparative analysis. Therefore, the goal of this study is to compare the accuracy of these two GPS sensors under different operating conditions [3]. As it is vital for those who make decisions about implementing GPS technologies in their projects. It also provides valuable information for engineers, developers, and other professionals who seek to optimize their systems by choosing the best components based on their technical and economic capabilities.

II. LITERATURE REVIEW AND PROBLEM STATEMENT

Accurate coordinate determination is critical in transportation, surveying, robotics, and mobile applications. In the context of increasing dependence on navigation technology, the accuracy and reliability of automatic coordinate measurement are essential parameters for ensuring safety, efficiency, and productivity. Previous studies have covered various aspects of using GPS technologies, including comparing different modules and the effect of external conditions such as environmental interference, weather conditions, building density, and magnetic anomalies on the accuracy of coordinates [4].

One of the main approaches to improve the accuracy of the GPS signal is the Kalman filter [5], which effectively reduces noise and improves coordinate stability, which is especially important for high-precision navigation systems under challenging environments, such as urban canyons or dense forest cover. This method allows one to smooth out noise and significantly improve the results of GPS receivers in real-time [6]. Moreover, recent studies demonstrate that combining the Kalman filter with other methods, such as machine learning and artificial intelligence, can further improve the accuracy of navigation systems and make them more adaptive to changing conditions [7].

Thus, the analysis of scientific papers indicates a significant difference in accuracy between different GPS modules and emphasizes the importance of choosing the correct signal correction method according to the conditions of use. For example, in the case of transport applications, the accuracy of coordinates determines the safety of traffic and the efficiency of logistics processes, while in geodesy and robotics, errors in coordinates can lead to significant deviations in measurements and automation processes.

This highlights the need for further research and evaluation of different GPS modules, their ability to work in conditions of external interference, and testing different filtering and data correction algorithms, which will be discussed in this article.

This study aims to compare the accuracy and reliability of two popular GPS sensors NEO-6M and Walksnail WS-M181 in different environments. The main question addressed in the study is whether it is worth investing in the more expensive Walksnail WS-M181 sensor for tasks that require high accuracy or whether the more budget-friendly NEO-6M can provide enough accuracy for practical use. The research aims to determine the expediency of choosing a specific GPS module depending on the accuracy requirements and operating conditions, which is critical for engineers, developers, and other specialists working with satellite navigation.

Hypotheses:

1. The Walksnail WS-M181 GPS sensor provides higher accuracy in determining coordinates in challenging environmental conditions (urban buildings, forested areas) compared to the budget NEO-6M due to using a more modern chipset and signal processing technologies.
2. In open spaces, the difference in accuracy between the NEO-6M and the Walksnail WS-M181 is negligible, which may indicate the feasibility of using the cheaper NEO-6M for tasks where high-precision positioning is not critical.
3. The use of the Kalman filter will significantly improve the accuracy of both sensors, but the effectiveness of this improvement will be more noticeable for the NEO-6M sensor, as it is prone to higher noise levels in the measurements.

III. MATERIALS

NEO-6M GPS module:

- *Chipset:* U-blox NEO-6M.
- *Price:* around 3\$.
- *Claimed accuracy:* Approximately 2.5 meters in open spaces.
- *Refresh rate:* Standard 1 Hz (up to 5 Hz maximum).
- *Power consumption:* 5V, 35mA.
- *Antenna:* External active antenna.
- *Main areas of use:* DIY projects, drones, robotics, trackers.

The NEO-6M is a popular choice among hobbyists and developers due to its affordability and ease of integration into various projects. This module is used for basic GPS navigation tasks where ultra-high accuracy is not critical.

Walksnail WS-M181 GPS module:

- *Chipset:* Modern M10 chipset supports several global navigation systems (GPS, GLONASS, BDS, Galileo).
- *Price:* around 15\$.
- *Claimed accuracy:* Approximately 1.5 meters in open spaces.
- *Refresh rate:* Up to 10 Hz (default).
- *Interfaces:* UART.
- *Power consumption:* 5V, 100mA.
- *Antenna:* Susceptible active ceramic antenna.

- *Main areas of use:* Professional tasks requiring high accuracy, such as geodesy, geocaching, and professional drones.

The Walksnail WS-M181 is a more advanced and accurate GPS module designed for professional applications where the accuracy of determining coordinates is critical. This module uses multi-channel signal reception, which allows it to work better in conditions where the GPS signal may be weak or subject to interference.

IV. METHODS

A. PREPARATION AND CONNECTION OF EQUIPMENT

For experiments, both GPS sensors NEO-6M and Walksnail WS-M181, were connected to the laptop via the UART interface. This ensured the possibility of continuous real-time collection of coordinate data. Sensors were connected according to the following scheme:

- *NEO-6M:* Connection to the UART port of a laptop with the data transfer rate of 9600 Baud.
- *Walksnail WS-M181:* Connection to the UART port of a laptop with the data transfer rate of 115200 Baud.

B. SELECTION OF LOCATIONS FOR TESTING

To evaluate the accuracy of GPS sensors, four different [8, 9] types of locations were chosen:

- *Open terrain:* An area without significant interference to the signal, such as a field.
- *Forest area:* An area with many trees that can partially block the GPS signal.
- *Low-rise:* A low-density area of a city.
- *Urban area:* An area with a high density of buildings, which can create reflections and other interference effects.

C. DATA COLLECTION

For each location, coordinate data was collected during 10 minutes. The data refresh rate for NEO-6M was 1 Hz, and for Walksnail WS-M181, it was 10 Hz. During data collection, the sensors were fixed on a platform with the same conditions for both modules.

D. DATE PROCESSING

The collected data were carefully processed to determine the error of each module:

Application of the Kalman filter [10]: The Kalman filter was used to smooth the noise and obtain more accurate coordinates. This method uses a motion model and actual measurements to predict the object's position, which is adjusted based on new data. This allows one to get more stable and accurate coordinates.

Calculation of the average value of the coordinates: For each module, the average values of latitude and longitude were calculated for each location. This allows one to get the object's position based on all the collected data and minimizes the impact of random errors.

Calculation of the 99th percentile (p99) [11]: This method was used to determine the maximum possible deviation of the coordinates from the mean value. It demonstrates how far the coordinates can deviate from the average value in 99% of cases, which is vital for evaluating the signal's stability under each module's operating conditions.

E. COMPARATIVE ANALYSIS

Based on the collected and processed data, a comparative analysis of the accuracy of each GPS module was carried out, including the evaluation of deviations from the reference coordinates. The analysis included the calculation of deviations using the Kalman filter, the mean value, and p99, which allowed us to assess the accuracy and reliability of each device.

F. VISUALIZATION OF RESULTS

For a visual presentation of the results, graphs were created that show the deviation of the coordinates of each module from the reference values in different locations. This made it possible to visually evaluate the performance and stability of each GPS sensor in different conditions.

V. CONDITIONS OF THE EXPERIMENT

To ensure the accuracy and reproducibility of the results, the experiments were conducted under controlled conditions, considering the following aspects:

1. *Stable weather conditions:* All measurements were carried out in clear weather without precipitation (summer around 20*), which minimized the possible influence of atmospheric conditions on the quality of GPS signal reception. This ensured the stabilization of signals and reduced the possible influence of the atmosphere.

2. *Fixed position of the sensors:* Both GPS modules NEO-6M and Walksnail WS-M181, were installed on the same platform, providing the same signal reception conditions. The antennas of both modules were directed vertically upwards.

3. *Minimization of interference:* To avoid exposure to radio frequency interference, the GPS modules were located away from metal objects, high-voltage power lines, and other sources of possible radio frequency noise. This made it possible to ensure the purity of the signal and minimize the influence of external factors on the results.

4. *Testing in different types of terrain:* Experiments were conducted in various environments to assess the performance of GPS modules under different conditions. In open spaces, testing was carried out in a wide field without significant interference to the signal, which provided baseline data in ideal circumstances. In contrast, trials in a forest area with dense vegetation partially blocking satellite signals simulated the challenges of operating in remote and hard-to-reach regions. Additional experiments took place in areas with low-rise buildings, where a large angle of open sky allowed

relatively unobstructed signal reception. Finally, studies in urban conditions with a high density of buildings highlighted the most challenging scenario, where reflections and overlaps of signals made reception considerably more difficult.

5. *Calibration of the reference device:* The smartphone used as a reference for coordinate comparison was pre-calibrated and had a stable connection with satellite systems, including GPS, GLONASS, Galileo, and BeiDou. This ensured the high accuracy of the reference measurements. These conditions were chosen to ensure the maximum objectivity and reliability of the obtained results, which allowed for the correct comparison of the accuracy of the GPS modules NEO-6M and Walksnail WS-M181 in various usage scenarios.

VI. DATA PROCESSING

During operation, two GPS sensors transmit much information in NMEA format [12], so it is necessary to process this data efficiently. The NMEA format contains several vital parameters, such as:

- *UTC:* Defines the exact moment of measurement.
- *Number of connected satellites:* Displays the accuracy of fixing the coordinates.
- *Other data:* For example, information about signal quality, HDOP (horizontal dilution of precision), and lock type.

Additionally, coordinates in NMEA come in degrees and decimal minutes [13], which include hours, minutes, and seconds. For further processing and use of this data in geographic information systems or other analytical applications, it is necessary to convert the coordinates into the decimal degrees format [14].

A Python script was written to automate this process. The script performs the following essential tasks:

Data filtering: It selects only those NMEA messages that contain coordinates (e.g., \$GPRMC, \$GPGLL) and discards information that does not affect the result.

Coordinate conversion: The formula for converting from decimal minutes to decimal degrees is used. This allows one to get exact coordinates in a convenient format for further use.

$$DD = \text{Degrees} + \frac{\text{Minutes} + \frac{\text{Seconds}}{60}}{60}. \quad (1)$$

Timestamp processing: UTC is converted into an understandable format for further analysis.

Processing additional parameters: The script also stores parameters such as the number of satellites and the signal quality, which is essential for evaluating the accuracy of the received data.

This Python script allows one to automate the processes of collecting, processing, and converting GPS data, significantly simplifying work with a large amount of sensor information.

VII. RESULTS

During the study, data on coordinates were collected from GPS modules NEO-6M and Walksnail WS-M181 in various environmental conditions. Below are the results in tabular form and map images showing the accuracy and reliability of each module.

Figures 1-4 visually represent the overlay of coordinates on the map. The blue dots are the more expensive Walksnail, and the green dots are the NEO-6M. As we can see, in 2 out of 4 locations, the more expensive sensor has a greater error, and as a result of using filters and coordinate processing, we get more deviation from the measurement point. However, if you take measurements longer, you can get more accurate results. Also, NEO-6M has a long, cold start.

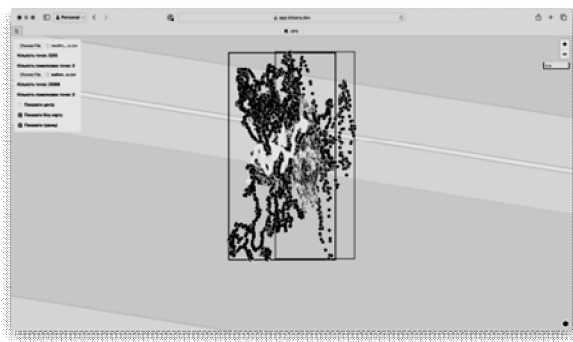


Fig. 1. Data visualization on the map in low-rise buildings

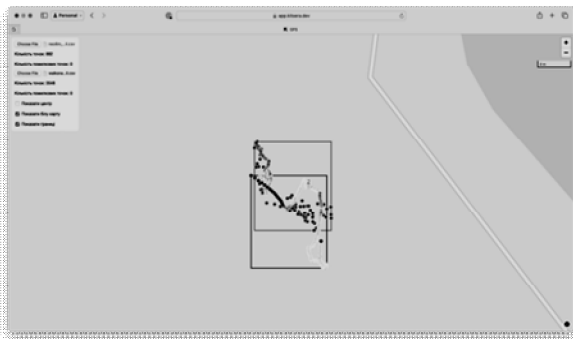


Fig. 2. Visualization of data on the map in an open field

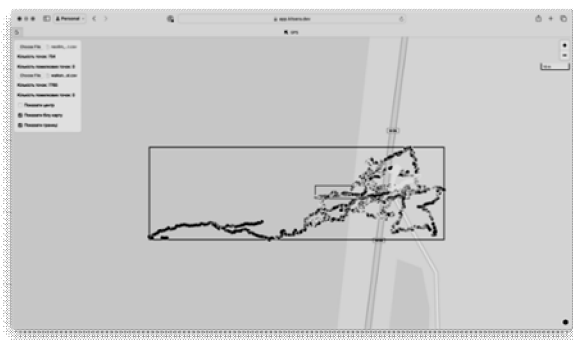


Fig. 3. Visualization of data on the map in a wooded area (the measurement took place on the side of the road with a forest strip on both sides)

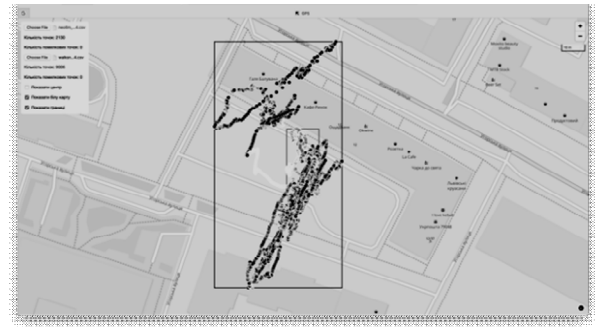


Fig. 4. Data visualization on the map in a high-rise building in the city

Table 1

Research results. Error from the point of measurement in meters

Location	Method	NEO-6M (m)	Walksnail WS-M181 (m)
Open area	Kalman filter	3.62	5.14
	Average value	3.12	3.7
	p99	0.84	1.55
Woodland	Kalman filter	4.1	6.72
	Average value	6.59	6.9
	p99	2.48	13.31
Low building	Kalman filter	5.38	5.61
	Average value	4.12	5.14
	p99	10.59	9.72
High building	Kalman filter	15.17	13.4
	Average value	8.55	2.53
	p99	22.85	49.21

Table 2

Additional results of GPS error measurements in various environmental conditions

Location	Sensor	Mean Error	Std
Woodland	NEO-6M	7.432551	8.136136
Woodland	Walksnail WS-M181	9.743796	12.132519
High building	NEO-6M	9.084357	1.400707
High building	Walksnail WS-M181	7.119592	1.600813
Low building	NEO-6M	12.884928	5.254063
Low building	Walksnail WS-M181	12.095498	10.434541
Open area	NEO-6M	3.329213	0.264332
Open area	Walksnail WS-M181	3.765819	2.042725

Table 2 presents the additional results of GPS error measurements in various environmental conditions.

Unlike Table 1, the error metrics are given as the mean error (in meters) and the corresponding standard deviation (Std) for each sensor in each location. This format provides a clear view of both the typical deviation from the measurement point and how much the measurements fluctuate. This table complements the comparisons shown previously by highlighting both the average offset from the reference position (Mean Error) and the variability of those measurements (Std). As with Table 1, the data illustrates how each sensor performs under different environmental conditions ranging from a relatively small mean error and tight grouping of coordinates (low standard deviation) to higher deviations that can indicate challenges in GPS reception.

VIII. CONCLUSION

The experimental results illuminate that the Walksnail WS-M181 GPS sensor generally provides better accuracy in challenging environments such as urban and forested areas, where it shows more minor deviations from the reference coordinates than the NEO-6M. However, in open spaces, the difference in accuracy between the two modules is minimal, making the NEO-6M a perfectly acceptable choice for less demanding tasks where high accuracy is not critical.

Kalman filter implementation for data processing significantly improves the results of both modules, especially for the NEO-6M, allowing it to achieve excellent stability and reduce the impact of noise. This confirms the effectiveness of the Kalman filter as a method to improve GPS accuracy under challenging environments.

Therefore, the choice between NEO-6M and Walksnail WS-M181 should be based on specific operating conditions and accuracy requirements. The Walksnail WS-M181 is preferable for tasks that require high precision in complex environments, while the NEO-6M is a more cost-effective solution for static application.

IX. ACKNOWLEDGEMENT

This paper is supported by the National Research Foundation of Ukraine, project number 2023.04/0116 “Modular acoustic system of airspace monitoring” from the contest Science to strengthen Ukraine's defense capabilities.

X. CONFLICTS OF INTEREST

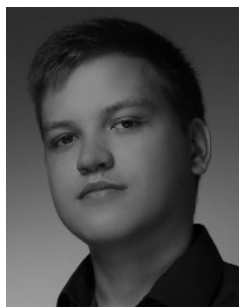
The authors declare no conflicts of interest.

XI. DECLARATION ON GENERATIVE AI

During the preparation of this work, the author(s) used ChatGPT, Grammarly in order to: Grammar and spelling check, Paraphrase and reword. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the publication's content.

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